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The Optimal Efficiency of Airline Operations in Nigeria Using Data Envelopment Analysis (Dea) Of Yola International Airport, Yola, Adamawa State, Nigeria.

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ABSTRACT
Airline efficiency has come under research searchlight a long time ago, as more and more inputs from technology and actors are being introduced to the industries on daily basis. The use of Data Envelopment Analysis (DEA) has now become the most adopted methodology to determine the performance of an organization in terms of efficiency. While various earlier studies have focused more on financial performance using various models, this paper used DEA to evaluate the efficiency of airline operations in Nigeria using data from five airline industries for the period of five years' operation (2018 – 2022). The paper used the literature gaps on the performance of airline industries in Nigeria especially those operating through the local Nigeria air routes. The DEA model was used to set a benchmark of unitary efficiency score and input such as Number of aircraft. The Number of employees, Gallons of fuel consumed in thousand was compared with the output parameters as Passenger revenue miles, Number of departures, and Number of passengers. The results of analysis showed that two out of five Airline industries sustained efficiency of the period of five-years (OVERLAND Airways and AZMAN Airline), while others showed a non-unitary performance efficiency but closely related to that of the benchmark. The DEA offer rooms for performance comparison among industries.

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I. INTRODUCTION

The importance of the transportation sector in every economy is critical, as it forms the bedrock of development (Coeilli,1996). Measuring efficient and effective performance of transportation sector becomes an important part of managing the national economy. Air transport sector facilitates the movement of people, goods, and services by aircrafts (Faajir & Zidan, 2020). Great amount of efficiency is obtained when long distances and heavy goods are covered and involved respectively (AMS et al., 2015).

However, the efficient air transportation required safety and conveniences at satisfactory level to airline industries, passengers and government agencies. In recent time, the relatively political stability and successful transition of democratization in Nigeria could be argued, this lead to the deregulation of airline transport sectors, which further promotes the construction of airports in some other parts of Nigeria and achieving the master plan for national air routes in Nigeria. The involvement of some private ownership in aviation industries has shown some initial positive impact on passengers and cargo traffic. Consequently, airports need to expand and improve their operational capacity, while the airline firms need to show more consistency in their services to yield better efficiency. Obviously, every effort geared towards enhancing workload will promote air traffic operations,

Reports by Suleiman (2012) has showned that there had been an increase in air transportation in Nigeria specifically at the early days of 2000 (New Millennium). This increment has been noticed in the number of departing or arriving passengers, loaded freight, as well as arriving aircraft. The liquidation of Nigerian Airways has led to the emergence of Air Nigeria as a new airline for Nigeria. The works by Faajir and Zidan (2016) showed that two years of operations after inaugural flight of Air Nigeria back in 28 June, 2005 from Lagos to London Heathrow using an Airbus A340-300 aircraft, the airline has become one of Nigeria's largest airlines carrying one million (1,000,000) passengers, as well as four thousand (4,000) ton of freight. Also, at local routes, there are numbers of private domestic airlines that operate within the country. Yet, these domestic airlines are fond of frequent flight cancellations and delays. This led to declining passengers' confidence on airline industries (Hassan & Dina, 2015).

Data envelopment analysis (DEA) is a well-established non-parametric method for measuring the associated efficiencies of decision making units (DMUs)departments in an organization (Chiou, Lan, & Yen, 2012). A good number of studies have used DEA to evaluate the performance efficiencies of airlines (Aliosio, Ameli., and D'amico., 2012 and Kartalopoulos, 2000.); airports (Jaspreet and Kochher,2015); seaports (Sunil, 2020); and football teams (Barros & Leach, 2006). It is appropriate to use DEA to measure performance efficiency of air routes in other to proffer solutions for inefficient DMUs (Chiou et al., 2012 and Kumar and Krishna, 2014.).

II. Methodology

This chapter discusses various methods and techniques adopted in this study. It includes the overall research plan and design that guided the process of data collection and the range of approaches used to collate the data. To be more specific, the chapter takes account of the sources of data, data analysis techniques according to the proposed research model.

Sources of Data

The data used for this research was sourced specifically from two sources namely: primary and secondary sources.

Primary sourced data are original data collected for the purposes of the problem under investigation (Onodugo et al., 2010). For the purpose of this study, the primary data were extracted from reports by airlines operators and as well operation records in open sources via webpage (Abd El–Naser et al.. 2011).

Based on evidences from reviewed related literatures, the airlinesoperators in Nigeria are mostly determined by their perfromaces based on physical (ATK per employee), economic terms (cost per ATK) or ratio approach (cost per total available killometer). Therfore, this study prefered a non-parametric approach which depends on a linear programming methodto evaluate operational performance of selected airlineoperators in Nigeria. Thus, the productivity of an organization (airlines) was determined by comparing the amount of output(s) recorded in respect of the total estimated input(s) used (.Khanaa, and Mohanta. 2012).

The consistent inputs and outputs parameters is among the constraints identified for determining optimal weights for each firm (Nissi & Rapposelli, 2008). The constraints are using weight that maximized the efficiency of the firm and no firm has efficiency greater than 1, and that these weights are nonnegative. Therefore, if maximum achievable efficiency of a firm *j* is less than 1, given the constraints, then it must be the case that for a given level of inputs, this firm either produced less than some other firm k, or, for a given level of outputs, it used more inputs than some other firm m.

In contrast to DEA, there is are parametric approaches to determine the efficiency for any given firm, though, the parametric approaches demand either a priory should define the production functions of the concerned firm and then compare the actual performance of a firm with the predictable production function, or using a linear regression analysis for determining an average relationship between inputs and output parameters of the firms.

The introduction of DEA has overcome many inherent problems in parametric techniques for determining organizational efficiency. Instead of almighty optimizing, the DEA optimizes each firm individually, with an objective of calculating a discrete piecewise frontier determined by a set of Pareto-optimal firms. Then DEA calculates the best efficiency measure respectively for each organization. Thus, any firm that lies on the frontier is considered efficient, while a firm that is below the frontier is considered inefficient. Additionally, DEA results provide estimates for desired changes in inputs and outputs that would propel inefficient firms on to the efficient frontier. Thus, DEA provides not only the identity of an inefficient firm, but also suggests ways to make it efficient. The DEA's efficiency is usually measured in reference to a best performing firm from actual data, rather than against an average performing firm observed through regression line.

Thus, suppose there is need to determine the relative efficiency of k firms using data envelopment analysis (DEA). Supposed each firm j produces m different types of outputs, using n different types of inputs.

Let Xj be an n x 1 vector consisting of inputs of firm j. Similarly, let Yj be an mx 1 vector of firm j's output factors. Each input and output can be assigned implicit prices (opportunity cost). Let Uj denote an n x 1 vector of implicit prices for inputs of firm j and Vj be an m x 1 vector of implicit prices for outputs. To make any economic sense, these prices should be positive.

Therefore,

$$U_j,\ V_j \geq 0 \qquad \ldots (1)$$

With these prices, the total value of inputs and outputs for firm j can be determined. Then the efficiency K of the firm j can be measured as follows

$$\eta=(V_jY_j)/(U_jX_j) \qquad \ldots(2)$$

In most cases, vector Uj and Vj are differed across the firm j = 1, k, due to varied opportunity cost for each firm. Likewise, there is need to ensure that all efficiency measure are in the range less than or equal to 1.

The constraints that has to be imposed on any firm j to ensure that the efficiency of the firm is less than or equal to 1 is:

$(V_jY_j) \leq (U_jX_j)$ …(3)

Thus, to know how other firms are performing when firm j's implicit prices were used during the time to determine efficiency for firm j, effort has to be made to ensure that efficiency measure does not exceed 1.

To determine the maximum efficiency using DEA for each firm j is given as:

Maximize $(V'_jY_j)/(U'_jX_j)$, …(4)

Therefore,

Subject to: $(V'_jY_j)/(U'_jX_j) \leq 1$ for k =1, k. …(5)

Thus, applied conditions for non-zero constraints

These conditions ensure that none of the firm is more than 100% efficient. Also, if the objective function is less than 1, then in comparison to firm j, one or more of the firms, denoted by constraints in equation (5) is producing more output using the same level of inputs, or producing the same level of output using less input, or both. Such a result would show that firm j is relatively inefficient with respect to these firms.

This maximization problem of (3) subject to (1) and (5) is a nonlinear programming problem. Transforming maximization problems to linear programing using Charnes et al. (1978) model:

Max (V'_jY_j) …(6)

Subject to:

$-V'_jY_j + U'_jX_j > 0$ for j = 1, k

$U_jX_j = 1$

$U_j,\ V_j > \varepsilon$ 86+

Where ε is small positive number

Formulation of linear programming problem consisting of equation (6) constitutes the basic DEA technique. This maximization problem is solved for each firm in the group. The firms which have objective functions value equal to 1 are deemed relatively efficient, while those less than 1 are deemed relatively inefficient. The maximization problem can easily be solved by a simple linear program

Requirements for Selecting Decision Making Units (DMUs)

According to Oyesiku et al. (2016), the basicrequirment for DEA is that the DMUs must be greater than two times the number of indexes (input and output). Another guide reported by Charnes, Cooper, & Rhodes, (1978) is anapproxmation based on rule of thumb with the following relationships:

$X > \max\{Y \times Z, 3(Y + Z)\}$

Where,

X is the number of DMUs,

Y is the number of inputs

Z is the number of outputs.

As a result, the data set that is considered for this work consists of 20 DMU (X = 20), Y = 3 and Z = 2.

Mathematically,

$$X > \max\{3 \times 2, 3(3+2)\text{, that is, } X > \{6, 15\}.$$

Therefore, the 20 DMUs is largly greater than 15 DMU minimum requirement. Thus, the dataset for this study satisfied the above given conditions.The details of DMUs adopted for this research is presented in the following table:

Table 1: *DMUs Considered for the Model*

AZMAN AIR 2018	ARIK AIR 2018	OVERLAND AIR 2018	PEACE AIR 2018	MEDVIEW AIR 2018
AZMAN AIR 2019	ARIK AIR 2019	OVERLAND AIR 2019	PEACE AIR 2019	MEDVIEW AIR 2019
AZMAN AIR 2021	ARIK AIR 2021	OVERLAND AIR 2021	PEACE AIR 2021	MEDVIEW AIR 2021
AZMAN AIR 2022	ARIK AIR 2022	OVERLAND AIR 2022	PEACE AIR 2022	MEDVIEW AIR 2022

Performance Metrics Considered

The physical (ATK per employee) and economic (cost per ATK) performance parameters were considered in this research. This parameter includes; number of planes per airline, number of employees per airline, fuel consumed by the airline planes in gallons, passenger revenue per miles per airline, number of passengers per year. These parameters are further subdivided into input and output variable for the DEA analysis.

Input variables	Output variables
1. Passenger Revenue per Miles	1 Number of Plates
2. Number of Passengers	2 Number of employees
	3 gallons og Fuel Comsumed

Software Used

In this study, DEA solver package (OSDEA) was adopted to evalute the efficiency of Airline operators. DEA solver package is an open source software that was based on linear programing to evaluate the efficiencies. Therefore, the technical efficiency (TE) is determined and organised thruough DEA solver. The DEA solvers integratednumerous linear programing models. Though, the current study considered implementation of the Envelopment model, which is used to evaluate technical efficincey. Also, the DEA library inculcates the linear programming solver (LPsolver) to carry out optimisations on the identified resources. The open soruces of DEA was considered for this study due to the fact that it is readily available online. Though, the open source still demand some technicality for the installation before it could be properlly used. Apart from little installaton challenge, the open source DEA offers flexiblity in the usage compared to propriety software. The open sources has been handy and being used for many academic researches that involved frontier analysis such as efficiency evaluation.

III. RESULTS AND DISCUSSION

This section presents the simulation results obtained from the DEAP and the Optiwave System software in order to determine the performance efficiency of the DWDM channel and how long the DWDM channels can be deployed with or without EDFA.

Simulation Results Obtained Using Data Envelopment Analysis Program (DEAP)

Simulation was carried out using the Data Envelopment Analysis Program (DEAP) for signal dropped at multiplexers and demultiplexers with and without EDFA. Tables 1 through 2 show the mean efficiencies of the DWDM channel with or without EDFA.

Table 2: Simulation parameter of signal dropped at multiplexer with EDFA

Distance in Kilometers (K/M)	**Power Margin (dB)**	**Technical Efficiency**
10	21	0.018
20	15	0.050
30	16	0.075
40	11	0.136
50	9	0.208
60	7	0.321
70	5	0.521
80	3	1.000
Mean		**0.291**

As shown in Table 2, columns 1, 2 and 3 shows the spacing of the channels in Kilometers, power margin and the cost efficiency of the DWDM channels. The mean efficiency of DWDM channels spaced at different kilometers apart is 0.291.

Table 3: Simulation parameter of signal dropped at demultiplexer with EDFA.

ADM Distance in Kilometers (K/M)	**Power Margin (dB)**	**Technical Efficiency**
5	14.8	0.059
10	13	0.135
15	12	0.219
20	11	0.319
25	10	0.438
30	9	0.583
35	8	0.766
40	7	1.000
Mean		**0.440**

Also from Table 3, columns 1, 2 and 3 shows the distance of OADM at different Kilometers from each other, the power margin and the cost efficiency of the DWDM channels placed at the demultiplexer. From the simulation results obtained, the mean efficiency of the OADM placed at different kilometers is 0.440.

Table 4 Simulation parameter of signal dropped at multiplexer without EDFA

Distance in Kilometers (K/M)	**Power Margin (dB)**	**Technical Efficiency**
4	18.2	0.087
8	17.4	0.181
12	16.6	0.285

16	15.8	0.399
20	15.0	0.525
24	14.2	0.665
28	13.4	0.823
32	12.6	1.000
Mean		**0.496**

As indicated in Table 4, columns 1, 2 and 3 shows the spacing of the channels in Kilometers, power margin and the cost efficiency of the DWDM channels. The mean efficiency of DWDM channels spaced at different kilometers apart is 0.496.

Table 5: Simulation parameter of signal dropped at demultiplexer without EDFA.

OADM Distance in Kilometers (K/M)	**Power Margin**	**Technical Efficiency**
6	13.8	0.239
8	13.4	0.328
10	13.0	0.423
12	11.8	0.559
14	12.2	0.631
16	11.8	0.746
18	11.4	0.868
20	11.0	1.000
Mean		**0.599**

Similarly, column 1 shows the distance of OADM at different Kilometers from each other, column 2 the power margin and lastly column 3 the cost efficiency of the DWDM channels placed at the demultiplexer. The DEAP was run and the results were obtained for the simulation. The simulation results clearly indicate that the mean efficiency of the OADM placed at different kilometers is 0.440.

Effective Performances of signals with or without EDFA

Table 6: Power margin (dB) of signal at the multiplexer

Power margin (dB) of signal at the multiplexer		
Channel	With EDFA	Without EDFA
1	14.8	18.2
2	13	17.4
3	12	16.6
4	11	15.8
5	10	15
6	9	14.2
7	8	13.4
8	7	12.6

Distance (Km)

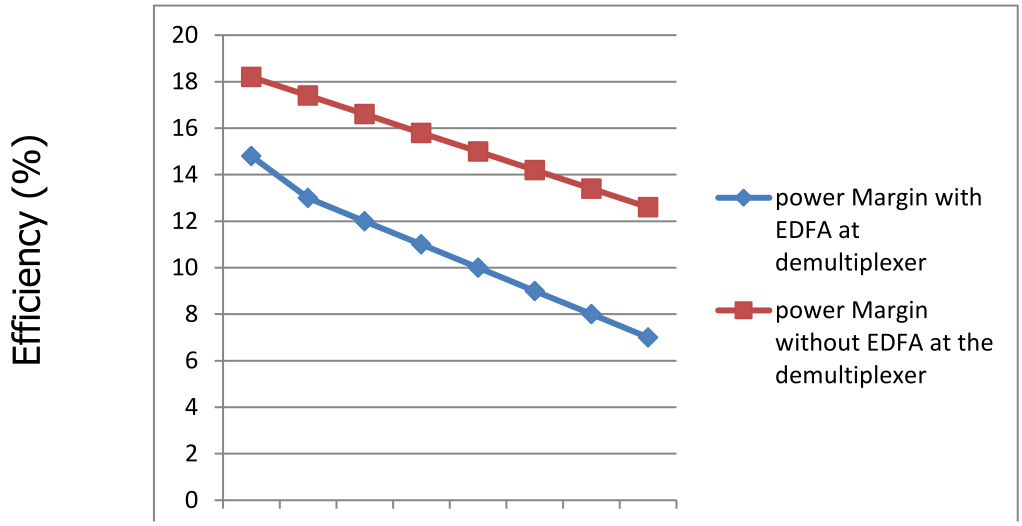
Figure 2: Power margin without EDFA at the multiplexer

Figures 1 and 2 show the power margin comparison at the multiplexers with and without EDFA figure 2 looks more efficient but covers less distance while figure 1 looks less efficient but covers more distance. In overall figure 1 covers a distance of 80km while figure 4.2covers just 32 km.

Table.7: Power margin (dB) of signal at the multiplexer

Power margin (dB) of signal at the multiplexer		
Channel	With EDFA	Without EDFA
1	100	100
2	44	48
3	27	30
4	19	22
5	13	17
6	10	13

7	8	11
8	6	9



Distance (km)

Figure 1: Power margin of signals at demultiplexers with and without EDFA.

It can be observed from Figure 1 that the Efficiency of the signal at demultiplexer without EFDA performs better than the efficiency of the signal with EDFA. This is evident from the graph presented. For example,the efficiency of the signal without EDFA is having a power margin of 18.2 when compared to 14.8 with EDFA.

Table 8: Efficiency of the signal dropped at the multiplexer with and without EDFA

Decision Makin unit	Efficiency
DMU1	1
DMU2	1
DMU3	0.441176
DMU4	0.728261
DMU5	0.254902
DMU6	0.565217
DMU7	0.161765
DMU8	0.427536
DMU9	0.105882
DMU10	0.378882
DMU11	0.068627
DMU12	0.320652
DMU13	0.042017
DMU14	0.275362

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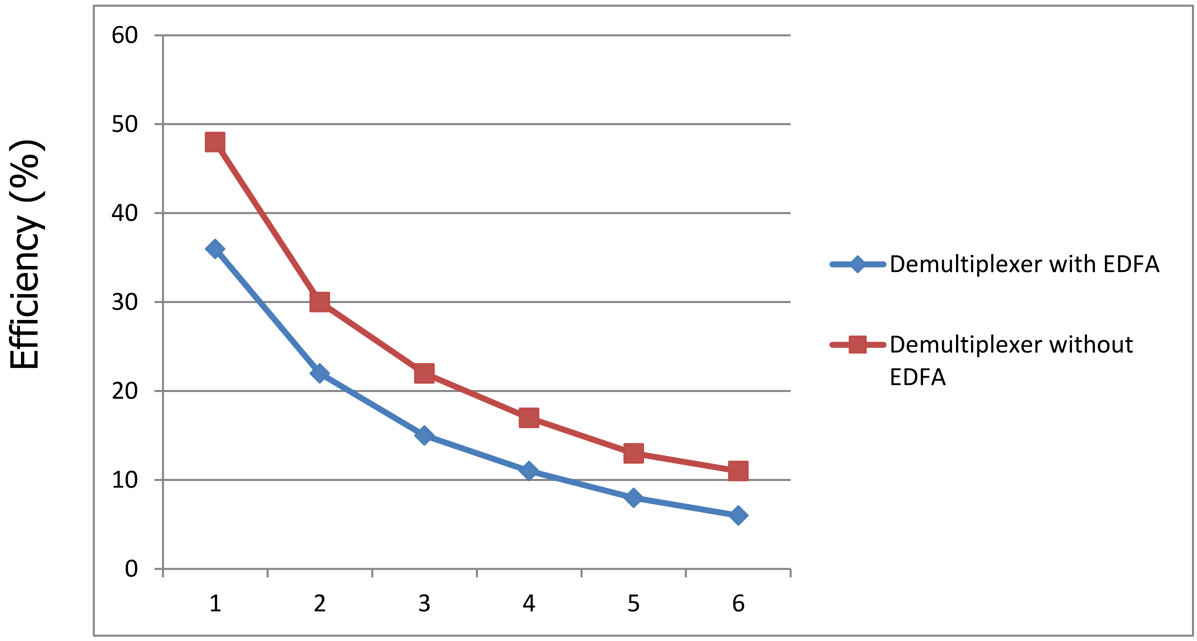
As shown in Table 4.8, the efficiency of the DWDM channel is presented for all the signal dropped at the multiplexer with EDFA and without EDFA.

Table 9: Efficiency of signal at the multiplexer with and without EDFA

Performance Efficiency in percentage	
Multiplexer with EDFA	Multiplexer without EDFA
100	100
44	73
26	57
16	43
11	38
7	32
4	28

Figure 2 shows the efficiency of signals being dropped at demultiplexers with and without EDFA in percentage.



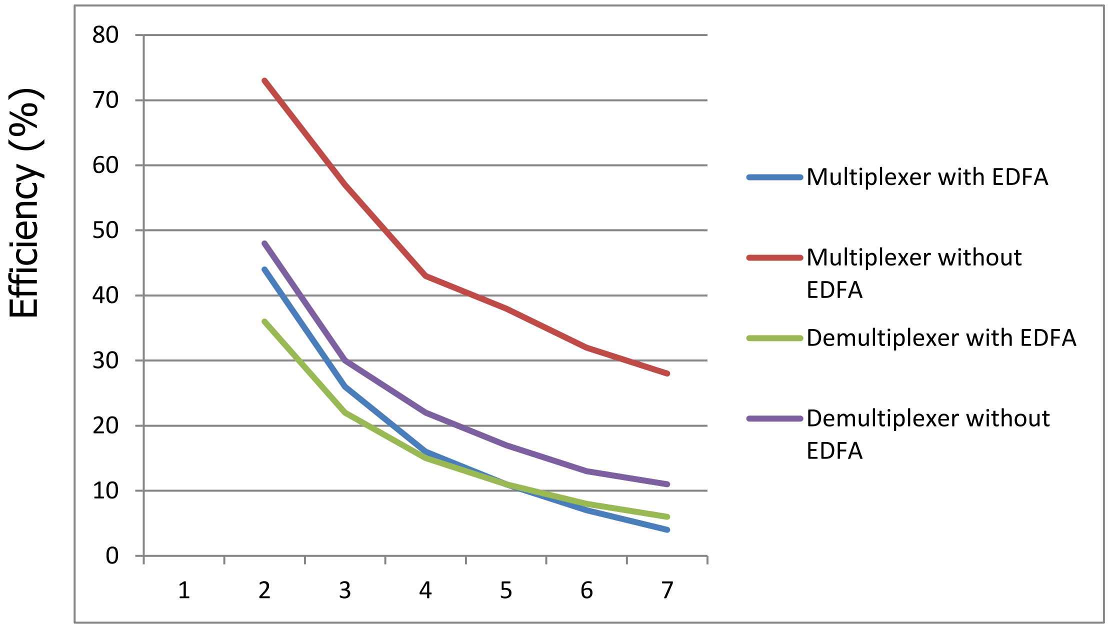
Distance (km)

Figure 2: Efficiency of the signal at the multiplexer with EDFA and without EDFA.

It can be observed from Figure 2 mthat the Efficiency of the signal at demultiplexer without EFDA performs better than the efficiency of the signal with EDFA. This is evident from the graph presented.The efficiency of the signal without EDFA is 48% when compared to 36% with EDFA.

Table 10: Comparison of Efficiency of Multiplexer and Demultiplexer

Multiplexer with EDFA	Multiplexer without EDFA	Demultiplexer with EDFA	Demultiplexer without EDFA
44	73	36	48
26	57	22	30
16	43	15	22
11	38	11	17
7	32	8	13
4	28	6	11



Distance (km)

Figure 3: Graphical Comparison of Efficiency of Multiplexer and Demultiplexer

Figure 8 presents the comparison efficiencies of the signal at the multiplexer and demultiplexer when EDFA is used and when it is not used. It can be observed clearly that the signal drop at the multiplexer without EDFA performs better than the other signals under observation attaining 73% as compared to 44% of signal drop with EDFA at the multiplexer to the ones at the demultiplexer with and without EDFA registering 36% and 48% respectively.

These variations are as a result of two (2) major factors which are: Distance and Overhead.

Distance

Distances travelled by multiplexed signals cover greater length or circumference than demultiplexed signals. From the core central office, signals covering the metropolitan ring network that are multiplexed have to be routed along or through the ring network back to the core central office while demultiplexed signal are dropped at subscribers' stations or offices.

Overhead

This deals with the processing of signals and other algorithms which include wavelength selection, coupling or launching, insertion loss optical to electrical to optical conversion (O-E-O conversion) and also additional algorithms involved with EDFA signal amplification (Albert, Ceveninni, and Izzo, 2004).

Simulation Results Obtained Using Optiwave System

Simulation was done using Optiwave System version 7.0 for all the signals dropped at the multiplexers and demultiplexers when EDFA is considered and when it is not considered in order to determine the effect of transmission impairments on the channels. An eye diagram was used to analyze the effect of noise, attenuation, degradation and other losses on each channel with the corresponding distances covered.

Eye Diagram of Signal Dropped At The Multiplexer With EDFA

This section shows the eye diagram obtained when the channels at the multiplexer are run with their corresponding distances and power margin.

Figure 3 shows an eye diagram of signal at 10km with a power margin of 21dB.

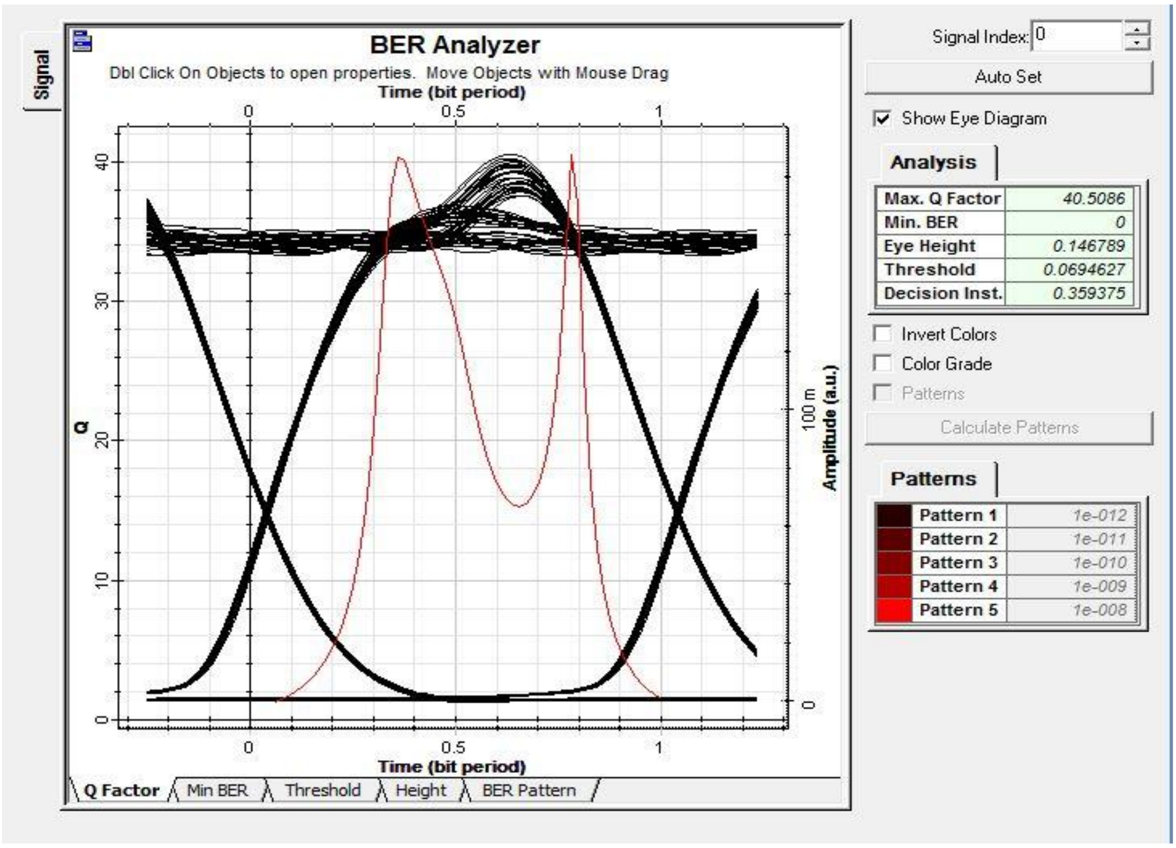


Figure 4 Eye diagram of channel 1 with Signal dropped at 10km form the multiplexer

As shown in Figure 9, the eye diagrams is very clear and have a very wide opening with an eye height of 0.1467m and a maximum Q-factor of 40.5. Signal can easily be sensed and recovered.
Figure 4.10 shows and eye diagram of signal dropped at 20km at the multiplexer with a power margin of 15dB.

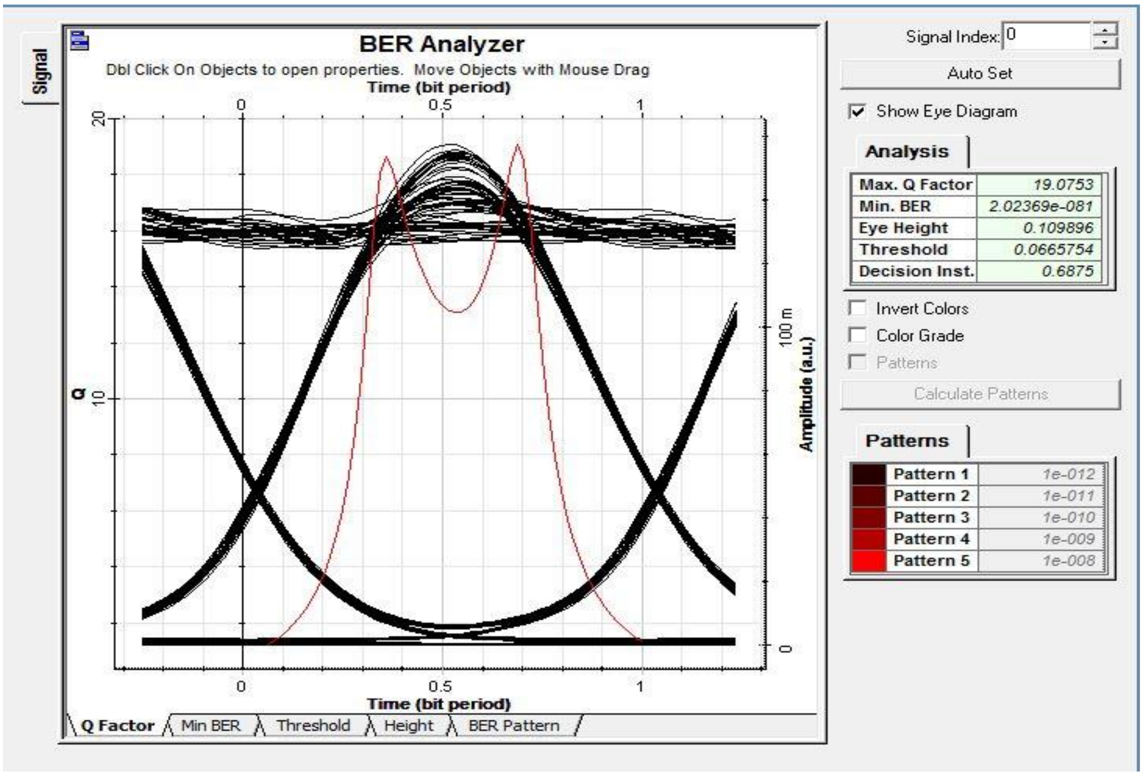


Figure 5: Eye diagram of signal dropped at the multiplexer at a distance of 20km
Figure 10 presents a good eye diagram of channel 2 with signal dropped at 20km from the multiplexer. This connotes that there are less losses on the channel at that distance.
Figure 4. shows an Eye diagram of channel 1 with an OADM placed at 5km at demultiplexer.

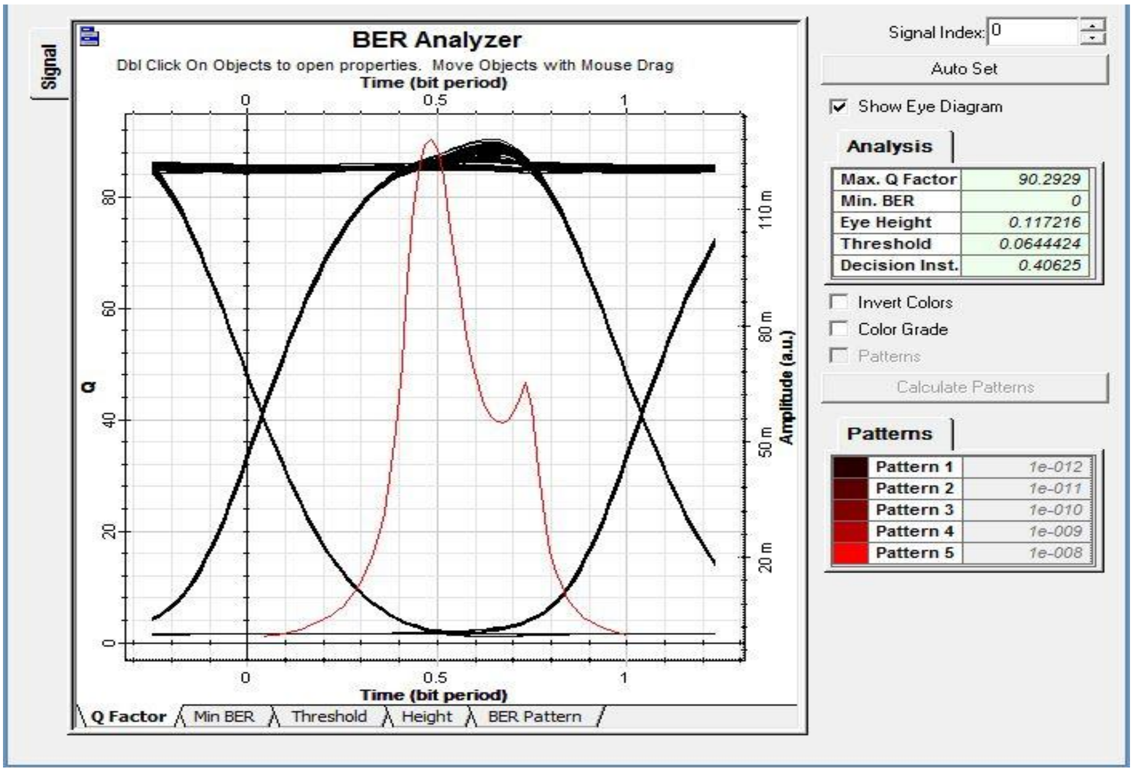


Figure 6 1st OADM of channel 1 at a distance of 5Km at demultiplexer.

As shown in Figure 4, the eye diagrams is very clear and have a very wide opening with an eye height of 0.11172m and a maximum Q-factor of 90.29m. Hence signal can easily be sensed and recovered.
The distance of the channel was extended to 10km in Figure 4.18 and the corresponding Eye

IV. DISCUSSION OF RESULTS

Result Discussion of DEA Performance Efficiency
Comparing the efficiency of the signal dropped at the multiplexer when EDFA is deployed and when EDFA is not deployed, simulation results shows clearly that the mean efficiency of the signal dropped at the multiplexer when EDFA is deployed is 0.291 as compared to 0.496 when EDFA is not deployed. It is evident from the simulation results that signal dropped at multiplexer when EDFA is not deployed is the most efficient. This is due to the fact that DWDM channels cover shorter distances and cannot go beyond these distances due to transmission impairments encountered owing to lack of amplifiers (EDFA).

Conclusion
The performance efficiency of the DWDM channels was achieved when EFDA is deployed and when EDFA is not deployed in order to determine the strength of the signal and the transmission impairment encountered. The research clearly revealed that a reasonable distance was achieved when EDFA is incorporated as compared to a situation when EDFA is not incorporated.

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