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An analytical study on impact of external transportation cost in linear programming problem and their application

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Abstract

The objective of this paper is to analyze the effect of external transport cost on the quality of logistics activities. In this paper, we analyze the impact of external transportation cost on short sea shipping. The aim of the research is to optimize the cost of transportation not only specifically but also another cost included in transportation costs. We measure certain parameters regarding internal transport cost which are isomorphic to each other in general cases under certain conditions.
The transportation problem is a special class of problem. Transportation problems may vary under certain conditions. We generally consider fuel charges, service charges, and vehicle charges for the necessary transport of an object from one place to another place. To achieve the Sustainable Development Goals-Agenda 2030 in the 21st century, it is necessary to create a safe environment on Earth. In most transport modes, the environment is a little affected. In the US, UK, and other countries, air pollution charges are separately paid to the service provider. Therefore, external transportation costs should be added to original transportation costs (internal transportation cost (ITC)). We derive the mathematical expression of the linear programming problem after External Transportation Cost (ETC) is included. We analyze that if some variable which does not affect the environment, by default environmental maintenance cost is zero. From this, that variable cost is zero. In assignment theory, when an object is assigned, a path is created. In this case, if greatest value among EMC says y_{kl} is less than or equal to the value of x_{ij} then path of assignment of transport a product is not change. If the greatest value among EMC say is less than or equal to the value of then the path of assignment of transporting a product is not changed.
Keyword: - External Transportation Cost (ETC), Environment Maintenance Cost (EMC), Transportation Path, Green Technology.

1. Introduction

During the solution of the transportation problem, we are primarily concerned with transportation costs. In the cost, we include all expenses associated with transportation. So, it is necessary to optimize the cost of transportation not only specifically but also another cost included in transportation costs. Although our problem may vary depending on the situation, minimizing costs is a certain part of our problem. Almost every cost of transportation is affected by a variable. We generally write it as. It shows the cost of transport from one destination to another. In order to improve the quality and capacity of an object in the sense of transport, more than one variable may be necessary. There are two types of improvement; continuous and discontinuous in transport costs. We know that transportation cost is changing in every field for example; in the energy sector, we measure not only the transport cost of energy transformation but also the cost of energy imparting and etc. For this, we optimize all transport values or costs which consider starting energy stage to the customer receiving energy stage.
The cost of production and transportation are most commonly measured and maintained in most industries, but the cost of inner transport is also a crucial element in determining probability. From the nature of internal transport cost, we measure certain parameters regarding external transport cost. We compare the graph of inner transportation cost and external transportation cost which are isomorphic to each other in general cases under certain conditions.

External Transport Cost (ETC) is determined according to international standards and national policies. We can estimate ETC but it is not a certain thing. For example, we buy fuel of Track. In that case, we pay a cost of production in industries; it is called internal transport cost (ITC) but in many countries, we also pay a cost for air pollution effect; it is called external transport cost (ETC).

External transportation costs are those connected with moving people or products from one place to another that are not directly supported by the persons or organizations who perform the transportation activity. These costs are externalized since they are frequently imposed on society at large or unrelated parties and are not taken into account in the pricing or decision-making of transport users. External transportation costs can take various forms, including:

Environmental Costs: These cover the harm that transportation does to the environment, such as noise pollution, greenhouse gas emissions, air pollution, and habitat degradation. These expenses lead to ecological deterioration, health issues, and climate change.

Congestion Costs: When the carrying capacity of the transportation infrastructure is exceeded by the demand for transportation, congestion results, causing delays, longer travel times, and decreased efficiency. It costs society money since it leads to wasted fuel, lost productivity, and more accidents.

Accidents and Safety Costs: Transportation-related activities have the potential to result in accidents and injuries, which can be expensive in terms of medical bills, property damage, and fatalities. Individuals, insurance companies, or the government healthcare system frequently foot the bill for these expenses.

Infrastructure Costs: Infrastructure for transportation, such roads, bridges, and railroads, requires enormous financial investment to build and maintain. These expenses are frequently paid for by governments or public resources, which places a strain on taxpayers.

Land Use and Urban Sprawl Costs: Land use patterns are influenced by transport networks, with expansive growth resulting in greater infrastructure needs and longer travel times. These expenses include the loss of agricultural land, an increase in energy use, and a decline in urban livability.

For transportation systems to be effective and sustainable, external transportation expenses must be addressed. There are several options, including internalizing the costs via tolls or congestion fees, supporting public transit, promoting environmentally friendly forms of mobility like walking and cycling, and making investments in clean and effective technology.

When the Sustainable Development Goals-Agenda 2030 has been set for sustainable growth in the world by 2030 in the 21st century, the world has seen that growth takes place in every sector to reach an all-time high height. One of them is the transportation sector. We all know that transportation connects two places or locations, but it is also necessary for business, a productive approach, etc. While transporting an item from one place to another, fuel costs and vehicle service charges are usually considered. But there are many changes in the present situation. Among them are climate change, global environmental effects, air pollution, sound pollution, etc. It is essential that each effect is addressed through a suitable method to minimize its impact. Hence now when the transport cost is determined, besides the fuel and vehicle services charges, the charges related to the situation or effect arising due to it are considered in the transport cost. We call it external transport costs (ETC).

2. Materials and Method

Mathematical Approach to Add External Transportation Cost in Existing Linear Programming Problem:

Operations research is developing field in Mathematics. Operations research gives us a problem-solving technique. There are many applications of Operations Research (OR) in Mathematics as well as other subject also. Transportations problem can be solved by using subject of OR. We solve transportation problem with linear programming or assignment theory. In most of cases, there are one dimensional variable, so it is easy to solve using linear programming. In assignment theory we draw a table of value of cost from one place to other places. In generally, we indicate as x_{ij}. So, if we have m destination and n company. So total number of variables is m*n. So, from huge collection of variables, we determine a variable to predict for optimization.

Table-1 Transportation Primary Problem

From (Company)	**To**					**Supply**
	D_1	**D_2**	**D_3**	**---**	**D_n**	
A_1	x_{11}	x_{12}	x_{13}	---	x_{1n}	b_1
A_2	x_{21}	x_{22}	x_{23}	---	x_{2n}	b_2
A_3	x_{31}	x_{32}	x_{33}	---	x_{3n}	b_3
|	|	|	|		|	|
A_n	x_{m1}	x_{m2}	x_{m3}	---	x_{mn}	b_m
Demand	c_1	c_2	c_3	---	c_n	

In the table, x_{ij} denotes the internal transportation costs per unit which transport a product from company C to destination D_j. C_i indicates the demand for that product in i^{th} destination and b_j is total capacity of supply in A_j company.

Let consider the linear programming problem (LPP)

$$\boldsymbol{minimize\ z} = \sum_{i=1\ \&\ j=1}^{i=n\ \&\ j=m} c_{ij}x_{ij}$$

Subject to the conditions

$$x_{11} + x_{12} + \cdots + x_{1k} + \cdots + x_{1n} \leq b_1$$

$$x_{21} + x_{22} + \cdots + x_{2k} + \cdots + x_{2n} \leq b_2$$

$$x_{31} + x_{32} + \cdots + x_{3k} + \cdots + x_{3n} \leq b_3$$

$$\ldots$$

$$x_{m1} + x_{m2} + \cdots + x_{mk} + \cdots + x_{mn} \leq b_m$$

$$x_{11} + x_{21} + x_{31} + \cdots + x_{m1} \geq c_1$$

$$x_{12} + x_{22} + x_{32} + \cdots + x_{m2} \geq c_2$$

$$x_{13} + x_{23} + x_{33} + \cdots + x_{m3} \geq c_3$$

$$\ldots$$

$$x_{1n} + x_{2n} + x_{3n} + \cdots + x_{mn} \geq c_n$$

and non-negative restrictions

$$x_{ij} \geq 0\ ; i = 1, 2, \ldots.m\ and\ j = 1, 2, \ldots., n,$$

Where all b_i's, c_j's are constants and x_{ij}'s are decision variables.

In above problem, we consider the transportation cost variable x_{ij} (from A_i Company to D_j destination) in which included fuel costs and vehicle service charges for transport a product. In 21[th] century, it is necessary to maintain our environment so we add the charges related to the situation or effects arising due to it, are considered in the transport cost indicates as y_{ij}.where y_{ij} is environmental maintenance cost (EMC) to transport product from A_i company to D_j destination.

External transportation cost is a variable independent of supply and demand parameters. But when this cost is added at the time of solution of the system, for the purpose of not unbalancing the system, we denote the amount obtained after adding the external transportation cost to the internal transportation cost by z_{ij} Now we have z_{ij} as the total cost (per unit) of transporting an item with the company as the origin and the city or other place as the destination. Hence again the problem can be solved with the help of linear programming.

Now, consider $x_{ij} + y_{ij} = z_{ij}$ then,

Table-2 External Transportation Cost Added Problem

From (Company)	**To**					**Supply**
	D1	**D2**	**D3**	**---**	**Dn**	
A_1	z_{11}	z_{12}	z_{13}	---	z_{1n}	b_1
A_2	z_{21}	z_{22}	z_{23}	---	z_{2n}	b_2
A_3	z_{31}	z_{32}	z_{33}	---	z_{3n}	b_3
|	|	|	|		|	|
A_n	z_{m1}	z_{m2}	z_{m3}	---	z_{mn}	b_m
Demand	c_1	c_2	c_3	---	c_n	

From the above table, let consider the linear programming problem (LPP)

$$\boldsymbol{minimize\ z} = \sum_{i=1\ \&\ j=1}^{i=n\ \&\ j=m} c'_{ij} z_{ij}$$

Subject to the conditions

$$\boldsymbol{z_{11}} + z_{12} + \cdots + \boldsymbol{z_{1k}} + \cdots + \boldsymbol{z_{1n}} \le \boldsymbol{b_1}$$

$$\boldsymbol{z_{21}} + \boldsymbol{z_{22}} + \cdots + \boldsymbol{z_{2k}} + \cdots + \boldsymbol{z_{2n}} \le \boldsymbol{b_2}$$

$$\boldsymbol{z_{31}} + \boldsymbol{z_{32}} + \cdots + z_{3k} + \cdots + \boldsymbol{z_{3n}} \le \boldsymbol{b_3}$$

$$\boldsymbol{\ldots}$$

$$\boldsymbol{z_{m1}} + \boldsymbol{z_{m2}} + \cdots + \boldsymbol{z_{mk}} + \cdots + \boldsymbol{z_{mn}} \le \boldsymbol{b_m}$$

$$\boldsymbol{z_{11}} + \boldsymbol{z_{21}} + \boldsymbol{z_{31}} + \cdots + \boldsymbol{z_{m1}} \ge c_1$$

$$\boldsymbol{z_{12}} + \boldsymbol{z_{22}} + \boldsymbol{z_{32}} + \cdots + \boldsymbol{z_{m2}} \ge c_2$$

$$\boldsymbol{z_{13}} + \boldsymbol{z_{23}} + \boldsymbol{z_{33}} + \cdots + \boldsymbol{z_{m3}} \ge c_3$$

$$\ldots$$

$$z_{1n} + \boldsymbol{z_{2n}} + z_{3n} + \cdots + \boldsymbol{z_{mn}} \ge c_n$$

and non-negative restrictions

$$\boldsymbol{z_{ij}} \ge \boldsymbol{0}\ ; \boldsymbol{i} = \boldsymbol{1}, \boldsymbol{2}, \ldots. \boldsymbol{m\ and\ j} = \boldsymbol{1}, \boldsymbol{2}, \ldots., \boldsymbol{n},$$

Where all $\boldsymbol{b}_i$'s and $\boldsymbol{c}_j$'s are constants and $\boldsymbol{z_{ij}}$'s are decision variables.

Analysis: -

(1) If some variable which are not affect the environment, so by default environmental maintenance cost is zero. From this, that variable cost is zero.
    a. In Mathematically, if $\boldsymbol{y}_{ik} = 0$ then obviously $\boldsymbol{z_{ik}} = \boldsymbol{x_{ik}}$; $\boldsymbol{i} = \boldsymbol{1}, \boldsymbol{2}, \ldots. \boldsymbol{m\ and\ k} = \boldsymbol{1}, \boldsymbol{2}, \ldots., \boldsymbol{n}$
(2) If more than two variable equal so it writes as $\boldsymbol{x_{ik}} = \boldsymbol{x_{il}}$ then $\boldsymbol{z_{ik}} = \boldsymbol{z_{il}}$
(3) If more than two variable equal and it is less than all other variable then $\boldsymbol{z_{ik}} = \boldsymbol{z_{il}}$.
(4) If Company A_i adopts the green technology, then the probability of allocation for transport a product is more than other company.
(5) In assignment theory, when an object is assigned, a path is created. In this case, If greatest value among EMC say $\boldsymbol{y}_{kl}$ is less than or equal to the value of $\boldsymbol{x}_{ij}$ then path of assignment of transport a product is not change.
(6) If the greatest value among EMC say is less than or equal to the value of then the path of assignment of transporting a product is not changed.
(7) The study concluded that,

If we solve the above transportation problem by North-West corner method,

a) Only in one case (using green technology) does the transport allocation path change.
b) Even in a situation where environmental transportation costs are the same for each company to transport an item at a destination, the original path may vary.
c) The probability of variation between the path allocated to the system of internal transport cost only and the path allocated to the total transport cost are also high.

3. Application of the ECALP

- Cost-Benefit Analysis: The study of external transport costs provides a thorough evaluation of the advantages and disadvantages linked to various transport choices or projects. By taking into account both economic aspects and environmental effects, cost-benefit analysis can support decision-makers in evaluating the trade-offs and making decisions that maximize society welfare.

- Policy Development: The formulation of laws and regulations aimed at decreasing or mitigating the harmful effects of transport on the environment can be informed by an awareness of external transport costs. Policymakers can implement policies like pollution limits, congestion pricing, or incentives for using green technology, supporting sustainable transportation practices, by calculating and taking into account these costs.
- Business Decision-making Understanding the external costs of transportation can have an impact on business choices, especially for logistics and transportation companies. Businesses may minimize their impact on the environment and cut total costs by taking these costs into account when making decisions regarding transportation modes, fleet management, and supply chain optimization.
- Technology Adoption: The adoption of greener and more sustainable technology can be influenced by knowledge of external transportation costs. For instance, businesses and people may be encouraged to switch to electric cars or other green technologies that have reduced or no environmental maintenance costs if the external costs associated with conventional fossil fuel-based transportation are significant. This might promote creativity and financial investment in sustainable transportation options.
- Infrastructure Planning: Urban and transport planners may priorities investments in effective and environmentally friendly transport systems by including external travel costs into designing infrastructure. The establishment of public transit systems, bike lanes, pedestrian-friendly infrastructure, or the incorporation of environmentally friendly innovations into already-existing transportation infrastructure is a few examples of this.
- Environmental Impact Assessment: External costs associated with transportation can help environmental impact analyses for transportation projects provide a more realistic picture of the project's entirety ecological impact. This knowledge is essential for making decisions and making sure that any probable environmental costs are adequately determined and reduced.

In general, recognizing and factoring in the effects of external transportation costs across a range of applications can aid in forming policies, directing choice-making, and promoting sustainable transportation practices that strike a balance between economic effectiveness and ecological concerns.

4. Scope of the Study

The aim of study is that what impact external cost related with transportation. We know there are many modes to transport a product. So, we can expand our study in each mode of transport. Every mode has its special characteristic and uses of it. Impact of each mode can be differently discussed and compare with its characteristic. We can prepare mathematical modeling by using comparative study. How to reduce the ETC in each transport mode? And what is effect after applied ETC $\boldsymbol{y}_{kl}$ in the graph. The scope of the research is in cost variation techniques (CVT) and cost affect techniques (CAT).

5. Results and Discussion

The results of the study indicate several important findings related to the impact of external costs on transportation and the allocation of transport paths. These findings are summarized as follows:
It was observed that if a variable does not affect the environment, the associated environmental maintenance cost (EMC) is zero. Consequently, the variable cost is also zero in such cases. This relationship can be expressed mathematically as follows: If$\boldsymbol{y}_{ik} = 0$, then it follows that $\boldsymbol{z_{ik} = x_{ik}}$; $\boldsymbol{i = 1, 2, \ldots . m \text{ and } k = 1, 2, \ldots ., n.}$ This result highlights the connection between environmental impact and associated costs.
When more than two variables are equal in value, their corresponding paths and costs are also equal. Specifically, if $\boldsymbol{x_{ik} = x_{il}}$ then it follows that$\boldsymbol{z_{ik} = z_{il}}$. This finding indicates that equal variables result in the same allocation paths and costs, reinforcing the notion of consistency in transport allocation.
Optimal Allocation and Green Technology: The study found that if Company A_i adopts green technology, the probability of that company being allocated is greater compared to other companies. This result suggests that the adoption of environmentally friendly practices can influence the allocation of transport paths and potentially provide advantages in terms of resource allocation.
To tackle transit issues, the research used the North-West corner technique. The allocation path for transport was changed in exactly one example, including the deployment of green technology. This demonstrates the impact of environmentally friendly policies on the distribution of transport routes.
Variation in Original Paths: The research discovered a significant chance of deviation between paths assigned only on internal transportation costs and those assigned solely on total transportation costs. This conclusion underlines the need of taking into account total costs, including external factors, when making transportation allocation decisions.
Impact of Internal and Total Transport Costs: The analysis found a substantial likelihood of variance between pathways assigned exclusively on internal transportation costs and those allocated on overall transportation costs. This conclusion emphasizes the need of considering overall costs, including external influences, when making transportation allocation choices.
Finally, the findings of the study show the delicate interaction between external prices, transportation allocation pathways, and the adoption of green technologies. The findings are useful for transportation planners, and businesses looking to optimize their transportation strategy while keeping environmental implications and cost-effectiveness in mind.

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Conflict of Interest

In this manuscript the authors declare that there is no conflict of interest.

References

i. Verhoef, E. (1994). External effects and social costs of road transport. *Transportation Research Part A: Policy and Practice*, *28*(4), 273-287. https://doi.org/10.1016/0965-8564(94)90003-5

ii. Abreu, H., Santos, T. A., Cardoso, V. (2023). Impact of external cost internalization on short sea shipping – The case of the Portugal-Northern Europe trade. *Transportation Research Part D: Transport and Environment*, *114*, 103544. https://doi.org/10.1016/j.trd.2022.103544

iii. Macioszek, E., Cieśla, M. (2022). External Environmental Analysis for Sustainable Bike-Sharing System Development. *Energies*, *15*(3), 791. https://doi.org/10.3390/en15030791

iv. Uchkun Rashidov, Abror Rashidov. (2022). Assessment of Costs for the Quality of Logistics Activities. *INTERNATIONAL JOURNAL OF BUSINESS DIPLOMACY AND ECONOMY*, *1*(3), 39–43.

v. Verhoef, Erik (1994). External effects and social costs of road transport, 28(4), 273–287. doi:10.1016/0965-8564(94)90003-5