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Application of Operations Research in environmental management

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ABSTRACT

The ecological balance and ecosystem stability are duly maintained by nature itself but the emergence of the modern industrial era has disturbed the ecological balance through heavy industrialization, faster growth of means of transportation, rapacious exploitation of resources, unplanned urbanization, etc. Environmental management is thus, the process to improve the relationship between human beings and the environment. Operations research creates mathematical models to maximize efficiency, which in turn reduces cost and minimal usage of resources. In this research paper, we will deeply review the applications of operations research in environmental management by using transportation problems as well as case studies to highlight the impact of operations research on the environment.

Keywords— Environmental crisis, Particulate matter, Air pollution, Transportation problem, Population

1. INTRODUCTION

Environmental problems are becoming serious in India because of the interacting effects of increasing population density, industrialization and urbanization, and poor environmental management practices. Air pollution in India is responsible for 12.5 percent of all deaths in the country, according to the State of India's Environment (SOE) report, 2019. 8.5 out of every 10,000 children in India die before they turn five due to poor air. This makes the study of environmental management especially air pollution very important. Hence, our research paper will be focused on conducting a deep study and finding the optimal solution to the concerned problem.

1.1 Boundaries of the Study

To highlight the boundaries of the study we are going to answer the questions of:

- What is environmental management?
- What is OR? and
- What constitutes environmental management?

We will consider a set of activities that are performed before, during and after and environmental operation with a goal of preventing loss of human life and reducing the impact on the economy and its effects on environment.

1.2 Environmental Management

Environmental management is defined as organizing environmental initiatives to tackle various ecological issues that adversely affect the planet. It deals with preventing ecological disasters and finding solutions to those environmental crises. Environmental management includes land, marine as well as atmospheric issues. The problem of ecological issues arises due to factors such as increased pollution, population and exploitation of natural resources are a result of human need for globalization, expansion, and development. So, to counter the pollution and preserve natural resources and environment the concept of environmental management has arisen in this contemporary era. According to NASA groundwater declines are highest on Earth between 2002 and 2008 in

northern India. Agricultural productivity is dependent on irrigation. A collapse of agricultural output and severe shortages of potable water may influence 114 million residents in India. In July 2012, about 670 million people or 10% of the world's population lost power blame on the severe drought restricting the power delivered by hydroelectric dams. To prevent such problems some measures have to be taken, which can be taken through study and analysing issues and calculated solutions have to be produced for current situations which can be done through operations research. Which provides us with exact mathematical solutions and measures to stop these issues.

1.3 Operations Research

Operations research (OR) is an analytical method of problem-solving and decision-making that is useful in the management of organizations. In operations research, problems are broken down into basic components and then solved in defined steps by mathematical analysis.

- **Creating a Model:** OR first makes a model. A model is a logical representation of a problem. It shows the relationships between the different variables in the problem. It is just like a mathematical formula.
- For e.g. $\text{Assets} - \text{Liabilities} = \text{Capital} + \text{Accumulated Reserves}$
- **Shows Important Variables:** OR shows the variables which are important for solving the problem. Many of the variables are uncontrollable.
- **Symbolises the Model:** The OR model, its variables and goals are converted into mathematical symbols. These symbols can be easily identified, and they can be used for calculation.
- **Achieving the Goal:** The main goal of OR is to select the best solution for solving the problem.
- **Quantifying the Model:** All variables in the OR model are quantified. That is, they are converted into numbers. This is because only quantified data can be put into the model to get results.
- **Using Mathematical Devices:** Data is supplemented with mathematical devices to narrow down the margin of error.
- **Use of a Computer:** The main focus is on decision-making and problem solving. For this purpose computers are widely used.
- **Interdisciplinary:** OR is interdisciplinary because it uses techniques from economics, mathematics, chemistry, physics, etc.
- **Highest Efficiency:** The main aim of OR is to make decisions and solve problems. This results in the highest possible efficiency.

1.4 Applications of Operations Research

Operations research is a problem solving and decision taking technique. It provides us with quantitative solutions for various problems. Operations research can be applied in areas:

- Where resources have to be allocated such as where men, machines, time, money, and raw material, it helps to make most efficient use of scarce resources to get most effective results.
- Scheduling and sequencing of production
- Budget allocation
- Making profit plans for companies
- It can be used in transport, loading, and unloading, minimizing the cost by providing with efficient solutions

Mainly operations research can be utilized in making management decisions and as corrective measures for past wrong decisions made. It provides us with efficient solutions but when supported with numerical data most optimal solutions can be found.

1.5 Applications of operations research in environmental management

1.5.1 Efficiency: Operations research creates a mathematical model to maximize efficiency, which in turn reduces cost and minimal usage of resources helping in energy and resource conservation and reducing harmful emissions by the manufacturing companies

1.5.2 Calculation of emissions: Operations research calculates the number of emissions done by companies and compares it with revival rate of environment by mathematically creating and solving the model. It can provide us with exact figures of emissions in which harm done to environment will not exceed the revival rate of nature, balancing the need for industrialization and development with conserving environment.

1.5.3 Forecasting resource availability: Operations research can calculate the current availability of resources and the current consumption rate, which will help us to predict the future availability of resources for development. Apparently which will give people incentives to conserve resources and shift their focus on renewable resources helping solve the ecological issues.

2. OVERVIEW OF THE INDUSTRY

In the last few decades, environmental problems have received increasing attention. The protection of the environment has become an issue at all levels of society. Within the field of Operation Research (OR), attention on environmental issues is now growing rapidly.

2.1 Interaction between OR (Operation Research) and EM (Environment Management)

2.1.1 Impact of Economic Activities on the Environmental Chain: The amount of waste and the level of emissions caused by the supply chain results in a number of serious environmental effects such as global warming and acid rain. These environmental problems are frequent and complex. The interaction between OR and EM can result in a clear formulation of these problems and bring new insights into the impacts of alternative policy measures.

3. RESEARCH OBJECTIVES

- To understand the factors that can affect the air quality and to integrate them into our solutions and suggestions

- To find solutions to the environmental problems that persist emphasising on fuel emissions which reduce the air quality of the area.
- To link the real life problems, policies and projects with applications in OR
- To outline the problems faced by the population due to the mismanagement of negative externalities (pollution)

4. RESEARCH METHODOLOGY

We will use transportation problems as well as a case study to highlight the impact of operations research on the environment.

4.1 Transportation Problem

For TP we will use minimization to find the optimal route of the transportation problem by replacing the cost unit by the distance (in km) to find the minimum value route so as to reduce the emission into the environment

4.2 Case Study

We will link the case study of New Delhi Odd Even Scheme which was implemented in 2016 with the help of graphs which will show the difference in the air quality before and after the scheme. Ultimately it will show the negative externality (pollution) being minimized with the policy being implemented.

4.3 Case Study: Odd Even Scheme

New Delhi has earned the tag of being the most polluted city in the world, outstripping the Chinese capital Beijing, known for its record pollution levels. Owing to the toxic air that Delhi is breathing, Odd Even Scheme was introduced. Under the scheme, cars with license plates ending in an odd number and even number were allowed to ply on alternate days. The scheme aimed to cut down vehicular traffic by half, thereby reducing air pollution.

5. LITERATURE REVIEWS

(Taneja, 2017; Thakur, n.d.; Bedekar, n.d.) Delhi is a highly populated metropolitan city with over 11 million population famous for high congestion and traffic jams. When the AAP government came into power, our CM Arvind Kejriwal introduced odd-even scheme. Under this scheme all the vehicles with odd and even numbers will be permitted to run on alternate days. The main vision behind this was restricting the number of cars running on the roads can lead to controlling the traffic rate and of pollution levels in the city. This plan also has two sides like a coin, there were many pros and cons of this plan. Some advantages were reduced the number of cars on the roads to almost half and make it even more convenient for people to reach on time, government is now introducing women-only buses which will ensure the safety of working women who have late working hours. Along with pros there were cons too, while some people are in support of this, many people are completely against it, because of their flexible work hours. With the restriction of being able to use their cars only on specific days makes them dependent on other sources, a lot of inconveniences were caused to everyone. After the first phase of odd-even, Anumita Roy Chowdhury of Centre for Science and Environment (CSE) had said that a sharp drop of pollutants from the peak levels was observed, "When vehicles slow down due to congestion they emit more. Free flow of traffic helps prevent that." Also the government did a survey and got 4.1 lakh responses from the public through multiple channels. 81 per cent of respondents want odd-even back and more than 60 per cent said the formula should be made permanent, Mr Kejriwal had said.

(Taneja, Odd Even rule returns in Delhi) Environmental issues have become a major reason while taking decisions relating to any commercial activity no matter what it may be, as they directly or indirectly have an impact on environment. Interaction between OR and EM can help in reducing the damage caused to environment. The first one is supply chain management, in this our main focus is on logistics, inventory control. In second type we concentrate on impact of economic activities on the environmental chain. The shift from effect-oriented control towards pollution prevention and the increasing acknowledgement of the complexity and international character of environmental problems are open invitations for the increasing interaction between OR and EM. Environmental policy has shifted from traditional single pollutant/ single effect abatement policies towards the development of sustainable integrated policies. Incorporating environmental issues in OR models enriches its working area and make it more dynamic. Even in the past environmental problems have been solved using OR and environmental variables. One of them was Dutch manure problem. It was initially it was treated as a local environmental problem to be solved through end-of-pipe techniques, however even after many years technical solutions did not solve the manure problem. As a result, policy makers changed their regional approach for at least two reasons: (i) air pollution due to ammonia emission requires regional legislation because of the transboundary effects of ammonia emission, and (ii) technical solutions are not sufficient to solve the problem. Another problem was with environmental policy making for the European pulp and paper industry. The European pulp and paper industry has environmental impacts associated with the consumption of scarce raw materials, emissions to air and water due to bleaching processes and the generation of waste paper. These impacts contribute to a wide range of environmental problems of local, regional and global significance. Environmental policy has to be developed on a regional level, since actions to reduce environmental impacts in one place may have serious implications for actions that occur elsewhere. Thus in many cases in the past OR is used to rectify environmental problems through various approaches.

6. FINDINGS

6.1 Transportation Problem

The transportation industry, as the carrier of goods and passengers, is undeniably one of the fundamental infrastructures, necessary for economic and industrial growth and development. Road transportation, in this amidst, has still kept its popularity, and in spite of air, sea, and rail transportation developments, companies rely greatly on road transportation as the most dependable choice yet. At the same time it is one of the huge consumers of petroleum products, and thus a big contributor to greenhouse gases and CO₂ emissions in the air. Being a threatening issue, environmental impacts of different industries as a whole, and transportation pollution

as specific ought not to be neglected anymore and immediate and proper studies, as well as actions, need to be thought of in dealing with this predicament.

“Green Transportation” is a highly interdisciplinary area and researchers and scholars of different realms of knowledge, including automotive engineers, policy makers, management intellectuals, urban planners, chemical engineers, and others, are trying to reduce CO2 emissions from the sector.

Amongst the lagging behind, but the pivotal and accommodating role of operation research (OR), with it becoming a tool of optimization, has not been fully regarded and needs to be more deeply reviewed. This paper tries to bridge this gap by providing an insight into what OR may contribute to the problem, by reviewing how it has already done it and how it is going to do further. How OR can help with environmental problems:

6.1.1 Least distance route: To minimise the fuel emissions caused by the transportation industry we can follow the least distance route wherein the cost unit of a TP problem is replaced by the distance.

	W	X	Y	Z	Supply
A	5	0	0	2	7
B	0	3	7	0	10
C	0	5	0	13	18
Demand	5	8	7	15	35

	W	X	Y	Z
A	20*	30	50	17*
B	70	35*	40*	60
C	40	12*	60	25*

= allocated cell

Total distance travelled = 20+17+35+40+12+25 = 149 kms

Which is the least distance route.

7. CASE STUDY

7.1 Delhi Odd-Even Rule

In January and April 2016, the government of Delhi piloted an “odd-even” traffic rule which mandated that only cars with odd (even) numbered license plates could ply on odd (even) dates. The scheme worked as follows: first, cars were classified into odd and even categories on the basis of the last digit of car licensing plates. Next, it was mandated that only vehicles with odd numbered license plates could ply only on odd numbered dates and even numbered plates on even dates. The scheme was effective during the hours of 8 am and 8 pm for the first 15 days of January 2016. A second round of the odd-even program was implemented between April 15-30, 2016.

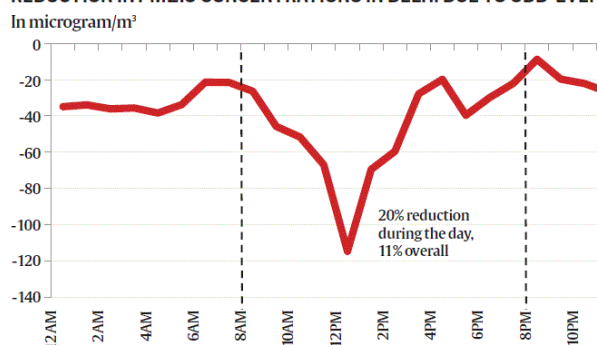
7.2 Objective

This case study emphasises on the impact of the odd-even program on air quality. To do so, we have collected high frequency data from monitoring stations to compare fine particulate concentrations in Delhi (where the odd even policy was implemented) to that reported for the neighbouring towns of Faridabad and Gurgaon (where the policy was not implemented). Our analysis period spans the six months between November 2015 and April 2016.

7.3 Analysis

We first put together a dataset of hourly air pollution numbers from 23 monitors in Delhi, and three monitors from Faridabad, Gurgaon and Noida, where the odd-even policy was not implemented. In December 2015, before the odd-even programme began, daily pollution trends in Delhi and the neighbouring regions were very similar. Starting January 1, while absolute pollution levels increased both inside and outside Delhi, the increase in fine particle levels in Delhi was significantly less than in the surrounding region. Overall, there was a 10-13 per cent relative decline in Delhi.

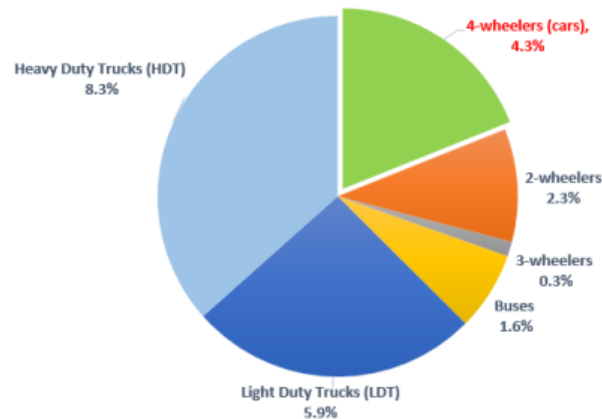
REDUCTION IN PM2.5 CONCENTRATIONS IN DELHI DUE TO ODD-EVEN



Line shows the difference between Delhi and surrounding regions during January 2016, relative to differences in December

Going one step further in our analysis by tracking pollution changes hour by hour from 8 am to 8 pm since the odd-even policy was only in effect in that timings of the day. The results are striking. Around 8 am, the gap between Delhi's pollution and that in neighbouring regions begins to form and steadily increases until mid-afternoon. As temperatures begin to fall, and pollution is less likely to disperse, this gap starts to close. We see another small gap emerge between 9-11 pm, which probably reflects the new limits on truck traffic in Delhi, which also came into force on January 1. Soon after midnight, the gap closes, and Delhi and neighbouring areas show similar pollution patterns until 8 am comes around again. When focusing just on the hours that the odd-even policy was in effect, our data and references suggest that particulates pollution declined by 18-20 per cent due to the pilot.

Breakdown of Delhi Transport's 22-23% PM2.5 Contribution



Even if the odd-even rule did manage to halve the number of road transport vehicles (and correspondingly reduce their emissions by half), pollution levels would only be reduced by 11% but when we breakdown transport emissions further by vehicle, we see that **4-wheel cars only contribute 4% to total emissions**. In this case, even when all private cars were included (i.e. no exemptions), we'd only be cutting emissions **by a few percent at the most**.

8. RELATION OF THE CASE STUDY WITH OR

Operations Research is applied to problems that concern how to conduct and coordinate the operations. It comprises of operations and research. Operations Research in this case study provides a systematic procedure to address the situation of air pollution by implementing the Odd – Even Policy in two phases. The policy was based on the model of – minimizing access to some resources (private cars) by restricting it to half the population on a given day thereby improving the public health in that region, maximising Delhi's ambient air quality by minimizing Particulate Matter in the air to reach sustainable standards.

In the given case study, Operations Research determines the root cause of the problem (traffic emission pollution) and helps in selecting the best alternative amongst the various alternatives.

9. CONCLUSION

The paper aimed at specifying the contribution of operations research in environmental management. To fulfil the purpose, we deeply reviewed the pivotal role of transportation problem as a tool of optimization, to minimise the fuel emissions caused by the transportation industry we followed the least distance route. Along with that, we also linked the case study of New Delhi Odd Even Scheme which was implemented in 2016 with operations research. It provided a systematic procedure to address the situation of air pollution in New Delhi by minimizing access to some resources by half to improve the public health and condition of air in that region.

10. LIMITATIONS

- Operations research is very costly as it is expensive to make mathematical models to for environmental management and solve them by hiring OR professionals and computers.
- The environmental factors required for calculating solutions are difficult to quantify and are harder to get the exact figures in this field of applications of operations research.
- It does not take human incentives and industrial behaviour towards the environmental management into account.

11. REFERENCES

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