Robust goal programming approach to an intermodal routing decision problem

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Abstract

Under fierce competition for today business, it is very important for companies to reduce their logistic cost. Intermodal transport can exploit transportation cost structure and gain service response. Selecting transportation routes under various factors such as minimum transportation cost, just-in-time commitment, and transit time variability is a crucial decision. Unlike traditional model assumption, uncertainty for data collection in each parameter is presented. In this paper, the intermodal transportation problem is formulated as a robust goal programming to address data uncertainty in transit time variability. The numerical result was tested against tapioca transportation network in Thailand.

Keywords: Transportation, Intermodal transportation, Goal programming, Robust optimization

1. Introduction

The economic integration is one of important driven forces of the growth of world’s trading. Multinational companies exploit the benefit of reducing trade barrier so that raw material, parts, sub-assemblies and assemblies can freely be moved between borders or boundaries. The developing countries started to upgrade their physical infrastructure such as highway or railway to lure foreign investors. The containerization is a driver of intermodal transportation due to the ease of handling between 2 modes of transports. “Intermodal” or “multimodal” is the way that shipment is transported by at least 2 different modes of transport and under a single freight bill.

In recent year with the increasing demand of freight transport, intermodal route transport gains a lot of attention from practitioners and scholars. However, there are some difficulties of collecting accurate data for each mode of transport. Data uncertainty is not uncommon in practice. The decision maker needs mathematical model to deal with this uncertainty to find the appropriate route to ship commodity. The objective of this paper is to address data uncertainty of transit time variability into mathematical programming model, since traditional mathematical model assume parameters to be known. This paper formulated a robust goal programming model for the intermodal transport, dealing with uncertain of data. The remainder of the paper is organized as follows. Section 2 reviews the literature review. Section 3 presents the model description and formulation, and Section 4 discusses the computational results and Section 5 conclusions.

2. Literature review

For a recent review of intermodal freight transportation, the reader is referred to Bontekoning and Priemus [1] and Macharis and Bontekonings [2].


While the literatures presented above provide solutions to a number of applications, they are mainly limited to known parameter values for planning application and not taking account to uncertain elements in the network. A robust integer programming to address data uncertainty for discrete optimization and control the degree of conservation of the solution in term of probability of constraint violation was proposed in Bertimas and Sim [7]. This paper formulated a problem as a robust goal programming and assumed that freight rates are linear and used tapioca distribution network in Thailand as the case study.
3. Model Description

We consider a cyclic directed transportation network where a tapioca product was shipped from its origin (Udon Thani) to its destination port e.g. Laem Chabang port, Bangkok port, Sriracha port, BKK port, Jira Train Station, ICD, Warehouse@Ayutthaya, Warehouse@Chacheonsao. There are modal shifts between origin and destination ports. We consider the cost of transportation, including packing, up-loading, un-loading, and documentations only from origin, northeastern of Thailand to Thailand’s exporting port, since selling price is quoted as FOB (Free on Board). Time and other expenses at exporting port are not taking account to this model. We assume this related logistic time and costs are equal among exporting ports.

Freight rates for truck, rail, and barge are nonlinear. This paper modeled these costs as ceiling function. No split deliveries are allowed. We treat time variability as data uncertainty. Cardinal weight on each criterion is depended on decision maker to arbitrarily choose the number. We formulate robust goal programming by following model of [7] and [9]. Because of small size of Thailand transportation network, we exploit the structure of network so that we use separate links to present for each route and mode of transport. Figure 1 shows the Tapioca transportation network in Thailand.

![Figure 1 Tapioca transportation network in Thailand](image)

Subscripts

- \( i, j \) set of all nodes (Udon Thani, Warehouse@Ayutthaya, Warehouse@Chacheonsao, BKK port, Sriracha port, BKK port, Jira Train Station, ICD, Srirach Pan Island Area, Laem Chabang port)
- \( J_i \) set of coefficients \( V_{ij}, i \in J_i \) that are subject to parameter uncertainty, i.e., \( \hat{V}_{ij} \) (independent, symmetric and bounded random variable but unknown distribution)

Parameters

- \( s \) shipment size (ton)
- \( R \) total shipping time
- \( T_i \) transit time from node \( i \) to node \( j \)
- \( F_d(s) \) unit freight rate from node \( i \) to node \( j \) according to shipment size \( s \)
- \( V_i \) transit time variability node \( i \) to node \( j \)
- \( W_i^c \) cardinal weight (lower transportation cost)
- \( W_i^s \) cardinal weight (late shipment)
- \( \Gamma \) the protection level for 4th constraints
- \( W_i^r \) cardinal weight (just in time shipping)
- \( W_i^t \) cardinal weight (transit time variability)
- \( \hat{V}_{ij} \) range of \( V_{ij} \) that are subject to parameter uncertainty

Decision variables

- \( X_{ij} \) 1, if we send shipment from node \( i \) to node \( j \), 0, otherwise
- \( s_i^- \) negative deviational variable that represent just in time requirement
- \( s_i^+ \) positive deviational variable that represent transit time variability
- \( p_{ij} \) robustness decision variables of 4th constraint
- \( s_i^+ \) positive deviational variable that represent distribution cost
- \( s_i^+ \) positive deviational variable that represent late shipment
- \( z_i \) robustness decision variables of 4th constraint

The robust goal programming can now be formulated as follows in which the formulation and notion is similar to Min’s [19].

Minimize \( W_i^r s_i^- + W_i^s s_i^- + W_i^s s_i^- + W_i^r s_i^- \), subject to

\[
\sum_{i \in J} \sum_{j \in J} X_{ij} F_d(s) - s_i^- = 0 \quad (1)
\]

\[
\sum_{i \in J} \sum_{j \in J} T_{ij} X_{ij} + s_i^- - s_i^+ = R \quad (2)
\]

\[
\sum_{j \in J} X_{ij} - \sum_{j \in J} X_{ji} = 0 \quad \text{for all } i \neq \text{source and sink} \quad (3)
\]

\[
\sum_{j \in J} X_{ij} - \sum_{j \in J} X_{ji} = 1 \quad \text{for source and -1 for sink} \quad (4)
\]

\[
\sum_{j \in J} V_{ij} X_{ij} + z_j \Gamma + \sum_{j \in J} p_{ij} - s_i^+ = 0 \quad (5)
\]

The objective function minimize the weighted sum of deviations from the lowest total distribution cost, just in time (JIT), and the lowest transit time variability. Constraints (1) minimize total transportation cost. Constraints (2) minimize total shipment time. Constraints (3) are conservative network flow. Constraints (4) adjust the robustness of time variability against the level of conservatism of the solution. Constraints (5) enforce robustness decision variables.

4. Discussion

We solve above mixed integer programming problem with Excel Solver. We use data from appendix to test our model. \( \Gamma \) take value in the interval \([0, |J_i|]\), where \( J_i = \{j | V_{ij} > 0\} \) and \( I_i \) are not necessarily integer. However, we use \( \Gamma_i \), since the parameter uncertainty is a time variability of northeastern railway of Thailand (Jira Train Station to ICD). The average delay is 14.66 (\( V_{ij} \)) hours and the maximum delay is (\( V_{ij} \)) 22.34 hours.

4.1 Numerical examples

We run numerical examples for our model by selecting \( W_i^r = 1, W_i^s = 1, W_i^s = 1, W_i^r = 3 \), and the result is shown in Table 1. The results indicate that the optimal route and mode of transport is to ship tapioca product from Udon Thani to
the destination port via truck except for Sichang Island. The main reason behind this may result from long delivery time for other modes of transportation.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Numerical example results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Γ</td>
<td>z_4</td>
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<tr>
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<td>0</td>
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<tr>
<td>0.4</td>
<td>0</td>
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<tr>
<td>0.6</td>
<td>0</td>
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<tr>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>22.34</td>
</tr>
</tbody>
</table>

5. Conclusions

This work is a pilot study to address data uncertainty for Thailand’s tapioca transportation problem. In the future, we investigate data uncertainty for both transit time and time variability of all links in the network. To take into account for those uncertainties, the size of the problem may be too large, so that meta-heuristics such as Genetic algorithm (GA), or Tabu search, could be used to deal with large scale optimization problem.

6. References