TRIBHUVAN UNIVERSITY

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PULCHOWK CAMPUS

THESIS NO: T12/078

Efficiency and Effectiveness Measurement of Public Transportation of Kathmandu Valley using Data Envelopment Analysis

by

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A THESIS

SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING

IN PARTIAL FULFULLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE IN TRANSPORTATION ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

LALITPUR, NEPAL

DECEMBER, 2023

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The undersigned certify that they have read and recommended to Institute of Engineering for acceptance, a thesis entitled "**EFFICIENCY AND EFFECTIVENESS MEASUREMENT OF PUBLIC TRANSPORTAION OF KATHMANDU VALLEY USING DATA ENVELOPMENT ANALYSIS**" submitted by **Sandeep Bhujel** in partial fulfillment of the requirement for degree of Master of Science in Transportation Engineering.

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ABSTRACT

The main objective of this research was to measure operational performance of public vehicles (efficiency and effectiveness). DEA was used for measurement of operational performance of public vehicles. Due to data and resources constraints only two public transportation company viz; Tarkeshwor Yatayat and Sajha Yatayat were selected for the research purpose. When different vehicles of Sajha yatayat are analyzed, most of vehicles running in Lagankhel to Budhanilkantha and Lagankhel are found running more efficiently and effectively despite having large number of buses. From comparison between 5 routes of Sajha yatayat, Lagankhel to Budhanilkantha route and Ratnapark to Godawari route are found both efficient and effective than other routes. Airport to Thankot route has least effectiveness and efficiency score. So, Sajha Yatayat should focus on changing modality of operating bus in that route. Being longer route vehicles of Sajha Yatayat runs continuously for whole day. So, their efficiency and effectiveness score have greater variance. But being short route vehicles of Tarkeshwor Yatayat have to wait in queue for longer period of time. Vehicles time period is distributed evenly to complete 5 to 6 trips per day. So, their effectiveness and efficiency score have less variance. The research also finds that efficiency and effectiveness score between vehicles running in longer route have greater variation. DEA analysis results and lower magnitude of collinearity between vehicle km and average number of passengers from PLS show that if a vehicle is operating efficiently it is not necessary that the vehicle is operating effectively also. So, efficiency and effectiveness should be measured differently. Also, efficiency score of almost all vehicles is higher than efficiency score. The study can be further extended including environmental efficiency too. GIS can also be used to evaluate efficiency and effectiveness of public transportation system.

Keywords: Decision making units (DMU), Frontier, Operation performance (efficiency and effectiveness), Variable Return Scale (VRS), Partial least square regression, data envelopment analysis

ACKNWOLEDGEMENT

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LIST OF ABBREVIATION

DEA	Data Envelopment Analysis
DMU	Decision Making Units
DEAP	Data Envelopment Analysis Program
SFA	Stochastic frontier analysis
CCR	Charnes, Cooper and Rhodes
VRS	variable return scale
PLS	Partial Least Squares

CHAPTER 1: INTRODUCTION

1.1   Background

For social and economic growth of a country, transportation plays a vital role. Due to the provision of door-to-door services, flexibility of operation, comparatively lower cost and reliability, road transportation is widely used rather than other modes of transportation. The transportation facilities in urban areas have undergone tremendous changes. Nepal is a developing country. So, all people are not able to afford the private vehicle and people are more dependent upon public transportation. Among various modes of road transportation, public vehicles have become an important mode of transportation to the general public in metropolitan and urban cities in Nepal. In addition to that, for management of traffic congestion also it is important to rely people on public transport rather than private vehicles.

As per record of Central Bureau of Statistics in 2018/19, 282,997 numbers of motorcycle, 23,019 car/jeep/vans, 11,025 tempo, 2,330 micro, 9,759 pickups, 2,409 mini buses and 3,722 buses were recorded in all over Nepal. This record shows that number of private vehicles registered are more than public vehicles.

Most of public bus operators in Kathmandu are private sectors (like Bagmati, Nepal, Mahanagar, etc.) that lack proper operation plans and policies regarding ticketing system, time schedule, interconnection, bus stations, and fares. As a result, general public does not consider public transportation as a proper means to travel. Sajha Yatayat is cooperative public transportation organization which was established in 1961/1962. But due to some institutional turbulence, the organization was closed in 1990. Again, Sajha Yatayat resumed its services from April 2013 with an aim to provide quality of services. Beside buses running by diesel, Sajha Yatayat has introduced new electric vehicles also. Four of new electric buses are running in Patandhoka to Dachindhoka. In addition to that, Sajha Yatayat is running some electric buses in other routes too for trial propose.

The government should prepare strategic plan for efficient and effective public vehicles system. As for efficiency, the service provider typically aims at minimizing the operational cost without hampering daily travel demand of passengers. The efficiency measurement represents the relationship between resource inputs and produced output and include indicators of overall cost efficiency, labor utilization, and vehicle utilization. As for effectiveness, people should feel that public vehicles are available to meet their daily travel demands at a lower cost. Effectiveness can be measured by accessibility service to public.

There has been an ever-growing concern to measure efficiency and effectiveness of Decision-Making Units (DMU) which evaluates performance of public transportation system facilities, operational improvement and strategic decisions. Data Envelopment Analysis (DEA) is one of the latest techniques used to evaluate the relative efficiency of decision-making units (DMUs) that use multiple inputs to produce multiple outputs.

Thus, this research aims to measure efficiency and effectiveness of the public transportation in Kathmandu Valley of selected routes. It also identifies the factors responsible for efficiency and effectiveness and their relationship with the help of DEA and regression model.

1.2   Problem Statement

According to the Central Bureau of Statistics, population of Kathmandu district has been increasing rapidly over the past few decades. In 1950 the population recorded was 104,479 number of people but it has reached to 2,041,587 number of people as per National Population and Housing Census 2021 (Government of Nepal, Nantional statistics office, 2021). With the increase in population of Kathmandu Valley, demand for public vehicles has also increased significantly. However, resources and road condition are limited which is leading to traffic congestion. As per study of *clean Air network Nepal/clean Energy Nepal* published in 2014, over past 10 years population of Kathmandu had increased by 4.32% per year and motorization had increased by 12% per year (CBS 2011; DoTM 2013) while modal share of public transport has remained stagnant (MoPIT/JICA, 2012). The same trend is following till now. With the limited

number of public vehicles and increased number of commuters, public vehicles are not able to provide efficient and quality service. So, people who are able to afford private vehicles are more oriented toward affording private vehicles. This is leading to a further increase in traffic congestion. In addition to that environmental condition is also getting worse due to increase in emission by vehicles. For minimizing the number of vehicles on road and maximizing serviceability of public transportation; efficiency and effectiveness of the public transportation need to be improved. Every stakeholder needs to know the various factors that are directly and indirectly responsible for affecting the efficiency of public transportation.

For increasing efficiency of public vehicles, an optimal solution for decreasing the operation cost and increasing the revenue is required. For balancing cost and level of service, efficiency and effectiveness of public buses must be evaluated. Factors affecting effectiveness and efficiency of public transportation must be identified and corrected. Vehicles which are running outside Kathmandu valley mostly do not experience traffic congestion. The average number of travelers are usually similar except during some occasions and festivals. So, this study mainly focuses on public transportation of Kathmandu Valley as proper management of public transportation has been a great challenge.

1.3 Objective of study

The main objective of this research is to measure effectiveness and efficiency of public transportation in different routes of Kathmandu valley. The objectives can be listed as follows:

- Measure efficiency and effectiveness of public transportation using DEA.
- Identify the most influencing factors responsible for efficiency and effectiveness and find relationship of input and output variables.

1.4 Scope of study

The study will be helpful for efficiency and effectiveness measurement of public transportation system. It will cover following scopes:

- Bus routes of Sajha Yatyat and Tarkeshwor Yatayat were selected for collection of data like Average travel time per day (hours), Average number of operators per day, other labors involved per day, Average number of buses per day, Vehicle Km per day, Average passengers per day, energy consumption, revenue and capital investment.

- Efficiency and Effectiveness Analysis: The efficiency and effectiveness of public vehicle was evaluated by using the Data Envelopment Assessment (DEA) technique. The efficiency and effectiveness of the public transport were measured based collected data. First efficiency and effectiveness of individual vehicles were calculated and later between routes.

- Relation between the variables: Relation between input variables and output variables using regression method to find the weightage factors of different input variables to give output. This relation shows the level of influence of input variables on efficiency and effectiveness.

- Recommendation for increasing efficiency and effectiveness.

1.5 Limitations of the study

As data were collected from the company itself, the accuracy of data is dependent on them. Some of buses with incomplete data were discarded from analysis. Physical characteristics like length, breadth, and width of lane of road was not considered. The study area is limited to selected route that may not cover all routes inside Kathmandu valley. Data collected were of limited time period. There is no any standard set to benchmark service standards. Only technical efficiency and effectiveness were evaluated rather than environmental efficiency.

1.6 Organization of Report

The report consists of following chapters:

Chapter 1: Introduction; This chapter deals with background, problem statement, objectives of the study, scope of the study and limitations of the study.

Chapter 2: Literature Review; It includes past researches and articles regarding efficiency and effectiveness measurement of public vehicles. Methodology, data and drawbacks are incorporated here. Also, this section defines past and present condition of public vehicles.

Chapter 3: Methodology; This chapter includes framework of research design, study area, data collection, their validation, and program used for research purpose.

Chapter 4: Analysis; this section includes analysis and interpretation of output results.

Chapter 5: Result, Conclusion and Recommendation; It provides summary of study, conclusion and recommendation.

CHAPTER 2: LITERATURE REVIEW

Public transportation agencies are more concerned to measure efficiency and effectiveness relative their competitors. The efficiency of public vehicles can be measured by relating various types of key performance indicators like ridership, frequency of run, on-time performance, capacity utilization, cost effectiveness, safety and reliability, etc. Most common methods of performance evaluation for public transportation during old days were regression, stochastic frontier analysis (SFA) and Data envelopment analysis (DEA). The regression analysis focusses on creating a relationship between variables and understand the impacts of independent variables over dependent variables. Regression method mainly focuses on finding coefficient of estimated production units creating a functional form between input and output variables. Stochastic frontier analysis (SFA) is a statistical analysis technique introduced by Aigner, Lovell and Schmidt and Meeusen and Van den Broeck (1977). This method is applicable for data including both random noise and systematic inefficiencies. SFA is used to analyze production efficiency, when there are random shocks or external influences affecting production frontier. It only shows the maximum attainable value from the input available but doesn't measure relative efficiency. The drawbacks of regression and SFA are solved in DEA. DEA provides efficiency scores for each DMU indicating relative efficiency. It measures technical efficiency rather than providing functional relation between the variables. So, DEA is used in this research.

2.1   DEA Model

Data Envelope Analysis (DEA) is a linear program that can calculate efficiency and effectiveness of set of peer units known as decision making units (DMUs). Efficiency and effectiveness are calculated on the basis of input resources and their production results of

DMUs. First of all an empirical piecewise linear production frontier is established which monitors the process to convert input variables to output variables and then efficiency/ effectiveness are calculated comparing the real time production with DEA calculated production frontier.

There are two types of DEA as per their orientation; input oriented and output oriented. Output oriented DEA focuses on maximizing the output with using maximum inputs whereas Input oriented DEA focuses on minimizing input and produces lowest outputs.

Charnes, Cooper and Rhodes (CCR) had developed an Input oriented model assuming constant rate of scale (CRS). In CRS Model, scale of operation does not influence efficiency i.e., if input and output are altered by equal factor then efficiency remains unchanged. Banker Charnes and Cooper (BCC) developed variable return scale (VRS) model an upgraded version of CRS where technical efficiency results are not confounded by scale efficiencies. In VRS model, efficiency gets altered with change in scale of operation, i.e., change in input and output by same scale can also change the efficiency. BCC model estimates pure technical efficiency of DMUs at which given DMU is operating. The research is oriented to attract the passengers towards public bus service rather than personal vehicles. For that, public buses should deliver better service to the consumers which is possible by maximizing output variables and lowering input variables. So, output-oriented Banker Charnes and Cooper (BCC) model was used to maximize the efficiency and effectiveness.

2.2   Data Envelopment Analysis Computer Program (DEAP)

DEA can be performed by various programs like DEAP, Malmquist DEA, Excel based DEA solver, etc. DEAP is a DOS based computer program used for calculation of efficiency and effectiveness measures. The software provides a user-friendly interface for inputting data and generating DEA results, and also includes a range of visualization tools

for interpreting and presenting DEA results. DEAP is based on three principles. First principle involves standard CRS and VRS models that calculates technical and scale efficiencies. In second principal CRS and VRS are used to calculate allocative and cost efficiency. The third principal includes the application of Malmquist DEA methods for total factor productivity (TFP), technological change, technical efficiency changes and scale efficiency change. First principal is used in this research as technical efficiency evaluates the ability of an input variables to produce maximum possible output, but scale efficiency evaluates whether the input variables are producing the most appropriate output variable scale or not. An example of technical efficiency measurement using DEAP is shown in figure 2.1.

In figure 2.1 y_1 and y_2 are two output variables and x is single input variable. The curve ZZ' is the maximum possible output curve. Point A represents the inefficient firm which should be shifted by distance AB to be efficient. Hence, AB represents technical inefficiency which is the measure of outputs that could be increased within the given inputs. The line DD' represents the allocative efficiency which compares if the resources are considered efficiently used or not. BC is the allocative inefficiency.
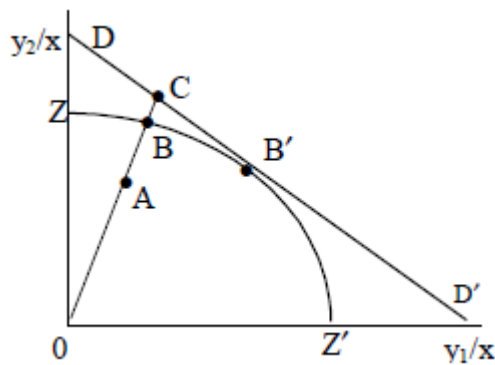
(Source: A Guide to DEAP Version 2.1)

Figure 2. 1 Output oriented BCC model

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Efficiency and effectiveness scores of 1 refer to as efficient and effective route. Similarly, if the score is less than 1 and greater or equal to 0.6, then route is fairly efficient and effective and if the score is less than 0.6, then if is inefficient and ineffective route.

2.3   Partial Least Square (PLS) Regression and Liner Regression

PLS (Partial Least Squares) is a statistical method that is commonly used in data analysis and modeling. PLS is a regression analysis method that proves valuable when working with datasets containing numerous variables or when there's strong correlation among these variables. PLS is adaptable and can be applied to both linear and nonlinear regression tasks, making it a versatile tool for data analysis and modeling. In PLS regression, it initially identifies latent factors, which are similar to principal components, to reduce the complexity of both the predictors and the outcome variables. As a result, PLS regression effectively manages highly correlated variables.

The partial least-square method states that the curve that best fits a given set of observations, is said to be a curve having a minimum sum of the squared residuals (or deviations or errors) from the given data points. Let us assume that given points of data are (x_1, y_1), (x_2, y_2), (x_3, y_3), …, (x_n, y_n) in which all x's are independent variables, while all y's are dependent ones. Also, suppose that $f(x)$ is the fitting curve and d represents error or deviation from each given point.

Now, we can write:

$$d_1 = y_1 - f(x_1)$$ eq 2.5

$$d_2 = y_2 - f(x_2)$$ eq 2.6

$$d_3 = y_3 - f(x_3)$$ eq 2.7

…..

$d_n = y_n - f(x_n)$ eq 2.8

The least-squares explains that the curve that best fits is represented by the property that the sum of squares of all the deviations from given values must be minimum, i.e.:

$$S = \sum_{i=1}^{n} d_i{}^2$$ eq 2.9

$$S = \sum_{i=1}^{n} [y_i - fx_i]^2$$ eq 2.10

$$S = d_1{}^2 + d_2{}^2 + d_3{}^2 + .. + d_n{}^2$$ eq 2.11

Sum=Minimum Quantity

The equation of line of best fit for given data can used determined by using formulae as follows;

Least square line equation ; $Y = a + bX$ eq 2.12

Normal equation for 'a':

$\sum Y = na + b\sum X$ eq 2.13

Normal equation for 'b':

$\sum XY = a\sum X + b\sum X^2$ eq 2.14

The trend line equation can be obtained by soling the equation 2.13 and equation 2.14

Thus, line of best fit is given by equation $y = ax + b$

After finding the most influencing variables, a linear regression model is created using the most influencing variables with output variables as independent variables and input variables as dependent variables. The linear regression model gives a functional form how output variables change under the changed input variables for different cases.

2.4　History of Public Transport in Kathmandu

Nepal Transport Service had started the local bus service from Kathmandu to Amlekhganj in July 1959 crossing Mahabharat Range and Hetauda which was the longest route. It also started its service in urban public transportation system from Kathmandu to Patan during September 1959. It owned a fleet of 11 buses serving more than 10,000 passengers daily but was closed in 1966 as company undergone financial issues. Sajha Yatayat a cooperative started mass transport service in Nepal in 1961/62 providing services inside Kathmandu Valley as well as inter-district commuters. In 1975, electric trolley buses were introduced along 13 km route from Tripureshwor to Suryabinayak. Although both Sajha Yatayat and Trolleybuses provided effective public transport services in Kathmandu for many years, they failed to retain their glory post 1990, when they suffered from poor management and political interference while the private sector started coming aggressively in transportation sector. The privatization of public transport brought more operators but services deteriorated with time as a result of syndicate system and lack of effective planning and regulation by the government.

2.5　Related Studies on evaluation of bus lines with DEA

Many studies have been done for the evaluation of public transport. Most of studies used DEA for the analysis of efficiency. Yong Lao and Lin Liu evaluated the performance of bus routes operated by Monterey-Salinas Transit (MST) using DEA and GIS using both operations and operational environment. GIS was used to prepare demographic profiles of paths of buses and DEA was used for calculating operational efficiency and spatial effectiveness. There are various methods to identify area of service provided and calculate required demand of public services. The author experimented both the polygon centroid allocation and uniform allocation methods.

Georgios Georgiadis, Ioannis Politis, Panagiotis Papaioannou evaluated public transport network in Thesasaloniki., Greece. The research had found out efficiency was quite better than that of effectiveness. The research found out that traffic conditions and population density were the most influencing factors for efficiency and effectiveness. Also, for improving performance of bus lines in Thessaloniki, scheduling of buses with fewer seats would give more efficient result than services with lower span. As per the research there is no ideal model for estimating performance. A model should be developed by transportation companies which can be measured and the model should represent their strategic objective. For improvement of present services, output oriented DEA can be used but for reallocating resources and adopting new techniques, input oriented framework can be used.\

Pragya Shrestha had evaluated the operational performance of Sajha Yatayat in terms of efficiency using DEAP. The author had used trips per day, running speed, diesel in liter etc. as input variables and amount collected and number of passengers as the output variables. The relation between input variables and output variables were also presented with graphical representation. The relation showed that there was relation between trips per day and diesel in Lagankhel to Buspark route and good relation between diesel in liters, number of passenger and vehicle km in Lagankhel to Budhanilkantha route. In Swoyambhu to Airport route there was not good relationship between the input and output parameters. The author's study was limited within single public transportation provider which compared only the buses within the service provider. But there was no comparison between different routes. Also, the variables used were limited

(Bhattarai, February, 2017), in a "Study on Efficiency and Satisfaction level of Public Transportation within Kathmandu Inner Ring Road" study had evaluated efficiency and satisfaction level of public vehicles which is one of the issues of present public transportation system in inner ring road. The variables average travel time, waiting time, running speed, and average passenger in this research area was collected by using moving

observer method. Later, efficiency was measured by Excel-based DEA and DOS-based DEAP model using the collected variables. Taking waiting time, travel time, running speed, and passenger in and out as independent parameters, the efficiency assessment model had been calibrated by regression analysis. Similarly, level of satisfaction of public vehicles was by questionnaire survey. Statistical significance of questionnaire survey was checked by using SPSS. In this study very limited number of input and output variables which has impact in efficiencies were considered. The important variables like revenue, capital investments, other employee, energy consumption, etc., were lacking which can affect the efficiencies. Also, the effectiveness of the public vehicle was not measured.

(Duwadi, 2019) had investigated the passengers' satisfaction and operational performance of the Lamachour Chhorepatan route public transportation. The operational performance had been evaluated as productive efficiency using Excel based DEA Solver based on BCC output method. Travel time, waiting time, running speed, number of bus-stops, average passengers were considered as the variables. The result showed only number of efficient DMUs and inefficient DMUs but don't show percentage of inefficiency and relative efficiency.

Sunil Sujhakhu together with Wenquan Li evaluated the efficiency and effectiveness of Sajha Yatayat using DEAP in 2020 using Average travel time per round trip (hours), Average passengers (ridership) per day, (effectiveness measure), Average number of operators per day as input variables vehicle km per day (efficiency measure), average number of buses per day as output variables. The author evaluated 8 routes of Sajha Yatayat. Partial least square (PLS) was used for to find collinearity between variables and find a relation between the input and the output data. The study was limited to the efficiency comparison between routes only but comparison between individual vehicles was not accommodated. In addition to that the study was limited within Sajha Yatyat which

compared efficiency within routes of Sajha Yatyat rather than efficiency comparison between different organizations. Also, the variables used were of limited number.

CHAPTER 3: RESEARCH METHODOLOGY

3.1   Research Design.

The research methodology describes working framework of whole research. Firstly, before starting research work, problem identification is required. After identification of problem only, research objectives could be defined which gave a basic direction for research works. Then we moved towards data collection task. Data required were first listed and their resources were identified. Both primary and secondary data were collected. Here the data were divided as input and output variables. Then we further moved towards data analysis and calculated efficiency and effectiveness score. As per the outcome of analysis results and recommendation were drawn. Above mentioned methodology is represented in tabular form as shown in the figure 3.1
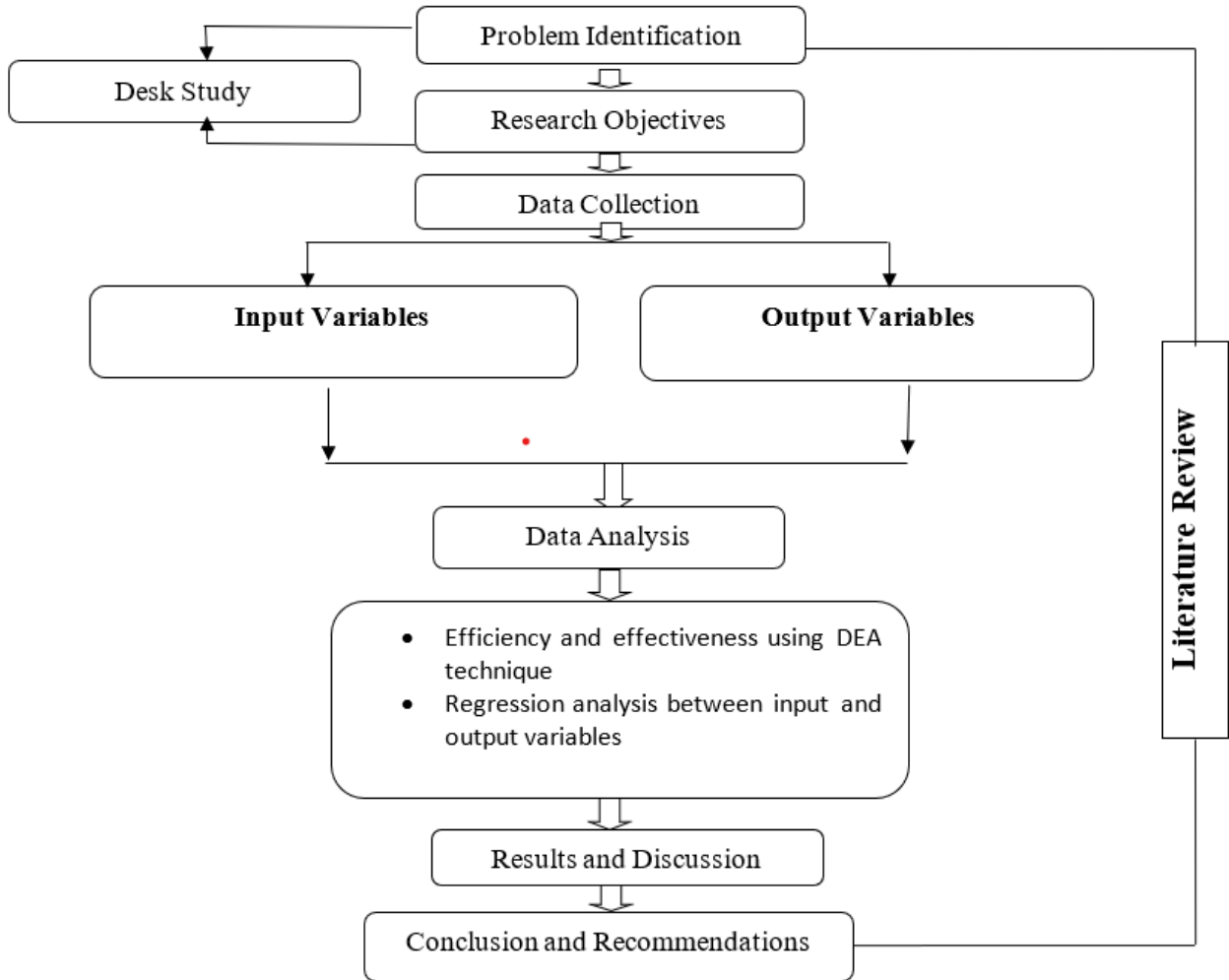
Figure 3. 1 Flow chart of research methodology

3.2 Study Area:

The comparison between the short routes and the long routes vehicles are irrelevant. So, public vehicles within Kathmandu Valley were studied discarding the long route vehicles. There are lots of public transportation companies running public vehicles in various routes within Kathmandu Valley. Due to the limitation of data availability only **Sajha Yatayat** and **Tarkeshwor Yatayat** were selected. Sajha Yatayat is running with the special investment of Nepal government, Kathmandu Metropolitan city, Lalitpur Metropolitan

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City, Mahalaxmi Municipality and some other personal investors consisting of 67 diesel buses and 5 electric buses.

Tarkeshwor Yatayat is a private company which has 15 different buses running in 4 different routes. Tarkeshwor Yatayat previously was committee working in syndicate system. But later it was converted to a company after end of syndicate system as per direction of Nepal government.

3.3   Data Collection

Secondary data were collected from offices of respective service providers. Being a quite systematic service provider, Sajha Yatyat had all required data but Tarkeshwor Yatyat had no system of collecting data on daily basis. So, primary data were collected by moving observer method. Data of a whole day was collected for each vehicle. The variables collected for study purpose are shown in (Table 3.1).

Table 3. 1 List of Input and Output variables

Input Variables	Output Variables
Average travel time (hours),	Revenue
Average number of operators per day	Vehicle Km per day (efficiency
Other manpower involved per day.	measure)
Average number of buses per day	Average passengers per day
Energy Consumption (Cost)	(Effectiveness measure)
Capital investment	

All the required data were collected from daily income sheets and daily registration sheet of the company itself. Overall data of 1 month for fuel and weekly data for the average number of passengers and revenue were collected in case of Sajha Yatayat but one day data was collected for Tarkeshwor Yatayata by moving observer method. To define input

variable (other manpower involved), all other manpower involving in organization including conductor were summed up and divided by total number of vehicles to distribute their contribution equally along each vehicle. Capital investment cost is taken as daily depreciation value of vehicle. 20% of depreciation rate is used as per income tax act, 2058. Average number of operators represents the driver operating vehicle for whole day.

Sajha Yatayat has altogether 72 (67 diesel and 5 electric) buses running through following routes as shown in table 3.2 inside Kathmandu valley.

Table 3. 2 Routes of Sajha Yatayat

SN	Route	Number of buses
1	Airport to Thankot	12
2	Lagankhel to Budanilkantha	15
3	Lagankhel to New Buspark	13
4	Lamatar to Ratnapark	5
5	Lele to Ratnapark	6
6	Nagdhunga to Narayanthan	16
7	Patandhoka to Dhanchindhoka	5

Tarkeshwor Yatayat has altogether 15 buses but only 13 buses are in operation through routes as mentioned in Table 3.3 inside Kathmandu valley. The vehicles start to operate from Tarkeshwor Municipality; outside of ring road area and later enter inside ring road.

Table 3. 3 Routes of Tarkeshwor Yatyat

Sn	Bus number	No. of buses
1	Sangla To RNAC	1

2	Kavresthali to RNAC	8
3	Paiyutar to RNAC	2
4	Goldhunga to RNAC	2

Sajha yatayat is running some electric vehicles in some routes occasionally. Since the efficiency of electric vehicles can't be compared with the diesel buses, they were not considered under this study. Collected data were averaged as per our requirements. After processing data, results as tabulated in appendix B were obtained which were further used for calculation. The travel time, distance travelled were exported using GPS installed in each vehicle in case of Sajha yatayat. Capital cost of each vehicle were calculated using the 20% depreciation rate and yearly depreciation were divided into 365 days. The table B.1 to B.13 show data used for calculations of efficiency and effectiveness of public vehicles.

3.4   Data Envelopment Analysis

Data Envelopment Analysis Program (DEAP) was used for calculating efficiency and effectiveness. DEAP used in this research is a DOS based program developed by Coelli T J under The Department of Econometrics, University of New England, Armidale, NSW 2351, Australia. DEAP program was used for executing DEA. In this research output-oriented DEA was used which was developed by Banker Charnes and Cooper (BCC) model.

Mathematically, the BCC (Banker, Charnes, & Copper, 1984) model can be written as follows:

$$\text{Max}u, \text{v}. \; \theta_k = \frac{\sum_{m=1}^{M} u_m y_{mk}}{\sum_{n=1}^{N} v_n x_{nk}} \qquad\qquad \text{eq :3.1}$$

Subject to
$$\frac{\sum_{m=1}^{M} u_m y_{mj}}{\sum_{n=1}^{N} v_n x_{nj}} \leq \forall j \qquad \qquad \text{eq: 3.2}$$

$$\sum_{n=1}^{N} V_n X_{nk} = 1 \qquad \qquad \text{eq: 3.3}$$

$$U_m, V_n, y_{mj}, X_{nj} > 0 \qquad \forall m, n, j \qquad \qquad \text{eq: 3.4}$$

Here,

J refers to (DMU), j=1,2,3…J

N refers to input, n=1, 2,3…,N

m refers to output, m=1, 2,3…,M

x_{nj} is n^{th} input for the jth DMU

y_{mj}: The mth output for j^{th} DMU

u_m, v_n : Non-negative constraints for m^{th} output and the nth input

θ is Efficiency and Effectiveness ratio

BCC model (Eq. 3.1) maximizes the weighted outputs to weighted inputs ratio. The weights u_m and v_n are the decision-making variables. u_m and v_n are altered till they become maximum for the targeted DMU, keeping weights of remaining DMUs constant. The value of, θ, in equation 3.1 is referred to as the efficiency/effectiveness score, where $0 \leq \theta \leq 1$. Value of θ as 1 refers to efficient DMU. The weights calculated are the decision variables whereas values of collected inputs and outputs are real-time values. Equation 3 shows that DEA model is Variable Returns to Scale (VRS). Constraints (Eq. 4) ensures non-negativity of calculated weights.

The output-oriented DEA model works in following steps:

1.   Define DMUs and the inputs and outputs they produce.

2. Normalize data to make the inputs and outputs comparable.

3. Determine the weights of inputs and outputs by solving the linear programming problem.

4. Calculate the efficiency score of each DMU by comparing its actual outputs to the outputs that it should have produced from given inputs.

5. Identify efficient and inefficient DMUs.

For analysis, input data were fed in DOS based text file with output variables at starting column and later input variables as shown in figure 3.2. For providing instruction command a text file was provided where we can select number of firms, principal to be followed, and number of input and output variables as shown in figure 3.3. Then DEAP program was instructed to follow the instruction file for input data file and later gives output in text file as shown in figure 3.4. A calculation sample of efficiency using DEAP is shown in Appendix A.

```
1 2 5 1 3            eg3-dta.txt              DATA FILE NAME
                     eg3-out.txt              OUTPUT FILE NAME
2 2 4 1 3            5                    NUMBER OF FIRMS
                     1                    NUMBER OF TIME PERIODS
3 6 6 1 3            1                     NUMBER OF OUTPUTS
                     2                     NUMBER OF INPUTS
1 3 2 1 3            0                     0=INPUT AND 1=OUTPUT ORIENTATED
                     0                     0=CRS AND 1=VRS
2 6 2 1 3            1                     0=DEA(MULTI-STAGE), 1=COST-DEA, 2=M
```

Figure 3. 2 Input Data File Format   Figure 3. 3 Instruction Data File

```
Results from DEAP Version 2.1

Instruction file = eg3-ins.txt
Data file        = eg3-dta.txt

 Cost efficiency DEA

 Scale assumption: CRS


 EFFICIENCY SUMMARY:
```

Figure 3. 4 Output data file

DEAP Version 2.0 generally consists of five files:

a.   An executable program file DEAP.exe

b.   The startup file DEAP.00

c.   An input data file (for e.g., called Eg1-dta.txt)

d.   An instruction data file (for e.g., called Eg1-ins.txt)

e.   An output data file (for e.g., called Eg1-out.txt)

   The startup file DEAP.00 stores all the key parameter value. The executable program file,
   startup file, data input file and instruction file must be kept in same folder location.

3.5   Regression

In order to find the most important variables responsible for efficiency and effectiveness, partial least square regression (PLS) was done using PYTHON programming language based on collected data. PLS result gives level of multi-collinearity between different variables. Positive multicollinearity shows that if one variable increases so does other variables with the scale factor equal to magnitude of collinearity. The collinearity matrix formed gives important input variables affecting output variables. PLS also filters the variables that are required for preparation of functional equation. After that, linear regression analysis gives us equation model between dependent (output) variable and independent (input) variables which is useful to find how the output can be maximized and efficiency and effectiveness can be increased.

Chapter 4:   RESULT AND ANALYSIS

4.1   General

All input and output variables were collected from respective offices of Sajha Yatayat and Tarkeshwor Yatayat. Being more systematic public transportation company Sajha Yatayat has different departments that store records of daily revenue, fuel expenses of each vehicle, vehicle km tracking, travel time tracking etc. In case of Tarkeshwor Yatayat, daily log books were not available. So, primary data were collected of each individual vehicles by moving observer method.

4.2   Efficiency and effectiveness assessment using weekly data.

Collected data was analyzed using DEAP for efficiency and effectiveness assessment. Analysis was done in two stages. First stage was the comparison of individual vehicles in each route and later comparison between total vehicles running in different routes. The efficiency and effectiveness score of each vehicle in each route of Sajha Yatayat using weekly data of each vehicle are tabulated in table 4.1 to table 4.6 and results of comparison of different routes are presented in table 4.7.

The table 4.1 shows that bus number 8770-7 is running both efficiently and effectively. 8769-7 and 8707-7 are operating efficiently but not effectively. Vehicle 8771-7 is found to be inefficient.

Table 4. 1 Effectiveness and Efficiency of Airport to Thankot route

Sn	Bus number	Efficiency score	Effectiveness score
1	8765-7	0.994	0.874
2	8766-7	0.921	0.84
3	8767-7	1.000	0.997
4	8768-7	0.982	0.965
5	8769-7	1.000	0.766
6	8770-7	1.000	1.00
7	8771-7	1.000	0.542

The table 4.2 shows that bus number 5654-4, 5659-4 and 5661-4 are operating efficiently and vehicle 5661-4 and 5663-4 are effectively running. Almost all vehicles are found to be efficient and effective.

Table 4. 2 Effectiveness and Efficiency of Lagankhel to Budhanilkantha route

Sn	Bus number	Efficiency score	Effectiveness score
1	3622-5	0.938	0.886
2	5654-4	1.000	0.961
3	5655-4	0.993	0.816
4	5656-4	0.987	0.950
5	5657-4	0.963	0.977
6	5658-4	0.912	0.930
7	5659-4	1.000	0.975
8	5660-4	0.913	0.809
9	5661-4	1.000	1.00
10	5662-4	0.938	0.884
11	5663-4	0.934	1.00
12	5665-4	0.939	0.950

13	5667-4	0.911	0.829

AS per result obtained in table 4.3, Lagankhel to New Buspark route shows almost all vehicles have similar efficiency greater than 0.9 except vehicle 5653-4. Vehicle 5648-4 is both efficient and effective and vehicle 5664-4 has least effectiveness score than other.

Table 4. 3 Effectiveness and Efficiency of Lagankhel to New Buspark route

Sn	Bus number	Efficiency score	Effectiveness score
1	5642-4	0.981	0.916
2	5645-4	0.976	0.926
3	5646-4	0.988	0.745
4	5647-4	0.983	0.898
5	5648-4	1.000	1.00
6	5649-4	1.000	0.904
7	5650-4	1.000	0.942
8	5651-4	1.000	0.855
9	5652-4	1.000	0.908
10	5653-4	0.896	0.863
11	5664-4	0.938	0.831
12	5666-4	0.997	0.964

Since there are only two vehicles used for comparison in Lamatar to Ratnapark route, 8752-7 is efficient and effective than 8753-7 as shown in table 4.4.

Table 4. 4 Effectiveness and Efficiency of Lamatar to Ratnapark route

Sn	Bus number	Efficiency score	Effectiveness score
1	8752-7	1.00	1

2	8753-7	0.98	0.872

When comparison was made for 14 vehicles in Nagdhunga to Budhanilkantha route in table 4.5 only buses 2221-3 and 2224-3 are found running less efficiently, but others have efficiency more than 0.9. In case of effectiveness, 2223-3 and 2227-3 are running efficiently. Bus number 5640-4 is found to be ineffective.

Table 4. 5 Effectiveness and Efficiency of Nagdhunga to Budhanilkantha route

Sn	Bus number	Efficiency score	Effectiveness score
1	2217-3	0.992	0.881
2	2218-3	1.00	0.892
3	2219-3	0.994	0.944
4	2220-3	0.973	0.755
5	2221-3	0.889	0.845
6	2223-3	1.000	1.00
7	2224-3	0.896	0.75
8	2227-3	1.000	1.00
9	2229-3	1.000	0.777
10	2228-3	0.977	0.797
11	5638-4	0.977	0.691
12	5639-4	0.921	0.704
13	5640-4	1.000	0.514
14	5641-4	1.000	0.801

Comparison of vehicles running along Ratnapark to Godawari route shows that bus 5643-4 has the lowest efficiency and 8762-7 has least effectiveness score as shown in table 4.6. Vehicle 8763-7 is found to be both efficient and effective.

Table 4. 6 Effectiveness and Efficiency of Ratnapark to Godawari route

Sn	Bus number	Efficiency score	Effectiveness score
1	5643-4	0.886	0.815
2	5644-4	0.989	0.933
3	8760-7	1.00	0.952
4	8761-7	0.990	0.956
5	8762-7	0.945	0.686
6	8763-7	1.00	1.00
7	8764-7	1.00	0.907

When comparison was made along all buses of different routes, route Lagankhel to Budhanilkantha and Ratnapark to Godawari are found to have greatest efficiency and effectiveness. Airport to Thankot route is found to have least effectiveness score than other routes as shown in table 4.7. Route Lamatar to Ratnapark has lowest efficiency than other routes.

Table 4. 7 Effectiveness and Efficiency of all routes of Sajha Yatayat

Sn	Bus number	Efficiency score	Effectiveness score
1	Airport to Thankot	1.000	0.693
2	Lagankhel to Budhanilkantha	1.000	1.000
3	Lagankhel to New Buspark	0.920	0.906
4	Lamatar to Ratnapark	0.860	0.910
5	Nagdhunga to Budhanilkantha	0.910	0.891
6	Ratnapark to Godawari	1.000	1.000

When efficiency and effectiveness of different vehicles were measured using weekly data, then relative efficiency and effectiveness were found to be almost similar. There were only few vehicles having efficiency and effectiveness below 0.6 and almost all vehicles were

found to be efficient and effective. So, again operational performance was measured using daily data.

4.3 Efficiency and effectiveness assessment using daily data.

Measurement of efficiency and effectiveness using daily data are shown in table 4.8 to 4.13. The table 4.8 shows that vehicles 8765-7, 8769-7 and 8767-7 are operating efficiently and the vehicles 8770-7 and 8767-7 are effectively running. Vehicle 8765-7 has lowest effectiveness score of 0.631.

Table 4. 8 Effectiveness and Efficiency of Airport to Thankot route (using daily data)

Sn	Bus number	Efficiency score	Effectiveness score
1	8765-7	1.00	0.631
2	8766-7	0.953	0.839
3	8767-7	1.00	1.00
4	8768-7	0.983	0.928
5	8769-7	1.000	0.726
6	8770-7	0.890	1.000

The table 4.9 shows operational performance of Lagankhel to Budhanilkantha route. Bus number 5660-4 and 5661-4 are operating efficiently and effectively. Vehicle 5655-4 and 5663-4 are ineffective and 5665-4 has least efficiency near to inefficiency.

Table 4. 9 Effectiveness and Efficiency of Lagankhel to Budhanilkantha route (using daily data)

Sn	Bus number	Efficiency score	Effectiveness score
1	3622-5	1	0.909
2	5654-4	0.926	0.869
3	5655-4	1.000	0.548
4	5656-4	0.893	0.880
5	5657-4	0.951	0.825
6	5658-4	0.927	0.754
7	5660-4	1.000	1.000
8	5661-4	1.000	1.000
9	5662-4	0.834	0.817
10	5663-4	0.853	0.433
11	5665-4	0.689	0.823
12	5667-4	0.906	0.904

AS per the result obtained in table 4.10, in Lagankhel to New Buspark route almost all vehicles are running efficiently with score greater than 0.9 and vehicles 5648-4 and 5649-4 are running effectively. Vehicle 5642-4, 5647-4 and 5651-4   are found ineffective.

Table 4. 10 Effectiveness and Efficiency of Lagankhel to New Buspark route (using daily data)

Sn	Bus number	Efficiency score	Effectiveness score
1	5642-4	0.996	0.572
2	5645-4	0.957	0.896
3	5646-4	0.987	0.667
4	5647-4	0.976	0.597
5	5648-4	1.000	1.000
6	5649-4	1.000	1.000
7	5650-4	0.912	0.782

8	5651-4	1.000	0.486
9	5652-4	0.980	0.887
10	5653-4	1.000	0.867
11	5664-4	0.950	0.664
12	5666-4	1.000	0.771

The table 4.11 shows that vehicle 8753-7 has more efficiency and effectiveness than vehicle 8752-7.

Table 4. 11 Effectiveness and Efficiency of Lamatar to Ratnapark route (using daily data)

Sn	Bus number	Efficiency score	Effectiveness score
1	8752-7	0.882	0.839
2	8753-7	1.000	1.000

When comparison was made for vehicles in Nagdhunga to Budhanilkantha route in table 4.12, vehicles 2218-3, 2227-3 and 2228-3 are found to be efficient and vehicles 2227-3 and 5638-4 are found to be effective. Vehicle 2224-3 is ineffective.

Table 4. 12 Effectiveness and Efficiency of Nagdhunga to Budhanilkantha route (using daily data)

Sn	Bus number	Efficiency score	Effectiveness score
1	2217-3	0.937	0.742
2	2218-3	1.000	0.950
3	2219-3	0.769	0.961
4	2221-3	0.731	0.719
5	2223-3	0.854	0.912

6	2224-3	0.744	0.448
7	2227-3	1.000	1.000
8	2228-3	1.000	0.936
9	5638-4	0.980	1.000
10	5639-4	0.990	0.788
11	5640-4	0.750	0.703
12	5641-4	0.990	0.836

Comparison of vehicles along Ratnapark to Godawari route shows vehicles 8764-7 and 8763-7 are efficient and vehicles 8761-7 and 8762-7 are effective as shown in table 4.13. Vehicle 5643-4 has least effectiveness score and 5643-4 has least efficiency score.

Table 4. 13 Effectiveness and Efficiency of Ratnapark to Godawari route (using daily data)

Sn	Bus number	Efficiency score	Effectiveness score
1	5643-4	0.892	0.671
2	5644-4	0.947	0.936
3	8760-7	0.973	0.719
4	8761-7	0.965	1.000
5	8762-7	0.899	1.000
6	8763-7	1.000	0.914
7	8764-7	1.000	0.993

When comparison was made along all buses of different routes using daily data in table 4.14, Ratnapark to Godawari route is found to be both effective and efficient. Lagankhel to Budhanilkantha route seems to be effective despite not having efficiency score 1. The reason behind that is, there are no other vehicles operating in that route. So, the passengers who travel from Lagankhel to Budhanilkantha have no other options of public vehicles. Airport to Thankot route is found to have least efficiency and Nagdhunga to

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Budhanilkantha route has least effectiveness score. The reason can be there are lots of other public vehicles operating in Chakrapath route. So, the consumers have lots of alternate options

Table 4. 14 Effectiveness and Efficiency of all routes of Sajha Yatayat (using daily data)

Sn	Bus number	Efficiency score	Effectiveness score
1	Airport to Thankot	0.780	0.971
2	Lagankhel to Budhanilkantha	0.898	1.000
3	Lagankhel to New Buspark	0.922	0.990
4	Lamatar to Ratnapark	0.979	1.00
5	Nagdhunga to Budhanilkantha	0.926	0.848
6	Ratnapark to Godawari	1.000	1.000

Efficiency and effectiveness comparison result for individual vehicles and individual routes of Tarkeshwor Yatayat are shown in table 4.15 to table 4.18. Sangla to RNAC route had only 1 vehicle in operation. So individual vehicle comparison was not performed in that route. Tarkeshwor Yatayat has no data previous data records. So, only daily data is used for analysis.

The results in table 4.15 shows that vehicle number 8289, 8286, 8287 and 8288 are efficient as compared to others and vehicle 8286 and 8289 have highest effectiveness.

Table 4. 15 Effectiveness and Efficiency of Kavresthali to RNAC route

Sn	Bus number	Efficiency score	Effectiveness score
1	8289	1.000	1.00
2	8236	0.950	0.741
3	8285	0.905	0.992

4	8286	1.000	1.00
5	8238	0.990	0.989
6	8287	1.000	0.922
7	8288	1.000	0.780
8	7414	0.970	0.869

From the comparison in table 4.16 it was found out that, vehicle 8290 is more effective than vehicle 7415 despite having similar efficiency.

Table 4. 16 Effectiveness and Efficiency of Paiyutar to RNAC route

Sn	Bus number	Efficiency score	Effectiveness score
1	7415	1.00	0.949
2	8290	1.00	1

Table 4.17 shows that when vehicle 7894 and 8284 are compared, vehicle 8284 is found most efficient and effective than vehicle 7984.

Table 4. 17 Effectiveness and Efficiency of Goldhunga to RNAC route

Sn	Bus number	Efficiency score	Effectiveness score
1	7894	1.00	0.768
2	8284	1.00	1

When 4 routes of Tarkeshwor Yatayat are compared as in table 4.18, Paiyutar to RNAC route is found both effective and efficient. Kavresthali to RNAC route has the least efficiency and Goldhunga to RNAC route least effectiveness score.

Table 4. 18 Effectiveness and Efficiency of all routes of Tarkeshwor Yatayat

Sn	Bus number	Efficiency score	Effectiveness score
1	Sangla To RNAC	0.91	1.00
2	Kavresthali to RNAC	0.89	0.92
3	Paiyutar to RNAC	1.00	1
4	Goldhunga to RNAC	0.97	0.890

4.4 Regression Model

To find collinearity between variables partial least square regression (PLS) was performed in PYTHON programming language. The result of multi-collinearity test obtained from partial least square regression (PLS) is as shown in table 4.19. The magnitude of collinearity between different variables shows dependency between variables. Positive magnitude indicates that if one variable is increased other variable also increases and negative magnitude indicates that if one variable is increased other variable decreases simultaneously. Table 4.19 shows that there is high collinearity between output variables; revenue and average number of passengers per day. This positive collinearity with high magnitude shows that if revenue increases, average number of passengers per day also increases with same scale. So only one of these variables can be used for preparation of linear regression model. Since the average number of operators and average number of buses per day had constant value during data collection, there seem to be no influence of these variables as their collinearity magnitude is 0. The magnitude of collinearity between vehicle km and average number of passengers per day is very low. So, these variables are not dependent to each other. The result shows negative correlation between energy consumption and capital investment. The reason behind that can be newly bought vehicles are costlier than previous vehicles but give good mileage than old vehicles.

Table 4. 19 Result of multi-collinearity test between variables obtained from PLS

	Vehicle km	Average number of passengers per day	Revenue	Average travel time	Average number of operators	Other employees	Average number of buses per day	Energy consumption	Capital investment
Vehicle km	1	-0.000605	0.099431	0.24392	0	0.109488	0	0.173366	0.105359
Average number of passengers per day	-0.000605	1	0.932246	0.225148	0	0.257293	0	0.276923	0.229806
Revenue	0.099431	0.932246	1	0.177668	0	0.337572	0	0.295213	0.319296
Average travel time	0.24392	0.225148	0.177668	1	0	0.462591	0	0.252288	0.484774
Average number of operators	0	0	0	0	0	0	0	0	0
Other employees	0.109488	0.257293	0.337572	0.462591	0	1	0	0.393942	0.991318
Average number of buses per day	0	0	0	0	0	0	0	0	0
Energy consumption	0.173366	0.276923	0.295213	0.252288	0	0.393942	0	1	-0.421008

Capital investment	0.105359	0.229806	0.319296	0.484774	0	0.991318	0	-0.421008	1

After finding collinearity variables, linear regression method was used for preparation of equation model using output variables as dependent and input variables as independent variables. Variables having collinearity magnitude greater than 0.1 were used for the preparation of equation model. The model thus formed with the coefficient of each variable and intercepts is as shown in eq 4.1 and eq 4.2.

Revenue= 164.608 * Average travel time (ATT) + 8685.94* Other Employees + 0.591 *Energy Consumption + 0.910*Capital Investment -10362.84   Eq 4. 1

Vehicle km= 2.173* Average travel time (ATT) + 0.004* Energy Consumption + 0.002* Capital Investment +71.485
      Eq 4. 2

The model was validated with collected data which is as shown in table 4.19 for revenue and table 4.20 for Vehicle km per day. The percentage error between the calculated value and observed value are shown in table which shows that all the errors are below 15%. So, the model is acceptable.

Table 4. 20 For validation of eq 4.1 with the real time data.

Revenue (Rs)		Average travel time	Other employees	Energy consumption (Rs)	Capital investment (Rs)	Error (%)
Calculated from	Collected data					
11,130.50	10,550.00	9.92	1.40	4924.00	5260.27	6%
10,061.73	9,340.00	6.87	1.40	3965.00	5260.27	8%
11,540.74	11,785.00	13.02	1.33	9859.84	2630.14	2%
9,679.15	9,436.43	14.36	1.33	7012.26	2191.78	3%
10,962.89	12,100.00	8.50	1.40	5035.00	5260.26	9%

Table 4. 21 For validation of eq 4.2 (vehicle km) with the real time data.

Vehicle km		Average travel time	Energy consumption (Rs)	Capital investment (Rs)	Error (%)
Calculated from model	Collected data				
123.2504567	126.80	9.92	4924.00	5260.27	3%
112.7867987	102.06	6.87	3965.00	5260.27	11%
144.4819177	126.36	13.02	9859.84	2630.14	14%
135.1242883	122.23	14.36	7012.26	2191.78	11%
120.616024	129.60	8.50	5035.00	5260.26	7%

CHAPTER 5: CONCLUSION AND RECCOMENDATION

5.1 Conclusion:

In this research study, operational performance of Sajha Yatayat and Tarkeshwor Yatyat have been measured using Data Envelopment Analysis. From the above results, it was seen that there is less variation in efficiency but greater variation in effectiveness. Results of operational performance measurement of Sajha Yatayat using weekly and daily data show there is greater variation in efficiency and effectiveness when comparison is made using daily data. Because when data are averaged, then data seem to give similar scale of outputs for their respective inputs. So, comparison using daily data gives more realistic results.

Results of vehicles in Lagankhel to Budhanilkantha route exhibit consistently high score (greater than 0.8) for both efficiency and effectiveness, indicating well-managed and effective service delivery. All vehicles are providing better revenue and services. However, other routes like Airport to Thankot, Lagankhel to New Buspark, Lamatar to Ratnapark, Nagdhunga to Budhanilkantha and Ratnapark to Godawari show variations in operational performance among different buses, suggesting opportunities for improvement in resource utilization and service quality. Further investigation of factors contributing to these variations is necessary to make informed decisions for route optimization and resource allocation. From the results of comparison between different routes, it was found that longest routes Airport to Thankot and Nagdhunga to Budhanilkantha have effectiveness score of 0.693 and 0.891 respectively which are low in comparison to other routes.

Being short route, efficiency and effectiveness of all vehicles of Tarkeshwor Yatayat are almost greater than 0.8. This shows that vehicles in Tarkeshwor Yatayat are well managed and running systematically. In addition to that, vehicles in Tarkeshwor Yatayat complete their journey within short period of time (i.e. 1 to 2.25 hours) and they have to wait for 1 hour to 1.67 hours in queue for making next trip. The vehicles are meant to complete 5 to 6 round trips per day. So, their revenue collection, fuel expenses and distance travelled are quite similar.

Efficiency and effectiveness scores are high when the passengers are more which may raise question to the costumer's satisfaction which is not considered in this study. In Nepal, there is the provision carrying consumers more than the seat capacity of bus. Higher efficiency and effectiveness could also be the caused due to increased number of passengers.

5.2   Recommendation

During the study period it was found that, Sajha Yatayat has comparatively better system of collecting and analyzing daily records than Tarkeshwor Yatayat though there are some improvements required in their system. Tarkeshwor Yatayat should introduce ticketing system, daily log book system, GPS in each vehicle and keeping good records of fuel expenses of each vehicle which can provide valuable information for measurement of operational performance using data of longer period of time. This can further provide valuable insight to compare operational measurement of different vehicles and identify inefficient and ineffective vehicles. The public transportation agencies can use these models for evaluating the efficiency and effectiveness of their service and can analyze in which route they are lacking quality of service. They can target to increase the output variables by using the equation model which is provided in equation 4.1 and 4.2. In addition to that, this research is limited due to short time period and lack of access to data. Other input variables like expenses in maintenance of vehicle, number of bus stops, time spent in

each bus stop, delays, etc. could be accommodated for analysis. For partial least square regression also, large volume of data could have been collected and used for regression to get better results of multicollinearity.

Only two of public vehicle company were used for efficiency and effectiveness. Instead of that other number of companies could be accommodated and efficiency and effectiveness comparison between the individual companies could be compared and the best operating company could be used as a better model for public vehicle service provider. The input variables like; number of bus stops, delay, maintenance cost of vehicle, overall expenses to run a company, etc. can also be used for evaluating operational performance of different vehicles which are not included in this study. Also, study of passenger's satisfaction level could be included provide extra support to measure operational performance of public vehicles. The study can be further extended including environmental factors to meet multi criteria objectives. GIS can be used to evaluate efficiency and effectiveness of public transportation system.

APPENDIX A: SAMPLE CALCULATION

Calculation for Efficiency score of Lagankhel to Budhanilkantha

Input Data

Bus number	Vehicle km per day	Revenue (Rs)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
3622-5	151.14	10138.57	1.00	1.33	1.00	6193.87	2191.78
5654-4	113.91	11301.71	1.00	1.33	1.00	5105.00	2191.78
5655-4	156.25	9724.29	1.00	1.33	1.00	6056.61	2191.78
5656-4	152.03	11232.86	1.00	1.33	1.00	6687.74	2191.78
5657-4	145.05	11072.86	1.00	1.33	1.00	7146.13	2191.78
5658-4	138.31	10430.00	1.00	1.33	1.00	6789.68	2191.78
5659-4	160.67	11181.43	1.00	1.33	1.00	6145.00	2191.78
5660-4	147.18	10008.00	1.00	1.33	1.00	6476.45	2191.78
5661-4	141.68	11757.50	1.00	1.33	1.00	7744.19	2191.78
5662-4	150.83	9458.75	1.00	1.33	1.00	7467.42	2191.78
5663-4	120.27	9527.50	1.00	1.33	1.00	5424.68	2191.78
5665-4	143.96	10582.00	1.00	1.33	1.00	6246.29	2191.78
5667-4	135.35	10337.86	1.00	1.33	1.00	6364.03	2191.78

Input Data format in txt file

151   10139 1   1   1   6194 2192

114   11302 1   1   1   5105 2192

156	9724	1	1	1	6057	2192
152	11233	1	1	1	6688	2192
145	11073	1	1	1	7146	2192
138	10430	1	1	1	6790	2192
161	11181	1	1	1	6145	2192
147	10008	1	1	1	6476	2192
142	11758	1	1	1	7744	2192
151	9459	1	1	1	7467	2192
120	9528	1	1	1	5425	2192
144	10582	1	1	1	6246	2192
135	10338	1	1	1	6364	2192

Instruction text file

eg1-dta.txt   DATA FILE NAME

eg1-out.txt   OUTPUT FILE NAME

13   NUMBER OF FIRMS

1   NUMBER OF TIME PERIODS

2   NUMBER OF OUTPUTS

5   NUMBER OF INPUTS

1   0=INPUT AND 1=OUTPUT ORIENTATED

1   0=CRS AND 1=VRS

0   0=DEA(MULTI-STAGE), 1=COST-DEA, 2=MALMQUIST-DEA,
3=DEA(1-STAGE), 4=DEA(2-STAGE)

Result for DEAP V2.1

Results from DEAP Version 2.1

 Instruction file = eg1-ins.txt

Data file   = eg1-dta.txt

 Output orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method

 EFFICIENCY SUMMARY:

 firm crste vrste scale

  1 0.938 0.938 1.000 -

  2 1.000 1.000 1.000 -

  3 0.983 0.993 0.989 irs

  4 0.987 0.987 1.000 -

  5 0.963 0.963 1.000 -

  6 0.912 0.912 1.000 -

  7 1.000 1.000 1.000 -

  8 0.913 0.913 1.000 -

  9 1.000 1.000 1.000 -

  10 0.938 0.938 1.000 -

11 0.893 0.934 0.956 irs

12 0.939 0.939 1.000 -

13 0.911 0.911 1.000 -

mean 0.952 0.956 0.996

Note: crste = technical efficiency from CRS DEA

vrste = technical efficiency from VRS DEA

scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm	output:	1	2
1		0.000	370.543
2		0.000	0.000
3		0.000	1403.467
4		0.000	0.000
5		0.000	0.000
6		0.000	0.000
7		0.000	0.000
8		0.000	219.857
9		0.000	0.000
10		0.000	1095.576
11		0.000	1064.923
12		0.000	0.000

13	0.000	0.000
mean	0.000	319.567

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3	4	5
1	0.000	0.000	0.000	49.000	0.000
2	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	122.750	0.000
6	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	331.000	0.000
9	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	1322.000	0.000
11	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000
mean	0.000	0.000	0.000	140.365	0.000

SUMMARY OF PEERS:

firm peers:

1   7

2   2

```
 3    7   2

 4    2   7   9

 5    7   9

 6    7   2   9

 7    7

 8    7

 9    9

10    7

11    7   2

12    7   2   9

13    7   2   9
```

SUMMARY OF PEER WEIGHTS:

(in same order as above)

firm peer weights:

```
 1  1.000

 2  1.000

 3  0.915 0.085

 4  0.009 0.645 0.345

 5  0.451 0.549

 6  0.539 0.035 0.426

 7  1.000

 8  1.000
```

9   1.000

10   1.000

11   0.308 0.692

12   0.758 0.108 0.134

13   0.578 0.173 0.249

PEER COUNT SUMMARY:

(i.e., no. times each firm is a peer for another)

firm peer count:

1   0

2   6

3   0

4   0

5   0

6   0

7   10

8   0

9   5

10   0

11   0

12   0

13   0

SUMMARY OF OUTPUT TARGETS:

firm	output:	1	2
1		161.000	11181.000
2		114.000	11302.000
3		157.023	11191.238
4		154.009	11381.449
5		150.564	11497.917
6		151.247	11431.212
7		161.000	11181.000
8		161.000	11181.000
9		142.000	11758.000
10		161.000	11181.000
11		128.462	11264.769
12		153.378	11271.140
13		148.158	11345.637

SUMMARY OF INPUT TARGETS:

firm	input:	1	2	3	4	5
1		1.000	1.000	1.000	6145.000	2192.000
2		1.000	1.000	1.000	5105.000	2192.000
3		1.000	1.000	1.000	6057.000	2192.000
4		1.000	1.000	1.000	6688.000	2192.000
5		1.000	1.000	1.000	7023.250	2192.000

6	1.000	1.000	1.000	6790.000	2192.000
7	1.000	1.000	1.000	6145.000	2192.000
8	1.000	1.000	1.000	6145.000	2192.000
9	1.000	1.000	1.000	7744.000	2192.000
10	1.000	1.000	1.000	6145.000	2192.000
11	1.000	1.000	1.000	5425.000	2192.000
12	1.000	1.000	1.000	6246.000	2192.000
13	1.000	1.000	1.000	6364.000	2192.000

FIRM BY FIRM RESULTS:

 Results for firm: 1

Technical efficiency = 0.938

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	151.000	10.000	0.000	161.000
output	2	10139.000	671.457	370.543	11181.000
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	6194.000	0.000	-49.000	6145.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer   lambda weight

7   1.000

Results for firm: 2

Technical efficiency = 1.000

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	114.000	0.000	0.000	114.000
output	2	11302.000	0.000	0.000	11302.000
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	5105.000	0.000	0.000	5105.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer   lambda weight

2   1.000

Results for firm: 3

Technical efficiency = 0.993

Scale efficiency   = 0.989 (irs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	156.000	1.023	0.000	157.023
output	2	9724.000	63.772	1403.467	11191.238
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	6057.000	0.000	0.000	6057.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer	lambda weight
7	0.915
2	0.085

Results for firm: 4

Technical efficiency = 0.987

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value

output	1	152.000	2.009	0.000	154.009
output	2	11233.000	148.449	0.000	11381.449
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	6688.000	0.000	0.000	6688.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer	lambda weight
2	0.009
7	0.645
9	0.345

Results for firm: 5

Technical efficiency = 0.963

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	145.000	5.564	0.000	150.564
output	2	11073.000	424.917	0.000	11497.917

input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	7146.000	0.000	-122.750	7023.250
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer	lambda weight
7	0.451
9	0.549

Results for firm: 6

Technical efficiency = 0.912

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	138.000	13.247	0.000	151.247
output	2	10430.000	1001.212	0.000	11431.212
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	6790.000	0.000	0.000	6790.000

input   5   2192.000   0.000   0.000   2192.000

LISTING OF PEERS:

peer   lambda weight

  7   0.539

  2   0.035

  9   0.426

Results for firm: 7

Technical efficiency = 1.000

Scale efficiency   = 1.000 (crs)

 PROJECTION SUMMARY:

variable		original	radial	slack	projected
		value	movement	movement	value
output	1	161.000	0.000	0.000	161.000
output	2	11181.000	0.000	0.000	11181.000
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	6145.000	0.000	0.000	6145.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer   lambda weight

7   1.000

 Results for firm: 8

Technical efficiency = 0.913

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	147.000	14.000	0.000	161.000
output	2	10008.000	953.143	219.857	11181.000
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	6476.000	0.000	-331.000	6145.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

 peer   lambda weight

  7   1.000

 Results for firm: 9

Technical efficiency = 1.000

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	142.000	0.000	0.000	142.000
output	2	11758.000	0.000	0.000	11758.000
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	7744.000	0.000	0.000	7744.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer	lambda weight
9	1.000

Results for firm: 10

Technical efficiency = 0.938

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	151.000	10.000	0.000	161.000
output	2	9459.000	626.424	1095.576	11181.000

input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	7467.000	0.000	-1322.000	6145.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer	lambda weight
7	1.000

Results for firm: 11

Technical efficiency = 0.934

Scale efficiency   = 0.956 (irs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	120.000	8.462	0.000	128.462
output	2	9528.000	671.846	1064.923	11264.769
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	5425.000	0.000	0.000	5425.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer   lambda weight

7   0.308

2   0.692

Results for firm: 12

Technical efficiency = 0.939

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	144.000	9.378	0.000	153.378
output	2	10582.000	689.140	0.000	11271.140
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	6246.000	0.000	0.000	6246.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer   lambda weight

7   0.758

2   0.108

9   0.134

Results for firm: 13

Technical efficiency = 0.911

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	135.000	13.158	0.000	148.158
output	2	10338.000	1007.637	0.000	11345.637
input	1	1.000	0.000	0.000	1.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	6364.000	0.000	0.000	6364.000
input	5	2192.000	0.000	0.000	2192.000

LISTING OF PEERS:

peer	lambda weight
7	0.578
2	0.173
9	0.249

Summary of Results

Sn	Bus number	Efficiency score
1	3622-5	0.938
2	5654-4	1.000
3	5655-4	0.993
4	5656-4	0.987
5	5657-4	0.963
6	5658-4	0.912
7	5659-4	1.000
8	5660-4	0.913
9	5661-4	1.000
10	5662-4	0.938
11	5663-4	0.934
12	5665-4	0.939
13	5667-4	0.911

Calculation for Effectiveness calculation score of Lagankhel to Budhanilkantha

Input Data

Sn	Bus number	Average number of passengers per day	Average travel time	Average number of operators	Other employees	Average number of buses per day
1	3622-5	496	10	1	1	1
2	5654-4	538	11	1	1	1
3	5655-4	401	11	1	1	1
4	5656-4	532	11	1	1	1
5	5657-4	547	11	1	1	1
6	5658-4	463	9	1	1	1
7	5659-4	546	12	1	1	1
8	5660-4	453	11	1	1	1
9	5661-4	560	10	1	1	1
10	5662-4	495	11	1	1	1
11	5663-4	436	8	1	1	1
12	5665-4	532	10	1	1	1
13	5667-4	464	10	1	1	1

Data fed in txt file

496   10   1   1   1

538   11   1   1   1

401   11   1   1   1

532	11	1	1	1
547	11	1	1	1
463	9	1	1	1
546	12	1	1	1
453	11	1	1	1
560	10	1	1	1
495	11	1	1	1
436	8	1	1	1
532	10	1	1	1
464	10	1	1	1

Instruction txt file

eg1-dta.txt   DATA FILE NAME
eg1-out.txt   OUTPUT FILE NAME
13   NUMBER OF FIRMS
1   NUMBER OF TIME PERIODS
1   NUMBER OF OUTPUTS
4   NUMBER OF INPUTS
1   0=INPUT AND 1=OUTPUT ORIENTATED
1   0=CRS AND 1=VRS
0   0=DEA(MULTI-STAGE), 1=COST-DEA, 2=MALMQUIST-DEA,
3=DEA(1-STAGE), 4=DEA(2-STAGE)

Result for DEAP V2.1

Results from DEAP Version 2.1

 Instruction file = eg1-ins.txt

Data file   = eg1-dta.txt

 Output orientated DEA

 Scale assumption: VRS

Slacks calculated using multi-stage method

 EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	0.886	0.886	1.000	-
2	0.961	0.961	1.000	-
3	0.716	0.716	1.000	-
4	0.950	0.950	1.000	-
5	0.977	0.977	1.000	-
6	0.919	0.930	0.988	irs
7	0.975	0.975	1.000	-
8	0.809	0.809	1.000	-
9	1.000	1.000	1.000	-
10	0.884	0.884	1.000	-
11	0.973	1.000	0.973	irs
12	0.950	0.950	1.000	-
13	0.829	0.829	1.000	-
mean	0.910	0.913	0.997	

Note: crste = technical efficiency from CRS DEA

    vrste = technical efficiency from VRS DEA

    scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

 SUMMARY OF OUTPUT SLACKS:

firm output: 1

1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.000
7	0.000
8	0.000
9	0.000
10	0.000
11	0.000
12	0.000
13	0.000
mean	0.000

SUMMARY OF INPUT SLACKS:

Firm input:	1	2	3	4
1	0.000	0.000	0.000	0.000
2	1.000	0.000	0.000	0.000
3	1.000	0.000	0.000	0.000
4	1.000	0.000	0.000	0.000
5	1.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000
7	2.000	0.000	0.000	0.000
8	1.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000

65

10	1.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000
Mean	0.615	0.000	0.000	0.000

SUMMARY OF PEERS:

Firm peers:

```
 1   9
 2   9
 3   9
 4   9
 5   9
 6   9  11
 7   9
 8   9
 9   9
10   9
11  11
12   9
13   9
```

SUMMARY OF PEER WEIGHTS:

(In same order as above)

Firm peer weights:

```
1  1.000
2  1.000
3  1.000
4  1.000
```

5 1.000

6 0.500 0.500

7 1.000

8 1.000

9 1.000

10 1.000

11 1.000

12 1.000

13 1.000

PEER COUNT SUMMARY:

(i.e., no. times each firm is a peer for another)

Firm peer count:

1   0

2   0

3   0

4   0

5   0

6   0

7   0

8   0

9   11

10   0

11   1

12   0

13   0

SUMMARY OF OUTPUT TARGETS:

Firm output: 1

1	560.000
2	560.000
3	560.000
4	560.000
5	560.000
6	498.000
7	560.000
8	560.000
9	560.000
10	560.000
11	436.000
12	560.000
13	560.000

SUMMARY OF INPUT TARGETS:

Firm input:	1	2	3	4
1	10.000	1.000	1.000	1.000
2	10.000	1.000	1.000	1.000
3	10.000	1.000	1.000	1.000
4	10.000	1.000	1.000	1.000
5	10.000	1.000	1.000	1.000
6	9.000	1.000	1.000	1.000
7	10.000	1.000	1.000	1.000
8	10.000	1.000	1.000	1.000
9	10.000	1.000	1.000	1.000
10	10.000	1.000	1.000	1.000
11	8.000	1.000	1.000	1.000
12	10.000	1.000	1.000	1.000
13	10.000	1.000	1.000	1.000

FIRM BY FIRM RESULTS:

Results for firm: 1

Technical efficiency = 0.886

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

Variable		original value	radial movement	slack movement	projected value
output	1	496.000	64.000	0.000	560.000
input	1	10.000	0.000	0.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

 peer   lambda weight

  9   1.000

Results for firm: 2

Technical efficiency = 0.961

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	538.000	22.000	0.000	560.000
input	1	11.000	0.000	-1.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

 peer   lambda weight

9   1.000

Results for firm: 3

Technical efficiency = 0.716

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	401.000	159.000	0.000	560.000
input	1	11.000	0.000	-1.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

peer   lambda weight

9   1.000

Results for firm: 4

Technical efficiency = 0.950

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	532.000	28.000	0.000	560.000
input	1	11.000	0.000	-1.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

peer   lambda weight

9   1.000

Results for firm: 5

Technical efficiency = 0.977

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	547.000	13.000	0.000	560.000
input	1	11.000	0.000	-1.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

peer   lambda weight

9   1.000

Results for firm: 6

Technical efficiency = 0.930

Scale efficiency   = 0.988 (irs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	463.000	35.000	0.000	498.000
input	1	9.000	0.000	0.000	9.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

peer   lambda weight

9   0.500

11   0.500

Results for firm: 7

Technical efficiency = 0.975

Scale efficiency   = 1.000 (crs)

 PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	546.000	14.000	0.000	560.000
input	1	12.000	0.000	-2.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

 LISTING OF PEERS:

 peer   lambda weight

 9   1.000

Results for firm: 8

Technical efficiency = 0.809

Scale efficiency   = 1.000 (crs)

 PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	453.000	107.000	0.000	560.000
input	1	11.000	0.000	-1.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

 LISTING OF PEERS:

peer   lambda weight

  9   1.000

Results for firm: 9

Technical efficiency = 1.000

Scale efficiency   = 1.000 (crs)

 PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	560.000	0.000	0.000	560.000
input	1	10.000	0.000	0.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

 LISTING OF PEERS:

 peer   lambda weight

  9   1.000

Results for firm: 10

Technical efficiency = 0.884

Scale efficiency   = 1.000 (crs)

 PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	495.000	65.000	0.000	560.000
input	1	11.000	0.000	-1.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

 LISTING OF PEERS:

73

peer   lambda weight

   9   1.000

Results for firm: 11

Technical efficiency = 1.000

Scale efficiency   = 0.973 (irs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	436.000	0.000	0.000	436.000
input	1	8.000	0.000	0.000	8.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

peer   lambda weight

  11   1.000

Results for firm: 12

Technical efficiency = 0.950

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	532.000	28.000	0.000	560.000
input	1	10.000	0.000	0.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

peer   lambda weight

  9   1.000

Results for firm: 13

Technical efficiency = 0.829

Scale efficiency   = 1.000 (crs)

PROJECTION SUMMARY:

variable		original value	radial movement	slack movement	projected value
output	1	464.000	96.000	0.000	560.000
input	1	10.000	0.000	0.000	10.000
input	2	1.000	0.000	0.000	1.000
input	3	1.000	0.000	0.000	1.000
input	4	1.000	0.000	0.000	1.000

LISTING OF PEERS:

peer   lambda weight

  9   1.000

Summary of effectiveness measurement

Sn	Bus number	Effectiveness score
1	3622-5	0.886
2	5654-4	0.961
3	5655-4	0.716
4	5656-4	0.950
5	5657-4	0.977
6	5658-4	0.930
7	5659-4	0.975
8	5660-4	0.809

9	5661-4	1.000
10	5662-4	0.884
11	5663-4	1.000
12	5665-4	0.950
13	5667-4	0.829

APPENDIX B: DATA PROCESSED FOR ANALYSIS

List of tables containing input Data of individual vehicles running in same route

Table B. 1 Input Data of individual vehicles running Airport to Thankot route

		Output			Input					
S n	Bus number	Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	8765-7	174.51	347	7,510.71	11.90	1	1.33	1	5,750.48	2,191.78
2	8766-7	162.53	319	6,725.00	10.87	1	1.33	1	6,855.81	2,191.78
3	8767-7	166.49	395	8,332.50	10.38	1	1.33	1	6,591.45	2,191.78
4	8768-7	169.37	382	7,727.71	11.69	1	1.33	1	6,558.71	2,191.78
5	8769-7	177.30	303	7,487.86	11.91	1	1.33	1	5,128.55	2,191.78
6	8770-7	129.25	397	7,291.00	9.31	1	1.33	1	4,475.32	2,191.78
7	8771-7	108.27	215	5,890.00	8.57	1	1.33	1	4,394.52	2,191.78
	Total	**1,087.71**	**2,360.69**	**50,964.79**	**74.63**	**7.00**	**9.30**	**7.00**	**39,754.84**	**15,342.47**

Table B. 2 Input Data of individual vehicles running Lagankhel to Budhanilkantha route

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1.00	3622-5	151.14	496	10138.57	10.02	1.00	1.33	1.00	6193.87	2191.78
2.00	5654-4	113.91	538	11301.71	11.43	1.00	1.33	1.00	5105.00	2191.78
3.00	5655-4	156.25	401	9724.29	10.58	1.00	1.33	1.00	6056.61	2191.78
4.00	5656-4	152.03	532	11232.86	10.98	1.00	1.33	1.00	6687.74	2191.78
5.00	5657-4	145.05	547	11072.86	10.92	1.00	1.33	1.00	7146.13	2191.78
6.00	5658-4	138.31	463	10430.00	9.28	1.00	1.33	1.00	6789.68	2191.78
7.00	5659-4	160.67	546	11181.43	12.01	1.00	1.33	1.00	6145.00	2191.78
8.00	5660-4	147.18	453	10008.00	10.51	1.00	1.33	1.00	6476.45	2191.78
9.00	5661-4	141.68	560	11757.50	9.58	1.00	1.33	1.00	7744.19	2191.78
10.00	5662-4	150.83	495	9458.75	10.67	1.00	1.33	1.00	7467.42	2191.78
11.00	5663-4	120.27	436	9527.50	8.36	1.00	1.33	1.00	5424.68	2191.78
12.00	5665-4	143.96	532	10582.00	9.68	1.00	1.33	1.00	6246.29	2191.78
13.00	5667-4	135.35	464	10337.86	9.74	1.00	1.33	1.00	6364.03	2191.78
	Total	1856.63	6463.00	136753.33	133.76	13.00	17.29	13.00	83847.09	28493.14

Table B. 3 Input Data of individual vehicles running Lagankhel to New Buspark route

| Sn | Bus number | Output | | | Input | | | | | |
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	5642-4	125.39	460	9,503.57	10.77	1.00	1.33	1.00	6,625.16	2,191.78
2	5645-4	121.95	465	9,698.33	10.44	1.00	1.33	1.00	5,735.81	2,191.78
3	5646-4	124.33	374	9,110.00	10.68	1.00	1.33	1.00	5,652.42	2,191.78
4	5647-4	125.51	451	9,431.43	10.28	1.00	1.33	1.00	6,020.65	2,191.78
5	5648-4	122.95	502	10,131.67	09.11	1.00	1.33	1.00	5,515.00	2,191.78
6	5649-4	127.92	454	9,542.83	10.75	1.00	1.33	1.00	5,805.81	2,191.78
7	5650-4	115.36	473	9,436.43	09.36	1.00	1.33	1.00	5,012.26	2,191.78
8	5651-4	137.79	429	8,047.14	11.09	1.00	1.33	1.00	7,947.74	2,191.78
9	5652-4	133.19	456	9,142.86	10.71	1.00	1.33	1.00	6,595.81	2,191.78
10	5653-4	129.33	433	9,225.71	10.04	1.00	1.33	1.00	6,942.58	2,191.78
11	5664-4	123.98	417	8,379.00	10.92	1.00	1.33	1.00	6,466.45	2,191.78
12	5666-4	127.01	484	9,677.50	11.58	1.00	1.33	1.00	6,651.94	2,191.78
	Total	1,514.71	5,398.00	111,326.47	125.73	12.00	15.96	12.00	74,971.63	26,301.36

Table B. 4 Input Data of individual vehicles running Lamatar to Ratnapark route

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	8752-7	120.97	405.00	7,055.00	11.76	1.00	1.33	1.00	5,132.90	120.97
2	8753-7	139.30	454.00	7,344.29	13.14	1.00	1.33	1.00	5,200.48	139.30
	Total	**260.27**	**859.57**	**14,399.29**	**24.90**	**2.00**	**2.66**	**2.00**	**10,333.39**	**4,383.56**

Table B. 5 Input Data of individual vehicles running Nagdhunga Budhanilkantha route

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	2217-3	171.68	482.00	8,910.00	10.42	1.00	1.33	1.00	6,199.03	2,630.14
2	2218-3	182.11	488.00	9,983.57	12.08	1.00	1.33	1.00	7,935.65	2,630.14
3	2219-3	123.85	474.00	9,881.57	9.10	1.00	1.33	1.00	5,184.68	2,630.14
4	2220-3	122.68	413.00	9,113.33	9.55	1.00	1.33	1.00	5,018.23	2,630.14
5	2221-3	133.76	462.00	9,719.17	10.28	1.00	1.33	1.00	6,950.16	2,630.14
6	2223-3	126.36	547.00	11,685.00	10.02	1.00	1.33	1.00	5,859.84	2,630.14
7	2224-3	137.81	410.00	9,012.14	11.42	1.00	1.33	1.00	6,030.81	2,630.14
8	2227-3	53.33	142.00	2,988.33	2.21	1.00	1.33	1.00	661.29	2,630.14
9	2229-3	186.83	425.00	9,737.50	12.72	1.00	1.33	1.00	6,822.58	2,630.14
10	2228-3	182.90	436.00	9,190.00	12.54	1.00	1.33	1.00	7,485.48	2,630.14
11	5638-4	183.17	378.00	9,302.14	11.11	1.00	1.33	1.00	8,545.65	2,191.78
12	5639-4	152.00	385.00	8,371.67	10.42	1.00	1.33	1.00	7,880.65	2,191.78
13	5640-4	135.82	281.00	7,633.33	9.53	1.00	1.33	1.00	5,698.06	2,191.78
14	5641-4	187.50	438.00	9,524.17	12.78	1.00	1.33	1.00	8,534.52	2,191.78
	Total	2,079.80	5,761.00	125,051.92	144.18	14.00	18.62	14.00	88,806.63	35,068.52

Table B. 6 Input Data of individual vehicles running Ratnapark to Godwari route

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1.00	5643-4	158.38	462.00	9367.50	10.65	1.00	1.33	1.00	7603.39	2191.78
2.00	5644-4	160.22	529.00	10918.57	10.98	1.00	1.33	1.00	7878.06	2191.78
3.00	8760-7	167.37	540.00	11046.43	11.15	1.00	1.33	1.00	7347.10	2191.78
4.00	8761-7	168.72	542.00	10774.29	10.54	1.00	1.33	1.00	7518.23	2191.78
5.00	8762-7	163.27	389.00	10220.57	10.86	1.00	1.33	1.00	7715.81	2191.78
6.00	8763-7	168.32	567.00	11000.71	10.73	1.00	1.33	1.00	7204.35	2191.78
7.00	8764-7	191.64	514.00	10002.00	12.54	1.00	1.33	1.00	8127.42	2191.78
	Total	1177.92	3543.00	73330.07	77.45	7.00	9.31	7.00	53394.36	15342.46

Table B. 7 Summarized daily data of Sajha Yatayat

S n	Bus routes	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	Airport to thankot	1,087.71	2,360.00	50,964.79	74.63	7.00	9.30	7.00	39,754.84	15,342.47
2	Lagankhel to Budhanilkantha	1,856.63	6,463.00	136,753.33	133.76	13.00	17.27	13.00	83,847.09	28,493.15
3	Lagankhel to New Buspark	1,514.71	5,398.00	111,326.47	125.73	15.96	12.00	74,971.63	74,971.63	26,301.36
4	Lamatar to Ratnapark	260.27	859.00	14,399.29	24.90	2.00	2.66	2.00	10,333.39	4,383.56
5	Nagdhunga to Budhanilkantha	2,079.80	5,761.00	125,051.92	144.18	14.00	18.62	14.00	88,806.63	35,068.52

| 6 | Ratnapark to Godawari | 1,177.92 | 3,543.00 | 73,330.07 | 77.45 | 7.00 | 9.31 | 7.00 | 53,394.36 | 15,342.46 |

Table B. 8 Input Data of individual vehicles running Goldhuga to RNAC route

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	7894	94.40	358.00	7,880.00	7.52	1.00	1.40	1.00	3650	5260.274
2	8284	118.00	466.00	10,200.00	8.48	1.00	1.40	1.00	4500	5260.274
	Total	212.40	824.00	18,080.00	16 .00	2.00	2.80	2.00	8,150.00	10,520.55

Table B. 9 Input Data of individual vehicles running Kavresthali to RNAC route

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	8289	101.60	396.00	8,950.00	7.17	1.00	1.40	1.00	3,945.00	5,260.27
2	8236	126.80	391.00	9,550.00	9.92	1.00	1.40	1.00	4,924.00	5,260.27
3	8285	102.06	393.00	8,340.00	6.87	1.00	1.40	1.00	3,965.00	5,260.27
4	8286	129.60	528.00	11,100.00	8.50	1.00	1.40	1.00	5,035.00	5,260.26
5	8238	130.23	522.00	11,500.00	8.78	1.00	1.40	1.00	5,065.00	5,260.26
6	8287	129.60	487.00	10,680.00	9.17	1.00	1.40	1.00	5,120.00	5,260.25
7	8288	130.10	412.00	9,100.00	9.92	1.00	1.40	1.00	5,035.00	5,260.25
8	7414	128.90	459.00	10,570.00	9.55	1.00	1.40	1.00	5,006.00	5,260.25
	Total	978.89	3,588.00	79,790.00	69.87	8.00	11.20	8.00	38,095.00	42,082.08

Table B. 10 Input Data of individual vehicles running Payiutar to RNAC route

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	7415	108.31	478	10,310.00	8.13	1.00	1.40	1.00	4,560.00	5260.274
2	8290	107.49	513.00	10,930.00	9.17	1.00	1.40	1.00	4,145.00	5260.274
	Total	215.80	991	21,240.00	17.30	2.00	2.80	2.00	8,705.00	10,520.55

Table B. 11 Input Data of individual vehicles running Sangla to RNAC route

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	8235	135.53	469.00	10,430.00	8.50	1.00	1.40	1.00	5,130.00	5260.274
	Total	135.53	469.00	10,430.00	8.50	1.00	1.40	1.00	5,130.00	5,260.27

Table B. 12 Summarized daily data of Tarkeshwor Yatayat

Sn	Bus number	Output			Input					
		Vehicle km per day	Average number of passengers per day	Revenue (Rs)	Average travel time (Hr)	Average number of operators	Other employees	Average number of buses per day	Energy consumption (Rs)	Capital investment (Rs)
1	Sangla To RNAC	135.53	469.00	10,430.00	8.50	1.00	1.40	1.00	5,130.00	5,260.27
2	Kavresthali to RNAC	978.89	3,588.00	79,790.00	69.87	8.00	11.20	8.00	38,095.00	42,082.08
3	Paiyutar to RNAC	215.80	991.00	21,240.00	17.30	2.00	2.80	2.00	8,705.00	10,520.55
4	Goldhunga to RNAC	212.40	824.00	18,080.00	16.00	2.00	2.80	2.00	8,150.00	10,520.55

Note: The table is titled "Summary of Primary Data of Tarkeshwor Yatayat"