Integration of Transport Model with Annual Average Daily Traffic

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Abstract: Economical transportation of manufactured goods and raw materials play a vital role in minimising the cost of the whole operation. Hence proper emphasis needs to be laid on designing the whole transportation system. The transportation model is used to design the routes so as to minimise the whole cost and at the same time bridge the gap between supply and demand. But this model does not include other factors which may augment the costs of this operation. This paper tries to integrate the transportation model with Annual Average Daily Traffic so as to reduce the effects of these factors which may incur additional costs.

1. Introduction

One of the main objectives of any organisation is the reduction in process costs and increase in its profit. To accomplish this task various techniques are deployed and transportation model is one of them. [1] Transportation problem is one of the sub-classes of LPP’s with the objective to transport various amounts of a single homogeneous commodity, that are initially stored at various origins, to different destinations in such a way that the total transportation cost is a minimum. In other words, the transportation problem arises when there is a number of sources, each with a given quantity of product or capacity and there are as number of destinations to which the product is to be transported. The job of transportation problem is to evolve an optimum plan which results in the least cost for transportation. However, this model does not take into account the other factors like road conditions, traffic etc. which may increase the cost of the whole operation. Road conditions and traffic are a major aspect in determining the efficient working of transportation vehicles. Poor road conditions and traffic jams adversely affect the working of heavy vehicles used in transportation. Hence, by taking these aspects into account an organisation can reduce its costs related to maintenance of vehicles and deliver the goods on time. This paper emphasises on the consideration of Annual Average Daily Traffic as a tool to combat the additional costs incurred in maintenance due to road conditions. We observe the AADT values for routes calculated by the transportation model and use the one with the minimum value of AADT. [2] Annual Average Daily Traffic (AADT) is the average 24-hour traffic volume at a roadway location over an entire year. AADT is required for many transportation analyses including economic evaluation of highway safety projects, estimation of highway user revenue, computation of highway statistics like vehicle miles travelled (VMT), development and improvement of maintenance programs etc. This paper presents how the integration of these two tools can help cut down transportation costs and help organisations to plan their routes effectively.

2. Solving the Transportation Problem

2.1. Definition of the Transportation Model

The general problem is represented in the Figure 1. [3] There are m sources and n destinations, each represented by a node. The arc represent the routes linking the sources and the destination. Arc (i, j) joining source i with destination j carries two pieces of information: the transportation cost per unit, $c_{ij}$, and the amount shipped, $x_{ij}$. The amount of supply at source i is $a_i$ and the amount of demand at destination j is $b_j$. The objective of the model is to determine the unknowns $x_{ij}$ that will minimise the total cost of transportation.
total transportation cost satisfying all the supply and demand restrictions.

2.2. Steps to solve Transportation Problems

[4] The solution of the transportation problem has the following algorithm:

**Step 1:** Formulate the problem and establish the transportation matrix or table, the cells indicating the parameters value for various combinations i.e., cost, profit, time, distance etc.

**Step 2:** Obtain an initial basic solution. This can be done in three different ways i.e. North-West Corner Rule, Least Cost Method and Vogel’s Approximation Method.

**Step 3:** Test the initial solution for optimality- This can be done either by Stepping Stone Method or MODI Method.

**Step 4:** Update the solution i.e. applying step 3 till optimal feasible solution is obtained.

### 2.3 Example

<table>
<thead>
<tr>
<th></th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>80</td>
<td>20</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>15</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>75</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Req.</td>
<td>80</td>
<td>30</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

The above table shows a transportation problem. The requirements and the capacities are given. We need to transport the goods in such a way that the total cost is minimum. The steps to solve it are as follows:

**Step 1:** We start by determining the initial solution of the given problem by applying methods like North West corner method, Least Cost method or Vogel’s Approximation method.

<table>
<thead>
<tr>
<th></th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>7</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>8</td>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>Req.</td>
<td>80</td>
<td>30</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

Hence initial solution:

\[(80\times5) + (5\times10) + (15\times2) + (25\times7) + (75\times4)\]

\[= 955\]

**Step 3.** On transferring 5 to empty cell CE and adjusting the other squares according we get total cost to be,

\[(80\times5) + (20\times2) + (25\times7) + (5\times8) + (70\times4)\]

\[= 935\]

**Step 4:** On transferring 25 to the empty cell BD and adjusting the other cells accordingly, the cost comes out to be,

\[(55\times5) + (45\times2) + (25\times3) + (30\times8) + (45\times4)\]

\[= 860\]

**Step 5.** Shifting 45 to CD and adjusting the other squares gives us,

\[(10\times5) + (90\times2) + (25\times3) + (45\times6) + (30\times8)\]

\[= 815\]

Hence, this is the optimal solution. Of all the solutions calculated in this example, step 5 has the lowest cost.

3. Annual Average Daily Traffic (AADT)

As discussed earlier, AADT is the average 24-hour traffic volume at a roadway location over an entire year. [5] The Annual Average Daily Traffic is utilised as an important basic data in transportation and road sector. Accurate calculation of AADT is required to construct the roads economically and facilitate traffic flow, while maintaining an appropriate level of traffic service. To calculate accurate AADT, it is desirable to install permanent traffic counters in all traffic count points. However, due to the limitations such as budget constraints, permanent traffic counters have been installed only in some points, and portable devices have been used in the rest of the point.

The permanent traffic count can be used to collect traffic volume 365 days a year, which makes it possible to identify time-series properties, including monthly and seasonal characteristics with respect to traffic variations. However, permanent traffic counters have been installed only at some points, and most of the traffic surveys have been carried out using portable devices. Therefore, since it is impossible to calculate accurate AADT, AADT estimation is utilised in this case.
3.1. AADT Calculations

There are two basic procedures for calculating AADT:

- A simple average of all days; and
- An average of averages (the American Association of State Highway Transportation Officials (AASHTO) method).

In the first of these techniques, AADT is computed as a simple average of all 365 days in a given year. When days of data are missing, the denominator is simply reduced by the number of missing days. The advantage to this approach is that it is simple and easy to program. The disadvantage is that missing data can cause biases (and thus inaccuracy) in the AADT value produced. In particular, blocks of missing days of data can bias the annual values by removing data that have specific characteristics. On a heavy summer recreational route, missing data may significantly affect the aerodynamic calculations for AADT.

These annual values by month are then averaged to yield the AADT. This method explicitly accounts for missing data by weighting each day of the week the same, and each month the same, regardless of how many days are actually present within that category; however, there must be between one and five records for each day of the week in each month.

The simple average method is certainly easier to compute. However, where data is likely to be missing the AASHTO method will provide a more reliable and accurate value. The AASHTO method for computing AADT is recommended. This is because it allows factors to be computed accurately even when a considerable number of data is missing from a year at a site, and because it works accurately under a variety of data conditions. Conversely, the simple average works only when the data set is complete, or when little bias is present in the missing data. Because a common method should be used for all AADT computations, the AASHTO method is preferred.

The AASHTO formulation for AADT is as follows:

$$ AADT = \frac{1}{7} \sum_{i=1}^{7} \bigg[ \frac{1}{12} \sum_{j=1}^{12} \left( \frac{1}{n} \sum_{k=1}^{n} VOL_{ijk} \right) \bigg] $$

Where:

- $VOL_{ijk}$ = Daily traffic of day $k$, of DOW $i$, and month $j$
- $i$ = day of the week
- $j$ = month of the year
- $k$ = 1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth day of the week
- $n$ = the number of days of that day of the week during that month (usually between one and five, depending on the number of missing data)

4. Traffic congestion effect

Traffic congestion has been defined as “a condition of traffic delay (i.e., when traffic flow is slowed below reasonable speeds) because the number of vehicles to use a road exceeds the design capacity of the traffic network to handle it.”

As traffic volumes and congestion grows on highways and urban roadways, freight and delivery service operators become increasingly challenged to maintain dependable and reliable schedules. This affects supply chains and truck-dependent businesses both of which are of increasing importance for both public policy and private sector operators. From the perspective of shippers and carriers, there are the day-to-day cost implications of delay and reliability as it affects supply chain management, and well as a longer-range need to assess opportunities, risks and returns associated with location, production and distribution decisions. Besides time delays there is also increase in the maintenance cost of the transporting vehicles due to the traffic congestion.

Traffic congestion not only increases the fuel consumption by the heavy vehicles, it also augments the maintenance costs due to vibration and other factors. Under congested conditions, there will be two additional influences on the vehicle fuel consumption.

- There will be a change in the vehicle speed which will affect the aerodynamic and rolling resistance fuel consumptions.
- There will be decelerations and accelerations which will influence the inertial fuel consumption.

The most significant component of the two is the inertial fuel consumption, particularly for heavy vehicles or those with high acceleration rates. These additional costs directly increases the overall operational costs. Hence traffic conditions should be considered as one of the factors for economical transportation.
5. Integration Model

As discussed above, traffic conditions play a major role in economical transportation of raw materials or products. Hence there is a need to introduce this factor so that organisations can make correct decisions about the routes to be followed for transportation. The current transportation model computes the transportation costs theoretically and does not take into account the traffic conditions. Even though we are able to minimise the cost of transportation, we may incur additional costs due to the traffic conditions on the given routes. Thus, increasing the overall costs. Hence, there needs to be a model which not only finds the most economical route but also takes into account the traffic conditions of the route so that transportation can be done in the most economical way.

Recent studies states that about thirty percent more fuel is wasted during traffic congestion. This is a very big number given to the increasing fuel prices. So even though the solution of the transportation problem may look economical, the cost will shoot up if there is congestion along the routes.

The suggested integration model takes into account the traffic congestion factor. We first calculate the solutions of the given transportation problem and then analyse the AADT values of the given routes. If the AADT value associated with a solution is of very high value, we discard it and move on to the next solution. We continue to do so until the most optimum solution having low transportation cost and AADT value is reached.

In the discussed example we get around five solutions. The solutions are shown in the table below.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Transportation Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1045</td>
</tr>
<tr>
<td>2</td>
<td>955</td>
</tr>
<tr>
<td>3</td>
<td>935</td>
</tr>
<tr>
<td>4</td>
<td>860</td>
</tr>
<tr>
<td>5</td>
<td>815</td>
</tr>
</tbody>
</table>

The figure shows the various solutions calculated starting from the basic feasible solution to the optimum solution. Now let us integrate these solutions with the AADT values of some routes. The following table gives the AADT values of some routes in the United States. These values have been taken from Nevada Department of Transportation, Annual Traffic Report. AADT values for the year 2010 and 2012 are given.

<table>
<thead>
<tr>
<th>Area Number</th>
<th>2010 AADT</th>
<th>2012 AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>330</td>
<td>350</td>
</tr>
<tr>
<td>2</td>
<td>220</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>750</td>
<td>800</td>
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<tr>
<td>4</td>
<td>2200</td>
<td>2100</td>
</tr>
<tr>
<td>5</td>
<td>2500</td>
<td>2300</td>
</tr>
</tbody>
</table>

From the table we can see that there is a huge difference in AADT values at some places. Region one has an AADT value as low as 350 as compared to region give having AADT value of 2300. Hence traffic conditions can play a significant role in determining whether a process really is economical or not. If the AADT value for a process having the least cost is very high, then choosing that route over the others would not be an economical decision.

For instance, if we choose the fifth solution from table 3 and its route has an AADT value of that of area 5 from table 4, then certainly there will be a wastage of time and money which can be utilised elsewhere. Hence we can choose an alternate route with less AADT value which may be a bit more expensive but will certainly save the costs incurred due to congestion.

Besides increasing the expenses the traffic congestion also results in wastage of time. The number of productive hours decrease significantly which may be used for other profitable purposes. There is also a risk of losing existing customers due to late deliveries and loss of trust in the organisation.

6. Conclusion

This paper highlighted the importance of considering traffic congestion as an important factor while designing the transportation problem. Traffic not only delays delivery time but also increase the maintenance cost of vehicles delivering goods. The consumer starts to lose trust in the organisation due to these delays. The integration of AADT helps the organisation to design transportation routes such that the deliveries are made within the stipulated time and also help save the additional cost that might be incurred in the operation. Hence the integration model if implemented, may help in timely and economical delivery of goods.

7. Acknowledgements

The author is thankful to the faculty of Mechanical and Automation Engineering, Northern India Engineering College, for their support and guidance.
7. References


