# Major Research Project on

# AN ASSESSMENT OF THE PERFORMANCE OF INDIAN RAILWAYS ZONES USING DATA ENVELOPMENT ANALYSIS


Submitted By

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2K21/DMBA/22

Under the Guidance of

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# CERTIFICATE

This is to certify that Mr. Akash Kumar Jain, have completed the project titled "**AN ASSESSMENT OF THE PERFORMANCE OF INDIAN RAILWAYS ZONES USING DATA ENVELOPMENT ANALYSIS**" under the guidance of Dr. Deepali Malhotra as a part of Master of Business Administration (MBA) curriculum of Delhi School of Management, New Delhi. This is an original piece of work and has not been submitted elsewhere.

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# DECLARATION

I hereby declare that the project report entitled "**AN ASSESSMENT OF THE PERFORMANCE OF INDIAN RAILWAYS ZONES USING DATA ENVELOPMENT ANALYSIS**" submitted by me to Delhi School of Management, DTU in partial fulfilment of the requirement for the award of the degree of Master of Business Administration is a record of bona fide project work carried out by us under the guidance of Dr. Deepali Malhotra.

**Akash Kumar Jain**

**(2K21/DMBA/22)**

# ACKNOWLEDGEMENT

The completion of my Major Research Project would not have been possible without the support of numerous people and association. First and foremost, I want to thank Delhi School of Management-DTU. I express my greatest honour to Dr. Archana Singh, HOD, DSM-DTU, Dr. Deepali Malhotra who was my mentor for the MRP and Mr. Dhiraj Kumar Pal for helping in identifying the topic for the research. Finally, I thank my friends and colleagues to help me in refining my study and suggesting required changes.

I offer my thanks toward my relatives and associates for their kind co-operation and consolation, which helped me in fulfilment of this venture.

Thanking You,

**Akash Kumar Jain**

**(2K21/DMBA/22)**

# EXECUTIVE SUMMARY

The Major Research Project is a vital part of the 2-year MBA course at Delhi School of Management, DTU. The MRP is required to be submitted in the 4th semester of the course. The topic for MRP is "AN ASSESSMENT OF THE PERFORMANCE OF INDIAN RAILWAYS ZONES USING DATA ENVELOPMENT ANALYSIS". The topic is in relation with Supply Chain and Logistics. My mentor for the same was Dr. Deepali Malhotra who provided necessary guidance, reviewed updates and suggested necessary changes required till the completion.

In this Major Research Project, I have tried to analyse the performance of various Indian Railways zones using Multi Criteria Decision Making tool called Data Envelopment Analysis. This tool provides the efficiency of various Decision-Making Units (DMU's) i.e., Railway Zones by weighing various inputs and outputs, which generally doesn't have linear relationship. This technique helps in measuring efficiency while acknowledging various inputs and outputs which have major impact on the performance, rather than judging the performance on the basis of certain aspects such as revenue or Net profit. In the case of latter method of judgement, the input variables are completely ignored thus not taking complete picture into consideration.

The tool used for analysis is DEAP which was developed by Tim Coelli, and made analysis really easy. It helped in conducting the analysis in very easy manner and provided results which were pretty easy to interpret.

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# 1.0 INTRODUCTION

## 1.1 Background

Indian Railways is an intensively complicated system of railway tracks which are used to ferry cargo and passengers from one location to another. It is the major mode of conveyance in many developed as well as developing nations, as it provides rapid, effective and reliable means of transportation. IR is an expansive and widespread connectivity that operates throughout the nation. It is divided into various zones on the basis of location. Following are the 18 zones of the Indian Railways.:

- Northern Railway (NR)
- North Eastern Railway (NER)
- Northeast Frontier Railway (NFR)
- Eastern Railway (ER)
- South Eastern Railway (SER)
- South Central Railway (SCR)
- Southern Railway (SR)
- Central Railway (CR)
- Western Railway (WR)
- South Western Railway (SWR)
- North Western Railway (NWR)
- West Central Railway (WCR)
- North Central Railway (NCR)
- East Coast Railway (ECoR)
- East Central Railway (ECR)
- Konkan Railway (KR)
- Metro Railway, Kolkata (MR)
- Chennai Metro Rail Limited (CMRL)

Ministry of Railways, which comes directly under the Government of India controls and manages the Indian Railways. They're also responsible for formulating various policies, plan and execute the projects and monitor the operations of Indian Railways. Each of these 18 zones is led by General Manager, who’s is in charge of the zone's overall operation, which covers the control of train stations, lines, rolling stock, and other operational elements. Each zone is further divided into divisions, which are headed by a Divisional Railway Manager (DRM). The DRM is responsible for managing the railway stations and operations within their jurisdiction. They are also responsible for implementing policies and projects formulated by the Ministry of Railways and the General Manager of the zone.

In addition to the General Manager and the DRM, each zone has a team of officers and staff who work together to ensure the efficient and reliable operation of the Indian Railways. These include officers responsible for areas such as finance, engineering, operations, personnel, and safety, among others.

As experienced by most of the users, Indian Railways needs a lot of expansion to cater to the needs of India Population, so this research project tries to find out how much efficiency could be increased by each zone in case the input factor remains constant (Output based DEA) along with few other objectives. The main goals of performance measurement in the public sector as noted by Radnor and McGuire (2004),

are to strengthen accountability so that organisations are held clearly accountable for the resources they use and the results they achieve, as well as to improve public services through increased economy and effectiveness in service delivery.

As one of the largest railway networks in the world, Indian Railways plays a crucial role in the country's supply chain. The network connects over 7,000 stations and moves more than 20 million passengers and 3 million tons of freight every day, making it an essential component of India's economy.

From the supply chain and logistics perspective, IR can be viewed as a highly complex network of interconnected nodes which helps in facilitation of transporting the commodities and goods through the nation. The model works as a hub and spoke architecture, and again each zone works on its own as well as in tandem with other zones to work as a unit. Transporting agricultural goods from farms to markets and ports depends heavily on the railroads. The network is also heavily utilised for the transportation of commodities across the nation's many regions.

In recent years, Indian Railways has modernised its supply chain procedures, utilising technology to boost productivity and shorten delivery times. Businesses may now plan and manage their shipments more easily thanks to the development of online freight booking and tracking tools. To increase capacity and shorten transit times, the railways have also invested in new rolling stock, including as high-speed trains and goods lanes.

However, the supply chain of the Indian Railways suffers a number of difficulties, including outdated infrastructure, capacity restrictions, and congestion at crucial nodes. Overall, the Indian Railways supply chain is a critical component of India's economy, connecting people and businesses across the country. With ongoing modernization efforts and investments in technology and infrastructure, the network is well-positioned to continue playing a vital role in the country's supply chain for years to come.

The efficacious transportation of passenger traffic and freight is the main focus of the entire IR. Its main goal is to maximise service levels within the restrictions of resources while simultaneously producing enough profits to finance their developmental efforts while considering the complicated social and economic structure of the country. The country's social and economic development has benefited greatly from the IR. Despite its financial challenges, IR has seen tremendous growth in its route miles, train stock, signalling, and telecommunication systems, as well as in electrification, the upgrading of diesel and electric traction, widespread IT use, and the creation of jobs (Agarwal and Makker, 2002). Although IR is a public sector monopoly, it has recently faced fierce competition from competitors in the public and private sectors who offer services in other available modes of transport, such as road and air, and as a result, its market share has been steadily declining. According to a 2001 assessment by an expert committee led by Dr. Rakesh Mohan, Indian Railways was on the edge of a financial crisis and was consequently its route to a fatal debt trap.

They insisted that in order to achieve more growth in both the passenger and freight divisions, the railways urgently needed to adopt a strategic perspective. They believed that one of the main factors contributing to the IR's financial problems was the absence of sufficient productivity growth that would eventually catch up with real wages. Over the past few years, IR has unpredictably managed to make money again, generating significant academic and professional interest from both India and abroad. The railway management made a variety of high-level strategic efforts that allowed for this outstanding performance.

## 1.2 Objectives

- To find out the most efficient railways zone in the given year.
- To find out scope of improvement in certain factors for specific railway zones.
- To compare results from various methods and factors to check for consistency
- To find out the best performing railways zone (in terms of growth) in the given year.

## 1.3 Scope of the research project

The research tries to find out the shortcomings in the current operations of various Indian Railways zones by comparing them from one another, based on the most pragmatic factors possible. It can be somehow related to the Supply chain and Logistics purpose of Indian Railways. This research can be useful for many stakeholders in the Railways, which may include senior administrators or someone responsible for creating the policies for Indian Railways. This analysis provides a clear picture about the current performance and the performance at best efficiency as per the results.

## 2.0 LITERATURE REVIEW

A performance benchmarking study of Indian Railway zones (Abraham George & Rangaraj, 2008) carried out the performance benchmarking study of the various Indian Railway to serve the same purpose as mentioned in the above paper discussed. The inputs and output factors were defined using the data from IR statistical publications available on the IR website. Applying DEA on this data, best performing zones and efficiency trends over the year were identified. Some weaknesses of DEA were addressed using cross-efficiencies with self-efficiencies.

This research project tries to perform the same analysis using Multi-stage and Malmquist DEA. The uniqueness of this project would be recency of the data and additional DEA method performed to get YOY insights.

Evaluation of MGNREGA: data envelopment analysis approach (Natesan & Marathe, 2017) discusses about how DEA could be used to compare relative efficiency of Indian Govt's scheme called MGNREGA which is implemented in each Indian states. They used a policy implementation method which worked as a central "black-box" about which much can't be inferred, to report for state-wise differences in the implementation.

Based on certain factors including Admin, Expenses, Employment, Fund, Tasks taken and completed, beneficiaries and households completing given target of employment (i.e., 100 days), the MIEM capture implementation efficiency at that point of time and provided suggestions to drive inefficient states towards achieving efficiency. In this paper, DEA has operationalized MGNREGA evaluation. IT acts as a decision support system and assists evaluators to take suggestions from better performing states.

Performance evaluation of Indian Railway zones using DEMATEL and VIKOR methods (Ranjan et al., 2016) tried to adopt the application of a MCDM tool for performance evaluation of Indian Railways. It tried to assess the effects of various criteria available for evaluation which involves MCDM approach called DEMATEL and VIKOR. The analysis tried to provide statistical results and the same is illustrated for providing better understanding of the working of these tools. The result of analysis ranked Western zone as best and North- Eastern zone as the worst performer. The analysis could serve as an approach for measurement of operational performance to gain insights about the possibility of improvement and may help IR administrators take further decisions in fostering services provided.

Financial Performance of Indian Railway (Shunmugaselvi & Selvi, 2022) discusses about the performance of IR in pure Financial terms as suggested by the title. It weighs in IR's assets and liabilities. It is purely based on the secondary data available from the railway's annual reports.

Performance Indicators of Indian Railways at Glance (Murugaiah & Kumar, 2017) tried to evaluate the IR's performance over the last ten years & study the comparative position of train accidents and safety improvement measures taken to avoid such instances. It also discusses about the new technology being adopted by the Indian Railways to provide better facilities and increase safety as well.

# 3.0 METHODOLOGY

The research project is based on the secondary data which is available in the public domain. The data is extracted from the Annual Statistics Report of Indian Railways which is available on their website. The various available methods along with the method used for analysis is discussed below. The selection of variables is also discussed further.

## 3.1 Various Techniques for Multi-Criteria Decision-Making Models

Data Envelopment Analysis (DEA): DEA is a non-parametric method used to evaluate the relative efficiency of a set of decision-making units (DMUs) based on their input and output data. DEA is commonly used in operations research and management science to measure the efficiency of organizations such as banks, hospitals, and schools. DEA does not require any assumptions about the underlying functional form of the relationship between inputs and outputs, and it is capable of dealing with multiple inputs and outputs.

### 3.1.1 DEMATEL

DEMATEL (Decision Making Trial and Evaluation Laboratory) is a method used to analyse complex interdependencies among different factors in a problem. DEMATEL is based on a matrix-based approach that involves identifying the cause-and-effect relationships between different factors and measuring their level of influence. In engineering, business, and social science research, DEMATEL is frequently used to pinpoint the key elements that shape a given issue and choose the best course of action to take.

### 3.1.2 VIKOR technique

The VIKOR method is a multi-criteria decision making (MCDM) or multi-criteria decision analysis method. It was originally developed by Serafim Opricovic to solve decision problems with conflicting and non-commensurable (different units) criteria, assuming that compromise is acceptable for conflict resolution, the decision maker wants a solution that is the closest to the ideal, and the alternatives are evaluated according to all established criteria. VIKOR ranks alternatives and determines the solution named compromise that is the closest to the ideal. In conclusion, DEMATEL is used to assess complicated interdependencies among diverse components in an issue, while VIKOR is used to rank alternatives based on their performance against various criteria.

### 3.2 DEA

DEA is a benchmarking tool that evaluates a population of DMUs/PMUs (countries in our case) in their performance in converting input to outputs. The purpose of the analysis is to identify the countries that most effectively transform their inputs to outputs. These units are located on the effectiveness frontier.

The efficiency score of DEA is 1.00 for frontier points; the virtual output then equals virtual input. It is less than one for sub efficient points located behind the frontier (virtual output falling short of virtual input). The frontier (envelope) itself consists of the efficient observations (with scores equal to one) and the surface of the convex hull enveloping them. Frontier points are referred to as "best practice" or "benchmarks." Any best practice point can be written as a linear combination of its "reference" units or "peers" (e.g., the corner points of the current frontier facet).

In the context of this research project, DEA method can be used to evaluate and compare the performance of various zones (selected 18 zones) based on how effectively they use their inputs (such as human capital, financial resources, and technological resources) to produce their outputs (such as passenger kilometres travelled, freight carried, and revenue earned).

DEA can also help identify the sources of inefficiency in each zone by deconstructing the efficiency score into its technical and scale components. The technical efficiency score reflects how well the zone is using its inputs to produce outputs, while the scale efficiency score reflects how well the zone is managing its resources in relation to the size of the operation.

In the case of this research project (Analysis of various zones of Indian Railways), some examples of input and output factors which can be used to perform DEA are:

Prospective Input factors:

- Total number of employees

- Total amount of capital invested
- Total length of railway tracks
- Total number of locomotives and rolling stock
- Total amount of fuel consumed
- Total maintenance and repair expenses

Prospective Output factors:

- Total passenger kilometres travelled
- Total revenue earned
- Average waiting time for passengers
- Safety and punctuality records

### 3.2.1 Multi Stage DEA

It is a variation of the standard DEA methodology which is used to assess the relative effectiveness of decision-making units (DMUs). It segments the DMUs into various phases, each of which represents a distinct level of production or transformation.

By taking into consideration the many stages of the production process, the multi-stage DEA technique enables a more in-depth investigation of the effectiveness of a production system. The inputs are converted into outputs in each stage, and the effectiveness of each stage is assessed based on the proportion of outputs to inputs. The efficiency of each individual stage is then combined to get the overall production process efficiency.

The multi-stage DEA method of enables a more complex examination of the manufacturing(operations) process, detecting inefficiencies at each stage that are generally ignored by a more aggregated analysis. Additionally, it offers a framework for locating specific places where the production process can be made more effective overall.

In multi stage DEA, the concepts of radial movement and slack movement are used to assess the effectiveness of decision-making units (DMUs) and pinpoint the causes of inefficiency.

When a DMU moves radially, it is moving in the direction of the efficiency frontier, which is the limit of the set of efficient DMUs. A DMU is considered efficient if it is located on the efficiency frontier, and radial movement shows how much progress must be made for a DMU to become efficient. The distance between the DMU's initial position and the efficiency frontier in a direction that increases its efficiency while maintaining its input and output levels is known as radial movement.

On the other side, slack movement describes the decrease in inputs or rise in outputs that an inefficient DMU can achieve without moving closer to the efficiency frontier. Slack movement shows how inefficiently a DMU is using its resources and where improvements could be made without raising inputs or lowering outputs. The amount of slack movement in a DMU is determined by comparing its actual input and output levels to the lowest and maximum levels necessary to operate efficiently while maintaining the same levels of the other inputs and outputs.

A DMU with a high radial movement has more room for improvement, and the size of the radial movement reveals how inefficient the DMU is. On the other hand, a DMU with significant slack movement is not using its resources effectively, and raising outputs or decreasing inputs can increase efficiency.

### 3.2.2 Malmquist DEA

In Malmquist DEA (Data Envelopment Analysis), using a two-stage approach, the Total Factor Productivity (TFP) change is calculated which involves two separate DEA models:

Model 1: Building a DEA model to evaluate the effectiveness of a group of decision-making units (DMUs) over a specific time period constitutes the first stage of the Malmquist DEA. The DEA model provides a score that represents the relative efficiency of each DMU by taking into consideration the inputs consumed and the outputs generated by each DMU.

Model 2: In the second step of the Malmquist DEA, another DEA model is constructed for the same collection of DMUs but for a new time period. The model's inputs and outputs are the same as those of the original DEA model, but the performance of the DMUs during the second time period is evaluated using the efficiency scores from the first stage as a standard.

The TFP change is then calculated using the Malmquist Productivity Index (MPI), which is based on the distance function approach. The MPI measures the change in total factor productivity between two time periods.

Following factors are involved in calculating Total Factor Productivity change:

- Input and output variables: The TFP change is primarily determined by the inputs and outputs utilised in the DEA models. In order to make sure that these factors are pertinent and properly reflect the production process, they should be carefully chosen.
- Reference points: The second DEA model uses the efficiency ratings achieved in the first DEA model as reference points. The TFP change calculation may be significantly impacted by the choice of reference locations.
- Efficiency change: An important variable in determining the TFP change is the efficiency difference between the two time periods. By comparing the efficiency scores from the first and second DEA models, this is calculated.

The **total factor productivity change (TFP)** between two time periods is divided into two components by the Malmquist DEA method: efficiency change and technological change.

- **Efficiency change** describes how a DMU's capacity to utilise its inputs to produce outputs efficiently changes over time, either improving or deteriorating. It can also be divided into two parts: changes in scale efficiency and pure technical efficiency.
- **Pure technical efficiency change (PTE)** assesses the improvement or decline in the utilisation of inputs and outputs during the production process while keeping the operation's scale constant.
- **Scale efficiency change (SE)** measures the change in efficiency due to changes in the scale of the operation while holding the technology constant. It occurs when a DMU is operating at a suboptimal scale, which means that it could have produced the same level of output with fewer inputs if it had operated at a more optimal scale.

- **Technological change**, on the other hand, measures the shift in the production frontier over time. It is the result of advancements in technology or changes in the production process that allow a DMU to produce more output from the same level of inputs, or the same level of output from fewer inputs.
- **Productivity change**, therefore, refers to the overall change in productivity between two time periods and can be decomposed into these two components: efficiency change and technological change.

### 3.2.3 Output based DEA

The goal of output-based data envelopment analysis (DEA) is to assess how effectively decision-making units (DMUs) transform inputs into outputs. The DMUs' outputs are the goods or services they generate, while their inputs are the resources they use. The objective is to identify the DMUs that are most effective at creating the greatest number of outputs from a specific set of inputs.

The output-based DEA input-target is used as a benchmark to assess the effectiveness of DMUs. It represents the degree of input necessary for a DMU to generate a specific level of output. The relative effectiveness of DMUs in turning their inputs into outputs is assessed using the input-target.

The maximum number of inputs that can be used to generate a certain level of outputs can be established by defining an input-target. This serves as a standard for evaluating the effectiveness of DMUs. A DMU is regarded as efficient if it can provide the same quantity of outputs as the input-target while using fewer inputs. On the other hand, a DMU is seen as inefficient if it requires more inputs than the input-target to generate the same level of outputs.

In conclusion, the output-based DEA uses the input-target as a reference point to assess how well DMUs transform their inputs into outputs. It serves as a standard for evaluating the performance of DMUs and aids in determining their relative efficacy.

### 3.3 Variables

The variables need to be kept minimum and input output set should follow exogeneity, exclusivity and exhaustiveness (Thanassoulis, 2001). The variables were selected on the results from previously conducted DEA studies and also as per the data's availability.

Input 1: Operating Expenses: The biggest input for any organization is their capital. It represents the aggregate investments made by each zone in form of grants, which include expenses for rolling stock, repairs, maintenance, fuel, staff etc.

In this research project, working expenses as available in the Annual Statistical Report of Railway have been used for this purpose. The input was taken in thousands of rupees.

Input 2: Tractive Effort: It is the effort needed for the locomotives to operated which determines the capacity of zones to handle the traffic. It included the passenger and freight trains locomotives and along with that locomotive running on different types of tracks.

There are 3 types of locomotives used namely diesel, diesel-electric and electric type. The Tractive effort was taken as total of Total Horse Power consumed by the above mention type of locomotives running on various tracks.

Output 1: Passenger Kilometres: From the perspective of a traveller, basic function of railways is efficient movement of passengers. The other major function includes transporting of goods as well. An appropriate representative of the carrying capacity of the zones is throughput. The throughput refers to the total amount of traffic carried in a particular time not in transport supply units like number of trains, but in demand units like number of passengers (Rangaraj and Srivastava, 2001). Passenger kilometres (PK) and ton kilometres are the most commonly used operating measures for passenger and freight traffic, respectively, (Ramanathan, 2003).

Output 2: Ton Kilometres: Distribution of Indian Railways revenue in financial year 2022 shows that Freight transport attribute to around 75% of the revenue, passenger movement around 20% and remaining was earned from various other activities. The freight traffic includes more than 20 commodities which includes coal, iron ore, food grains etc. It is represented in thousands.

There were other factors considered but not used in the final model due to various reasons, these are discussed below:

Input 3: Employees: The total number of people employed by the zones for daily for purpose of administration and daily operations. This may include the train pilots, engineers, maintenance staff etc.

Input 4: Passenger Carriages and Wagons: These are the number of passenger carriages and wagons available for handling passenger and freights respectively.

These variables weren't considered as they were having high correlation with other variables and wouldn't provide much improvements in the results.

## 4.0 ANALYSIS

There were various factors which could be used for the purpose of this report but many of them would be redundant, so as suggested in the previous studies correlation between these factors is determined using excel. The input factor having high correlation with another input factor can be removed solely on the discretion of the analyst. The same process has been identified in the previous research papers and results of this analysis lead to the selection of same variables as in the almost similar previous study.

*Table 4.1: Summary of Correlation of various Input and Output Factors*

| *2017-18* | *PK* | *TK* | *EMP* | *OE* | *HP* | *PC* | *WG* |
|---|---|---|---|---|---|---|---|
| PK | 1 | | | | | | |
| TK | 0.135294 | 1 | | | | | |
| EMP | 0.039211 | 0.658717 | 1 | | | | |
| OE | 0.158385 | 0.665425 | 0.947729 | 1 | | | |
| HP | 0.597922 | 0.577904 | 0.528992 | 0.590164 | 1 | | |
| PC | -0.22182 | 0.612641 | 0.849323 | 0.79398 | 0.40451 | 1 | |
| WG | 0.779672 | 0.006932 | 0.125466 | 0.148097 | 0.46563 | -0.19139 | 1 |

| *2018-19* | *PK* | *TK* | *EMP* | *OE* | *HP* | *PC* | *WG* |
|---|---|---|---|---|---|---|---|
| PK | 1 | | | | | | |
| TK | 0.181366 | 1 | | | | | |
| EMP | 0.059315 | 0.669616 | 1 | | | | |
| OE | 0.223187 | 0.726755 | 0.945995 | 1 | | | |
| HP | 0.643827 | 0.583981 | 0.514663 | 0.624216 | 1 | | |
| PC | -0.23408 | 0.59837 | 0.808796 | 0.766267 | 0.355391 | 1 | |
| WG | 0.790428 | 0.023373 | 0.128632 | 0.177506 | 0.47692 | -0.21849 | 1 |

| *2019-20* | *PK* | *TK* | *EMP* | *OE* | *HP* | *PC* | *WG* |
|---|---|---|---|---|---|---|---|
| PK | 1 | | | | | | |
| TK | 0.105691 | 1 | | | | | |
| EMP | 0.011976 | 0.687077 | 1 | | | | |
| OE | 0.186895 | 0.806144 | 0.880846 | 1 | | | |
| HP | 0.606411 | 0.624377 | 0.544994 | 0.673353 | 1 | | |
| PC | -0.21267 | 0.599694 | 0.783414 | 0.710966 | 0.376751 | 1 | |
| WG | 0.804389 | 0.031997 | 0.102383 | 0.154285 | 0.479385 | -0.20942 | 1 |

| *2020-21* | *PK* | *TK* | *EMP* | *OE* | *HP* | *PC* | *WG* |
|---|---|---|---|---|---|---|---|
| PK | 1 | | | | | | |
| TK | 0.139362 | 1 | | | | | |
| EMP | 0.134034 | 0.530983 | 1 | | | | |
| OE | 0.259915 | 0.493354 | 0.907609 | 1 | | | |
| HP | 0.623498 | 0.440616 | 0.686671 | 0.69564 | 1 | | |
| PC | 0.187178 | 0.362328 | 0.742056 | 0.673407 | 0.460977 | 1 | |
| WG | 0.346472 | 0.097672 | 0.129363 | 0.225075 | 0.496988 | -0.18198 | 1 |

*Source: Self Analysis*

Initially, 5 Input variables and 2 output variables were considered. Above table shows the correlation among all the variables. The input variables having high correlation (No. of Employees, Passenger Carriages and Wagons) were removed as they would be considered redundant and DEA requires minimum number of variables possible. In previous study, the same process was followed along with multiple DEA models to figure out the most appropriate factors. This study didn't follow the latter part of that research, and factors are considered on the basis of that study along with the correlation analysis and availability of the appropriate data.

**YoY Comparison (Selected Factors)**

*Table 4.2: YOY comparison of considered Input factors*

| Zones | Operating Expenses | | | Horse Power(Tractive Effort) | | |
|---|---|---|---|---|---|---|
| | 2018-19 | 2019-2020 | 2020-21 | 2018-19 | 2019-2020 | 2020-21 |
| Central Railway (CR) | 6.8% | 15.8% | -37.8% | 7.9% | 5.1% | -1.6% |
| Eastern Railway (ER) | 2.8% | -13.5% | 5.9% | 4.3% | 16.8% | 25.6% |
| East Central Railway (ECR) | 3.0% | -4.8% | -21.0% | 8.8% | 10.5% | 9.9% |
| East Coast Railway (ECoR) | 5.8% | -1.4% | -9.3% | 10.0% | 1.6% | 12.3% |
| Northern Railway (NR) | 4.1% | -20.0% | -25.9% | 6.8% | 12.8% | 35.8% |
| North Central Railway (NCR) | -0.7% | -7.8% | -21.5% | 6.4% | 0.9% | 5.5% |
| North Eastern Railway (NER) | 8.2% | -7.3% | -22.4% | -16.4% | 13.4% | -5.3% |
| Northeast Frontier Railway (NFR) | -14.4% | 10.9% | -14.3% | 2.0% | 4.3% | -14.3% |
| North Western Railway (NWR) | 6.2% | -6.7% | -16.7% | 6.3% | -0.6% | 5.0% |
| Southern Railway (SR) | 4.8% | -7.2% | -26.3% | 3.3% | 7.3% | 5.3% |
| South Central Railway (SCR) | 8.5% | -3.5% | -20.9% | 4.6% | 8.5% | 4.2% |
| South Eastern Railway (SER) | 4.3% | -6.4% | -19.4% | 8.9% | 11.5% | 4.4% |
| South East Central Railway (SEcR) | 11.3% | -5.6% | -13.5% | 6.3% | 10.0% | 15.0% |
| South Western Railway (SWR) | 5.2% | -7.6% | -16.6% | 2.8% | 7.7% | 7.2% |
| Western Railway (WR) | 8.6% | -7.2% | -23.7% | 2.2% | 5.9% | -7.1% |
| West Central Railway (WCR) | 5.8% | -5.0% | -21.0% | 10.0% | 7.5% | -16.7% |

*Source: Self Analysis*

*Table 4.3: YOY comparison of considered Output factors*

| Zones | Passenger Kilometres | | | | Tonne kilometres travelled | | |
|---|---|---|---|---|---|---|---|
| | 2018-19 | 2019-2020 | 2020-21 | | 2018-19 | 2019-2020 | 2020-21 |
| Central Railway (CR) | -13.6% | -10.4% | -76.4% | | 10.6% | -5.2% | -5.2% |
| Eastern Railway (ER) | -0.1% | -0.6% | -74.9% | | 5.2% | 4.9% | 1.5% |
| East Central Railway (ECR) | 0.9% | -34.0% | -72.8% | | 5.9% | -1.9% | -1.0% |
| East Coast Railway (ECoR) | 18.8% | 6.6% | -81.2% | | 3.6% | 5.5% | 3.8% |
| Northern Railway (NR) | -1.2% | -6.7% | -82.5% | | 5.1% | -9.3% | 12.2% |
| North Central Railway (NCR) | 0.1% | -1.8% | -67.9% | | 1.9% | -19.2% | -0.9% |
| North Eastern Railway (NER) | 2.5% | -47.3% | -72.7% | | 4.2% | -8.9% | 12.8% |
| Northeast Frontier Railway (NFR) | 8.7% | 5.0% | -76.4% | | 4.4% | 0.5% | 14.1% |
| North Western Railway (NWR) | -10.7% | -9.6% | -84.1% | | -1.3% | -2.0% | 18.3% |
| Southern Railway (SR) | 0.0% | 2.6% | -83.8% | | 9.6% | -8.9% | 1.9% |
| South Central Railway (SCR) | 0.3% | -5.5% | -81.9% | | 9.5% | -10.6% | -5.4% |
| South Eastern Railway (SER) | 2.2% | -5.9% | -79.5% | | 5.5% | 7.8% | 0.7% |
| South East Central Railway (SEcR) | 0.7% | -3.0% | -87.4% | | 10.9% | 0.0% | 2.6% |
| South Western Railway (SWR) | 5.2% | -3.4% | -84.7% | | 3.7% | -4.1% | 9.9% |
| Western Railway (WR) | -7.2% | -9.2% | -79.5% | | 11.7% | -11.4% | -2.0% |
| West Central Railway (WCR) | 5.0% | -3.2% | -70.3% | | 9.9% | -4.7% | -5.8% |

*Source: Self Analysis*

From the YoY analysis of the selected factors nothing much can be inferred with certainty except the sudden drop in Operating Expenses and Passenger Kilometres which could be attributed to the pandemic. The effect is very well present in 2020-21 and somewhat affecting the results of year 2019-20. Apart from these, there is no clear trend or pattern which is being followed throughout. The tonne kilometres are increased for most of the zones during pandemic as railways was the most sought-after mode of transporting various commodities.

## 4.1 Multi Stage DEA

*Figure 4.1: Technical Efficiency (2017-18)*

```
Results from DEAP Version 2.1

Instruction file = Eg1-ins
Data file        = eg1-dta.txt

 Output orientated DEA

 Scale assumption: CRS

 Slacks calculated using multi-stage method


 EFFICIENCY SUMMARY:

  firm     te
    1  1.000
    2  0.562
    3  0.673
    4  1.000
    5  0.569
    6  1.000
    7  1.000
    8  0.328
    9  1.000
   10  0.600
   11  0.855
   12  0.704
   13  1.000
   14  0.506
   15  0.944
   16  1.000

 mean  0.796
```

*Source: Screen capture, Result file generated by DEAP software*

This is the result for the Multi-Stage DEA for 1st year, where it can be seen that 7 organisations were able to achieve maximum efficiency. Here, firms are addressed by a no. as the DEAP software only takes numbers as input. In 2017-18, firm 8th was having worst efficiency which is Northeast Frontier Railways.

*Figure 4.1: Input & Output Targets*

```
SUMMARY OF OUTPUT TARGETS:

firm  output:           1           2
   1         4507524.90017624392.500
   2         3785792.98611986923.310
   3         7463273.64310815945.886
   4         7783111.300 2460813.400
   5         8287075.57820060933.808
   6         6474676.200 9005064.800
   7         1181799.100 6371000.800
   8         4321123.284 5853136.270
   9         3569799.600 4729672.600
  10         3473514.22714322759.624
  11         7486519.37912980028.782
  12         9118353.177 5016821.090
  13         6130480.400 3071658.800
  14         3032690.026 5977419.661
  15         5688765.72713375166.631
  16         5131695.700 8093836.700


SUMMARY OF INPUT TARGETS:

firm  input:            1           2
   1        15094081.100     454.732
   2        12431616.719     208.803
   3        12287633.300     343.559
   4         8751894.800     329.070
   5        20610358.900     413.216
   6        10518946.200     256.551
   7         5512708.500      98.320
   8         9329878.831     139.650
   9         7642018.700     114.036
  10        12290342.700     341.564
  11        13226002.800     549.454
  12        10614486.000     328.226
  13         7008141.500     206.130
  14         6237142.800     144.136
  15        13001699.400     354.561
  16         8216879.200     439.152
```

*Source: Screen capture, Result file generated by DEAP software*

This is the most crucial part of DEA analysis as it gives the output targets (as well as input targets) which are fundamental to this research project. Since, it is an Output based DEA study, the input targets are same as the input data. In case of Output targets, these are same only for zones having maximum efficiency of 1, for others these differ for each zone. It suggests the output which these zones should have to lie on the efficiency frontier or in easier terms to effectively utilise the resources which acts as an input.

*Figure 4.2:Zone-wise detailed result*

```
Results for firm:     1
Technical efficiency = 1.000
 PROJECTION SUMMARY:
  variable           original       radial        slack     projected
                        value     movement     movement         value
 output     1     4507524.900        0.000        0.000   4507524.900
 output     2    17624392.500        0.000        0.000  17624392.500
 input      1    15094081.100        0.000        0.000  15094081.100
 input      2         454.732        0.000        0.000       454.732
 LISTING OF PEERS:
  peer   lambda weight
    1      1.000


Results for firm:     2
Technical efficiency = 0.562
 PROJECTION SUMMARY:
  variable           original       radial        slack     projected
                        value     movement     movement         value
 output     1     2126991.900  1658801.086        0.000   3785792.986
 output     2     6734675.900  5252247.410        0.000  11986923.310
 input      1    13402643.000        0.000  -971026.281  12431616.719
 input      2         208.803        0.000        0.000       208.803
 LISTING OF PEERS:
  peer   lambda weight
    9      0.580
    7      1.451


Results for firm:     3
Technical efficiency = 0.673
 PROJECTION SUMMARY:
  variable           original       radial        slack     projected
                        value     movement     movement         value
 output     1     5022110.400  2441163.243        0.000   7463273.643
 output     2     7278156.600  3537789.286        0.000  10815945.886
 input      1    12287633.300        0.000        0.000  12287633.300
 input      2         343.559        0.000        0.000       343.559
 LISTING OF PEERS:
  peer   lambda weight
    1      0.024
    6      0.997
   16      0.175
```

*Source: Screen capture, Result file generated by DEAP software*

The above image shows the detailed result generated by the DEAP software; the terms shown in the image have been explained in the methodology.

Radial Movement and Slack Movement represent the distance from the efficiency frontier or the increase in output to reach the frontier. Lambda weight is the measure of how much another peer influences your weights in the cross-efficiency analysis.

*Table 4.4: Percentage Improvement required in Output factors to achieve efficiency*

| | Percentage Improvement required | |
|---|---|---|
| Zones | PK | TK |
| Central Railway (CR) | 0.0% | 0.0% |
| Eastern Railway (ER) | 78.0% | 78.0% |
| East Central Railway (ECR) | 48.6% | 48.6% |
| East Coast Railway (ECoR) | 0.0% | 0.0% |
| Northern Railway (NR) | 75.8% | 75.8% |
| North Central Railway (NCR) | 0.0% | 0.0% |
| North Eastern Railway (NER) | 0.0% | 0.0% |
| Northeast Frontier Railway (NFR) | 204.5% | 204.5% |
| North Western Railway (NWR) | 0.0% | 0.0% |
| Southern Railway (SR) | 124.2% | 66.8% |
| South Central Railway (SCR) | 17.0% | 17.0% |
| South Eastern Railway (SER) | 42.1% | 42.1% |
| South East Central Railway (SEcR) | 0.0% | 0.0% |
| South Western Railway (SWR) | 97.5% | 97.5% |
| Western Railway (WR) | 6.0% | 6.0% |
| West Central Railway (WCR) | 0.0% | 0.0% |

*Source: Self Analysis*

*Table 4.5: Multi Stage DEA result for all 4 years*

| Years -> Zones | 2017-18 | 2018-19 | 2019-20 | 2020-21 |
|---|---|---|---|---|
| Central Railway (CR) | 1 | 0.894 | 0.848 | 0.74 |
| Eastern Railway (ER) | 0.562 | 0.514 | 0.777 | 0.51 |
| East Central Railway (ECR) | 0.673 | 0.663 | 0.588 | 0.602 |
| East Coast Railway (ECoR) | 1 | 1 | 1 | 1 |
| Northern Railway (NR) | 0.569 | 0.539 | 0.685 | 0.478 |
| North Central Railway (NCR) | 1 | 1 | 1 | 1 |
| North Eastern Railway (NER) | 1 | 1 | 1 | 1 |
| Northeast Frontier Railway (NFR) | 0.328 | 0.385 | 0.44 | 1 |
| North Western Railway (NWR) | 1 | 1 | 1 | 0.55 |
| Southern Railway (SR) | 0.6 | 0.611 | 0.799 | 0.74 |
| South Central Railway (SCR) | 0.855 | 0.82 | 0.796 | 0.738 |
| South Eastern Railway (SER) | 0.704 | 0.72 | 0.77 | 0.806 |
| South East Central Railway (SEcR) | 1 | 1 | 1 | 0.287 |
| South Western Railway (SWR) | 0.506 | 0.51 | 0.608 | 1 |
| Western Railway (WR) | 0.944 | 0.868 | 0.902 | 0.668 |
| West Central Railway (WCR) | 1 | 1 | 1 | 1 |

*Source: Self Analysis*

The table describes the technical efficiency of each zones obtained using Multi-stage DEA analysis. The zones having value of 1 are efficient and subsequent zones have scope of improvement in their efficiency, based on the given input and output factors.

In this analysis, 4 zones have been efficient throughout the span of 4 years which are namely East Coast Railways, North Central Railways, North Eastern Railway and West Central Railways. In 2017-18, maximum number of zones (7) came out to be efficient.

*Figure 4.4: Analysis of Technical Efficiency*

| Effc. Score -> Years | 1 | .75-.99 | .5-.74 | 0 - 0.49 |
|---|---|---|---|---|
| 2017-18 | CR,ECoR,NCR,NER,NWR, SEcR,WCR | WR,SCR | SER,ECR,SR,NR | ER,SWR,NFR |
| 2018-19 | ECoR,NCR,NER,NWR,SEc R,WCR | CR,WR,SCR, | SER,ECR,SR,NR,ER,SWR | NFR |
| 2019-20 | ECoR,NCR,NER,NWR,SEc R,CR | WR,CR,SR,SCR,ER,SER | NR,SWR,ECR | NFR |
| 2020-21 | ECoR,NCR,NER,NFR,SWR ,CR | SER,CR,SR,SCR | WR,ECR,NWR,ER | NR,SEcR |

*Source: Self Analysis*

This table represent the zones distributed according to the technical efficiency. As already mentioned, 4 zones have been consistently efficient throughout these 4 years, South Coast Railways have consistently lied between .75-.99 range, whereas NFR has significant drop from being in the red zone to being efficient in 2020-21 and NR dropped to the subsequent range in last year.

## 4.2 Malmquist DEA

*Figure 4.5: Malmquist DEA Result - All Factors (2018-19)*

MALMQUIST INDEX SUMMARY

year = 2

| firm | effch | techch | pech | sech | tfpch |
|---|---|---|---|---|---|
| 1 | 0.894 | 0.937 | 1.000 | 0.894 | 0.837 |
| 2 | 0.915 | 1.070 | 1.019 | 0.898 | 0.979 |
| 3 | 0.985 | 1.009 | 1.011 | 0.974 | 0.994 |
| 4 | 1.000 | 0.982 | 1.000 | 1.000 | 0.982 |
| 5 | 0.947 | 1.012 | 1.019 | 0.930 | 0.958 |
| 6 | 1.000 | 0.992 | 1.000 | 1.000 | 0.992 |
| 7 | 1.000 | 1.079 | 1.000 | 1.000 | 1.079 |
| 8 | 1.172 | 0.917 | 1.127 | 1.040 | 1.075 |
| 9 | 1.000 | 0.915 | 1.000 | 1.000 | 0.915 |
| 10 | 1.018 | 0.938 | 1.143 | 0.891 | 0.955 |
| 11 | 0.959 | 0.996 | 1.000 | 0.959 | 0.955 |
| 12 | 1.023 | 0.983 | 1.003 | 1.019 | 1.006 |
| 13 | 1.000 | 1.010 | 1.000 | 1.000 | 1.010 |
| 14 | 1.008 | 0.991 | 1.042 | 0.967 | 0.999 |
| 15 | 0.919 | 0.982 | 1.035 | 0.888 | 0.903 |
| 16 | 1.000 | 1.009 | 1.000 | 1.000 | 1.009 |
| mean | 0.988 | 0.988 | 1.024 | 0.965 | 0.976 |

*Source: Screen capture, Result file generated by DEAP software*

*4.6: Malmquist DEA Result - All Factors (Average of all years)*

MALMQUIST INDEX SUMMARY OF FIRM MEANS

| firm | effch | techch | pech | sech | tfpch |
|---|---|---|---|---|---|
| 1 | 0.904 | 0.710 | 1.000 | 0.904 | 0.642 |
| 2 | 0.968 | 0.660 | 0.931 | 1.040 | 0.639 |
| 3 | 0.964 | 0.877 | 0.980 | 0.984 | 0.845 |
| 4 | 1.000 | 1.014 | 1.000 | 1.000 | 1.014 |
| 5 | 0.944 | 0.758 | 0.975 | 0.968 | 0.716 |
| 6 | 1.000 | 0.777 | 1.000 | 1.000 | 0.777 |
| 7 | 1.000 | 0.635 | 1.000 | 1.000 | 0.635 |
| 8 | 1.449 | 0.776 | 1.421 | 1.020 | 1.125 |
| 9 | 0.820 | 0.766 | 0.823 | 0.996 | 0.628 |
| 10 | 1.073 | 0.761 | 1.108 | 0.968 | 0.817 |
| 11 | 0.952 | 0.846 | 1.000 | 0.952 | 0.806 |
| 12 | 1.047 | 0.999 | 0.989 | 1.059 | 1.045 |
| 13 | 0.659 | 0.941 | 0.661 | 0.998 | 0.620 |
| 14 | 1.255 | 0.788 | 1.233 | 1.018 | 0.989 |
| 15 | 0.891 | 0.768 | 0.961 | 0.927 | 0.685 |
| 16 | 1.000 | 0.831 | 1.000 | 1.000 | 0.831 |
| mean | 0.982 | 0.800 | 0.993 | 0.989 | 0.786 |

*Source: Screen capture, Result file generated by DEAP software*

*Table 4.6: Results for all 3 years and Average*

| Years-> | Total Factor Productivity Change | | | |
|---|---|---|---|---|
| Zones | 2017-18 to 2018-19 | 2018-19 to 2019-20 | 2019-20 to 2020-21 | Overall |
| Central Railway (CR) | 0.837 | 0.802 | 0.394 | 0.642 |
| Eastern Railway (ER) | 0.979 | 0.994 | 0.268 | 0.639 |
| East Central Railway (ECR) | 0.994 | 0.858 | 0.709 | 0.845 |
| East Coast Railway (ECoR) | 0.982 | 1.069 | 0.993 | 1.014 |
| Northern Railway (NR) | 0.958 | 1.016 | 0.376 | 0.716 |
| North Central Railway (NCR) | 0.992 | 0.931 | 0.509 | 0.777 |
| North Eastern Railway (NER) | 1.079 | 0.538 | 0.441 | 0.635 |
| Northeast Frontier Railway (NFR) | 1.075 | 0.979 | 1.354 | 1.125 |
| North Western Railway (NWR) | 0.915 | 0.952 | 0.284 | 0.628 |
| Southern Railway (SR) | 0.955 | 1.064 | 0.536 | 0.817 |
| South Central Railway (SCR) | 0.955 | 0.954 | 0.575 | 0.806 |
| South Eastern Railway (SER) | 1.006 | 1.125 | 1.01 | 1.045 |
| South East Central Railway (SEcR) | 1.01 | 0.983 | 0.241 | 0.62 |
| South Western Railway (SWR) | 0.999 | 0.98 | 0.987 | 0.989 |
| Western Railway (WR) | 0.903 | 0.925 | 0.384 | 0.685 |
| West Central Railway (WCR) | 1.009 | 1.001 | 0.568 | 0.831 |
| | | | | |
| Mean | 0.976 | 0.937 | 0.53 | 0.786 |

*Source: Self Analysis using the selected dataset*

As discussed earlier, Total Factor Productivity change is a result of 5 factors but for this research project's purpose only Total Factor Productivity change is discussed, as it summarises the whole idea in brief.

From 2017-18 to 2018-19, North Eastern Railway and North East Frontier Railway performed the best having productivity change of 7.9% and 7.5% respectively, whereas Central Railway's productivity declined the most (16.3%).

Subsequently, Southern Railways had most growth in productivity i.e., 12.5% whereas North Eastern Railways having decline of 46.2% when compared to the previous year, this drop can be attributed to high jump in Operating Expenses (8.2%), without having significant change in Output factors.

The last year is anomalous as the operations were deeply affected due to the ongoing pandemic. The transportation sector was hit badly and IR could not operate at ongoing scale for passenger services after the first quarter of the year. The Freight services were somehow not interrupted as it was covered under necessary services. The situation is depicted by the results in the Malmquist DEA analysis, the zones which were most dependent on the freight services performed significantly better than the ones having less weightage of freight services. Here Northeast Frontier Railways is having most productivity change (35.4%), which is solely because of its dependence on the freight services. It also had an increase of 14.1% in Tonne Kilometrage in the same year. Most of the zones suffered drastically due to the pandemic having performance even less than 50% of the previous year.

*Table 4.7: Total Factor Productivity Change, Technical Efficiency and Operating Ratio (2018-19)*

| 2018-19 | | | |
|---|---|---|---|
| Factor-><br>Zones | Productivity Change | Technical Efficiency | Operating Ratio(%) |
| Central Railway (CR) | 0.802 | 0.848 | 1.05 |
| Eastern Railway (ER) | 0.994 | 0.777 | 1.70 |
| East Central Railway (ECR) | 0.858 | 0.588 | 1.03 |
| East Coast Railway (ECoR) | 1.069 | 1 | 0.51 |
| Northern Railway (NR) | 1.016 | 0.685 | 1.56 |
| North Central Railway (NCR) | 0.931 | 1 | 0.74 |
| North Eastern Railway (NER) | 0.538 | 1 | 1.88 |
| Northeast Frontier Railway (NFR) | 0.979 | 0.44 | 1.52 |
| North Western Railway (NWR) | 0.952 | 1 | 1.13 |
| Southern Railway (SR) | 1.064 | 0.799 | 1.46 |
| South Central Railway (SCR) | 0.954 | 0.796 | 0.88 |
| South Eastern Railway (SER) | 1.125 | 0.77 | 0.65 |
| South East Central Railway (SEcR) | 0.983 | 1 | 0.54 |
| South Western Railway (SWR) | 0.98 | 0.608 | 1.24 |
| Western Railway (WR) | 0.925 | 0.902 | 1.15 |
| West Central Railway (WCR) | 1.001 | 1 | 0.71 |

*Source: Self Analysis*

This table shows the Total Factor Productivity change, Technical Efficiency and Operating Ratio for the year 2019-20. These factors for few of the zones are highly correlated, whereas they are contradictory for others. This supports the fact that the performance cannot be adjudged on the basis of single factor. Here, East coast Railways have highest synchronisation among the 3 whereas Northeast Railway despite of performing good when compared to other zones have high operating ratio and didn’t have good growth when compared to the last year.

## 5.0 CONCLUSION

The Indian Railways which were basically started during the colonial period by Britishers for goods movement is now the backbone of Indian Public transport system as well as Logistical Operations as well. The current parameters for evaluating the performance were only based on specific factors which were generally output and didn't consider the Input factors. This research project tried to evaluate the performance on the basis of both Input and Output factors.

The Multi Stage DEA shows that there are many zones who needs to improve their operation to reach the efficiency frontier, only 6 zones (varies YOY) were able to be efficient which shows the condition of Indian Railways. The Total productivity in the span of 4 years dropped collectively for all zones (or for IR) by 21.4%. The major contribution could be attributed to the pandemic. The performance was dropping in the previous years too, but it worsened in the year 2020-21. The scope of improvement for each zone is decided on the basis of input and output targets projected by the analysis. This value will try to maximise efficiency for each zone and as a single unit help IR perform well. The comparison of TFP change, Tech Eff. and OR for a year shows that there is not much consistency if various factors are combined, so it would be necessary to identify which factor is most suitable to get the desired results.

Based on the results of the analysis, the Indian Railways need to work a lot to achieve the maximum efficiency which is necessarily required as there is not much scope in terms of expansion, so better utilisation of resources becomes necessity to perform better and cater to as much population as possible. The recent disruption caused due to the pandemic, couldn't affect the freight services of Indian Railways which could be seen as quite big of an achievement. The recent development specifically for the freight transportation, Dedicated Freight Corridor could prove to be a huge breakthrough as it would result in better freight services and it would not impact passenger services and vice-versa. This research project tried to identify the major shortcomings based on the selected input and output factors and provides a statistical solution to the same. The project didn't take into account any of the qualitative factors which could act as further scope for this research project.

## 5.1 Implications

- The research indicates the most efficient zones as well as the least efficient zones, it may help the authorities responsible with the operations of particular zones in analysing their shortcomings and perform better in upcoming years.
- The Indian Railways can also try to conduct similar kind of study and figure out how to provide better services with the existing infrastructure and also expanding the network to the remote villages as well.
- This research is an analysis based on certain factors where a specific methodology has been applied, there may be other ways to do the benchmarking which can also be used to validate this research project as well. The limitations of this research are discussed in the subsequent part of this research project, which can could be addressed to have a pragmatic approach in analysing the performance.

## 5.2 Limitations

- This research project evaluates the performance on the basis of selected factors but is not able to identify the underlying reason for the results. To further explore, another research can be conducted to figure out the underlying reason which may validate the result of the current research project. Following methods may be applied to conduct further study:
    - Analysis of Twitter complaints related to the various Railway zones of Indian Railways.
    - Analysing the Audit reports published by CAG.
- This result is purely based on the statistical front, and ignore the qualitative aspect which is somewhat depicted in the previous point. Further studies can be conducted to analyse performance on the basis of some qualitative aspects as well. Again, that could be used to validate the results of this research (or it may contradict).

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# ANNEXURE

## 7.1 Input and Output Factors data

*All the data values are in 10000s

*Table 7.1 Input Factors Data*

| Zones | Operating Expenses | | | | | Horse Power(Tractive Effort) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2017-18 | 2018-19 | 2019-2020 | 2020-21 | | 2017-18 | 2018-19 | 2019-2020 | 2020-21 |
| Central Railway (CR) | 15094081.10 | 16116454.90 | 18664904.00 | 11604865.40 | | 454.73 | 490.62 | 515.58 | 507.20 |
| Eastern Railway (ER) | 13402643.00 | 13774104.70 | 11913042.10 | 12614099.30 | | 208.80 | 217.70 | 254.21 | 319.32 |
| East Central Railway (ECR) | 12287633.30 | 12660569.90 | 12049734.90 | 9518182.20 | | 343.56 | 373.81 | 412.91 | 453.69 |
| East Coast Railway (ECoR) | 8751894.80 | 9257358.40 | 9125050.80 | 8272123.80 | | 329.07 | 362.11 | 367.86 | 413.28 |
| Northern Railway (NR) | 20610358.90 | 21463246.30 | 17179022.10 | 12737612.70 | | 413.22 | 441.30 | 497.94 | 676.16 |
| North Central Railway (NCR) | 10518946.20 | 10449680.90 | 9638411.70 | 7570081.00 | | 256.55 | 272.92 | 819.60 | 290.64 |
| North Eastern Railway (NER) | 5512708.50 | 5967483.30 | 5530075.70 | 4293613.90 | | 98.32 | 82.24 | 93.28 | 88.31 |
| Northeast Frontier Railway (NFR) | 10145471.20 | 8681981.60 | 9632524.20 | 8254979.90 | | 139.65 | 142.39 | 148.51 | 127.27 |
| North Western Railway (NWR) | 7642018.70 | 8118138.40 | 7573713.90 | 6312332.30 | | 114.04 | 121.23 | 120.47 | 126.51 |
| Southern Railway (SR) | 12290342.70 | 12883339.40 | 11959101.30 | 8817330.70 | | 341.56 | 352.96 | 378.78 | 398.78 |
| South Central Railway (SCR) | 13226002.80 | 14351142.10 | 13847603.20 | 10946952.20 | | 549.45 | 574.57 | 623.19 | 649.55 |
| South Eastern Railway (SER) | 10614486.00 | 11069907.50 | 10360133.00 | 8345633.20 | | 461.54 | 502.59 | 560.47 | 584.86 |
| South East Central Railway (SEcR) | 7008141.50 | 7802772.70 | 7362508.20 | 6367145.00 | | 206.13 | 219.02 | 240.91 | 277.02 |
| South Western Railway (SWR) | 6237142.80 | 6558646.60 | 6058530.70 | 5052260.00 | | 144.14 | 148.16 | 159.60 | 171.04 |
| Western Railway (WR) | 13001699.40 | 14125606.00 | 13113832.40 | 10005124.30 | | 354.56 | 362.34 | 383.75 | 385.40 |
| West Central Railway (WCR) | 8216879.20 | 8696271.10 | 8261403.30 | 6525018.90 | | 439.15 | 482.99 | 518.98 | 432.55 |

*Source: Annual Statistical Statements,2017-18 & 2018-19, Indian Railways*

*Table 7.2: Output Factors data*

| Zones | Passenger Kilometres | | | | Tonne Kilometres | | | |
|---|---|---|---|---|---|---|---|---|
| | 2017-18 | 2018-19 | 2019-2020 | 2020-21 | 2017-18 | 2018-19 | 2019-2020 | 2020-21 |
| Central Railway (CR) | 17624392.50 | 15225912.60 | 13644025.20 | 3226534.10 | 4507524.90 | 4984243.90 | 4725320.90 | 4477689.20 |
| Eastern Railway (ER) | 6734675.90 | 6727815.00 | 6687442.80 | 1676705.30 | 2126991.90 | 2237255.40 | 2346286.10 | 2380882.80 |
| East Central Railway (ECR) | 7278156.60 | 7346831.30 | 4850245.80 | 1320708.90 | 5022110.40 | 5316019.20 | 5217572.30 | 5164848.60 |
| East Coast Railway (ECoR) | 2460813.40 | 2924601.70 | 3116604.60 | 586030.30 | 7783111.30 | 8066648.50 | 8509634.70 | 8830183.90 |
| Northern Railway (NR) | 11408918.90 | 11267082.60 | 10514168.80 | 1840777.70 | 4712969.70 | 4953087.20 | 4491698.00 | 5040510.50 |
| North Central Railway (NCR) | 9005064.80 | 9015707.70 | 8856825.00 | 2846058.30 | 6474676.20 | 6597443.50 | 5327743.60 | 5280847.00 |
| North Eastern Railway (NER) | 6371000.80 | 6529989.50 | 3444139.00 | 940078.40 | 1181799.10 | 1231539.50 | 1122171.90 | 1265322.70 |
| Northeast Frontier Railway (NFR) | 1922220.90 | 2089073.60 | 2193001.30 | 516632.50 | 1419094.50 | 1480862.90 | 1488657.40 | 1698828.50 |
| North Western Railway (NWR) | 4729672.60 | 4224123.80 | 3816662.90 | 606395.50 | 3569799.60 | 3524543.90 | 3454548.10 | 4088368.70 |
| Southern Railway (SR) | 8587332.80 | 8587271.00 | 8810427.10 | 1430901.70 | 1549556.50 | 1697608.80 | 1547324.20 | 1576469.40 |
| South Central Railway (SCR) | 11093993.30 | 11125883.50 | 10517967.40 | 1899294.30 | 6398706.60 | 7009039.70 | 6263623.20 | 5926944.70 |
| South Eastern Railway (SER) | 3529583.50 | 3608984.80 | 3397808.50 | 696465.60 | 6415215.60 | 6766461.00 | 7295144.60 | 7349498.00 |
| South East Central Railway (SEcR) | 3071658.80 | 3094571.90 | 3003090.10 | 377387.30 | 6130480.40 | 6797725.30 | 6796603.90 | 6974106.10 |
| South Western Railway (SWR) | 3025956.70 | 3183832.10 | 3074274.80 | 470868.80 | 1535242.50 | 1592109.00 | 1526888.40 | 1677302.90 |
| Western Railway (WR) | 12623752.90 | 11711797.70 | 10631124.70 | 2184333.50 | 5369172.20 | 5998929.30 | 5315736.20 | 5209246.30 |
| West Central Railway (WCR) | 8093836.70 | 8498528.50 | 8227190.50 | 2445630.40 | 5131695.70 | 5638783.40 | 5374494.90 | 5064322.00 |

*Source: Annual Statistical Statements,2017-19 & 2018-19, Indian Railways*

## 7.2 YoY Analysis of Non-selected factors

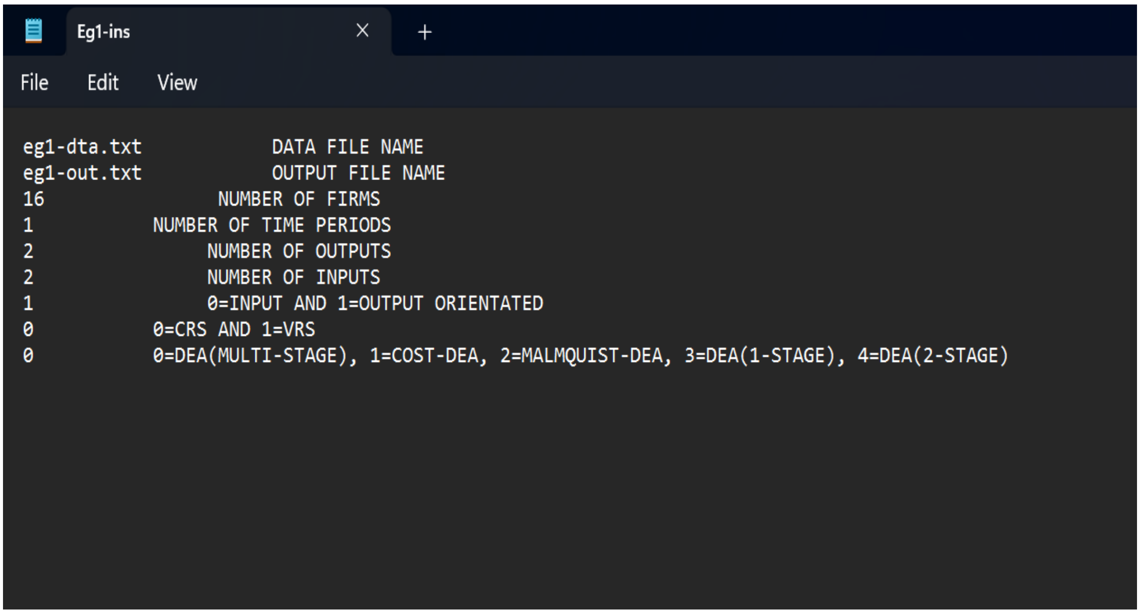
*Table 7.3: YoY Analysis for non-selected factors*

| Zones | Total number of employees | | | | Passenger Carriages | | | | Carriage Wagons | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017-18 | 2018-19 | 2019-2020 | 2020-21 | 2017-18 | 2018-19 | 2019-2020 | 2020-21 | 2017-18 | 2018-19 | 2019-2020 | 2020-21 |
| Central Railway (CR) | 102754 | 99931 | 101137 | 99932 | 5863 | 6010 | 6272 | 5943 | 17701 | 19007 | 16447 | 17242 |
| | | -2.7% | 1.2% | -1.2% | | 2.5% | 4.4% | -5.2% | | 7.4% | -13.5% | 4.8% |
| Eastern Railway (ER) | 111074 | 107726 | 107742 | 106022 | 5764 | 5775 | 6260 | 6224 | 16919 | 17482 | 18114 | 19516 |
| | | -3.0% | 0.0% | -1.6% | | 0.2% | 8.4% | -0.6% | | 3.3% | 3.6% | 7.7% |
| East Central Railway (ECR) | 78771 | 77800 | 79707 | 83261 | 3693 | 3816 | 4220 | 4260 | 23061 | 22888 | 23237 | 23780 |
| | | -1.2% | 2.5% | 4.5% | | 3.3% | 10.6% | 0.9% | | -0.8% | 1.5% | 2.3% |
| East Coast Railway (ECoR) | 46663 | 46163 | 47233 | 47491 | 2606 | 2704 | 3188 | 3184 | 20124 | 21933 | 23343 | 24229 |
| | | -1.1% | 2.3% | 0.5% | | 3.8% | 17.9% | -0.1% | | 9.0% | 6.4% | 3.8% |
| Northern Railway (NR) | 138782 | 130095 | 136733 | 135563 | 6855 | 6580 | 6234 | 7332 | 14649 | 15517 | 16307 | 16500 |
| | | -6.3% | 5.1% | -0.9% | | -4.0% | -5.3% | 17.6% | | 5.9% | 5.1% | 1.2% |
| North Central Railway (NCR) | 64654 | 62721 | 63003 | 65687 | 1543 | 1610 | 1659 | 1713 | 28075 | 29600 | 30009 | 30209 |
| | | -3.0% | 0.4% | 4.3% | | 4.3% | 3.0% | 3.3% | | 5.4% | 1.4% | 0.7% |
| North Eastern Railway (NER) | 49775 | 48150 | 49504 | 49121 | 2653 | 3087 | 3470 | 3327 | 4719 | 4711 | 4718 | 4625 |
| | | -3.3% | 2.8% | -0.8% | | 16.4% | 12.4% | -4.1% | | -0.2% | 0.1% | -2.0% |
| Northeast Frontier Railway (NFR) | 58905 | 57781 | 60555 | 60629 | 2396 | 2255 | 1988 | 2028 | 5801 | 6130 | 6123 | 6098 |
| | | -1.9% | 4.8% | 0.1% | | -5.9% | -11.8% | 2.0% | | 5.7% | -0.1% | -0.4% |
| North Western Railway (NWR) | 46956 | 45149 | 47398 | 46956 | 2773 | 3025 | 3304 | 3528 | 7958 | 8260 | 8550 | 8729 |
| | | -3.8% | 5.0% | -0.9% | | 9.1% | 9.2% | 6.8% | | 3.8% | 3.5% | 2.1% |
| Southern Railway (SR) | 88921 | 84554 | 87248 | 84211 | 6830 | 7363 | 7078 | 6985 | 8960 | 9263 | 9748 | 9748 |
| | | -4.9% | 3.2% | -3.5% | | 7.8% | -3.9% | -1.3% | | 3.4% | 5.2% | 0.0% |
| South Central Railway (SCR) | 81733 | 78495 | 81609 | 81845 | 4660 | 4616 | 4965 | 5867 | 21759 | 22232 | 22234 | 22139 |
| | | -4.0% | 4.0% | 0.3% | | -0.9% | 7.6% | 18.2% | | 2.2% | 0.0% | -0.4% |
| South Eastern Railway (SER) | 84463 | 81284 | 81417 | 81377 | 3515 | 3782 | 4036 | 4025 | 32346 | 31840 | 33273 | 33723 |
| | | -3.8% | 0.2% | 0.0% | | 7.6% | 6.7% | -0.3% | | -1.6% | 4.5% | 1.4% |
| South East Central Railway (SEcR) | 45801 | 44994 | 45104 | 46204 | 922 | 918 | 1000 | 995 | 28921 | 30268 | 30515 | 31035 |
| | | -1.8% | 0.2% | 2.4% | | -0.4% | 8.9% | -0.5% | | 4.7% | 0.8% | 1.7% |
| South Western Railway (SWR) | 36487 | 35516 | 36662 | 36382 | 3056 | 3195 | 3593 | 3500 | 7718 | 8781 | 7718 | 10104 |
| | | -2.7% | 3.2% | -0.8% | | 4.5% | 12.5% | -2.6% | | 13.8% | -12.1% | 30.9% |
| Western Railway (WR) | 96434 | 92338 | 95044 | 93200 | 5476 | 5582 | 6033 | 9830 | 11654 | 12453 | 13224 | 14418 |
| | | -4.2% | 2.9% | -1.9% | | 1.9% | 8.1% | 62.9% | | 6.9% | 6.2% | 9.0% |
| West Central Railway (WCR) | 55031 | 53330 | 55189 | 55428 | 1446 | 1541 | 1879 | 1803 | 12848 | 13178 | 13427 | 13655 |
| | | -3.1% | 3.5% | 0.4% | | 6.6% | 21.9% | -4.0% | | 2.6% | 1.9% | 1.7% |

*Source: Self Analysis using Annual Statistical Statements 2018-19, Indian Railways*

## 7.3 DEAP software

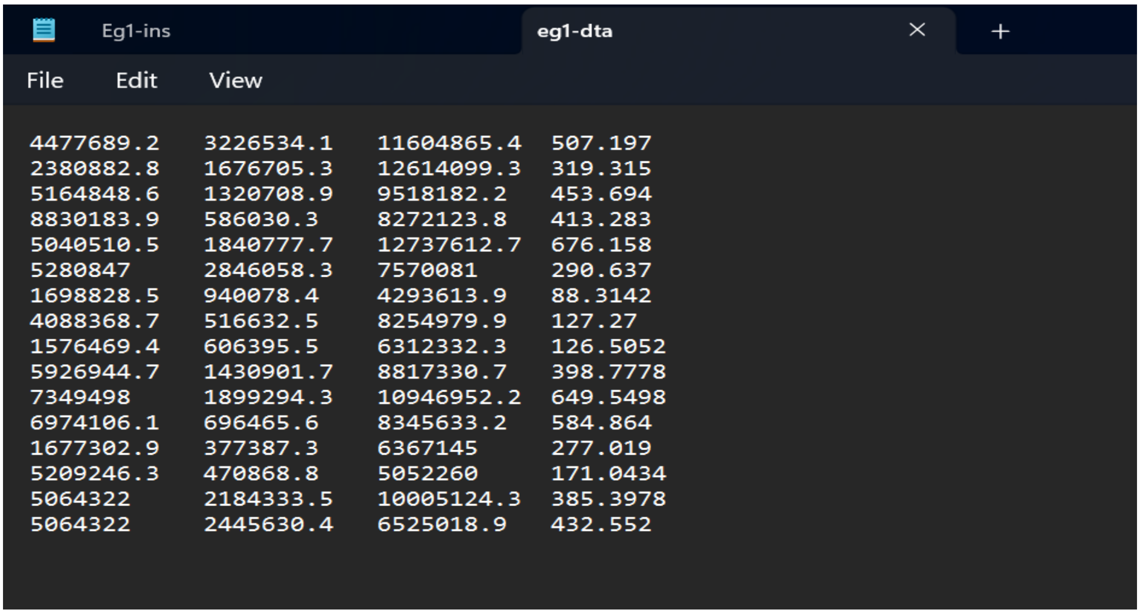
*Figure 7.1: DEAP Instruction File*



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

*Source: Screen capture from DEAP software package*

*Figure 7.2: DEAP data input file*



| | | | |
|---|---|---|---|
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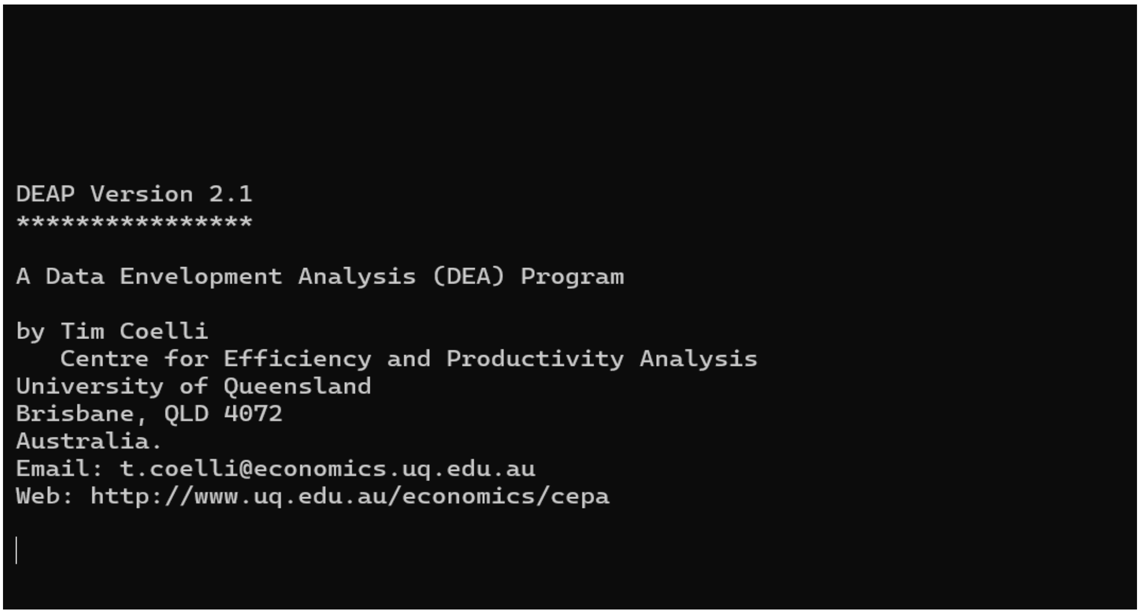
| 2380882.8 | 1676705.3 | 12614099.3 | 319.315 |
| 5164848.6 | 1320708.9 | 9518182.2 | 453.694 |
| 8830183.9 | 586030.3 | 8272123.8 | 413.283 |
| 5040510.5 | 1840777.7 | 12737612.7 | 676.158 |
| 5280847 | 2846058.3 | 7570081 | 290.637 |
| 1698828.5 | 940078.4 | 4293613.9 | 88.3142 |
| 4088368.7 | 516632.5 | 8254979.9 | 127.27 |
| 1576469.4 | 606395.5 | 6312332.3 | 126.5052 |
| 5926944.7 | 1430901.7 | 8817330.7 | 398.7778 |
| 7349498 | 1899294.3 | 10946952.2 | 649.5498 |
| 6974106.1 | 696465.6 | 8345633.2 | 584.864 |
| 1677302.9 | 377387.3 | 6367145 | 277.019 |
| 5209246.3 | 470868.8 | 5052260 | 171.0434 |
| 5064322 | 2184333.5 | 10005124.3 | 385.3978 |
| 5064322 | 2445630.4 | 6525018.9 | 432.552 |

*Source: Screen capture from DEAP software package*

*Figure 7.3: DEAP starting interface*




*Source: Screen capture from DEAP software package* turnitin

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Summary