Modelling the Incomplete Intermodal Terminal Location Problem

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Abstract: In this paper, we introduce and study the incomplete version of the intermodal terminal location problem. It’s a generalization of the classical version by relaxing the assumption that the induced graph by located terminals is complete. We propose a mixed integer program to model the problem and we provide several extensions. All models are tested through validation in CPLEX solver. Numerical results are reported using well-known data set from the literature.

Keywords: location, intermodal, terminal, optimization, heuristics.

1. INTRODUCTION

Due to its reliability, sustainability and its economic competitiveness, Intermodal Transportation (IT) has gained a good reputation. In fact, despite its lack of flexibility in the transport chain, intermodal transportation operators strikes to respect time schedules. Furthermore, the intermodal transportation is gaining ground over road transportation due to large investments in infrastructure development. Moreover, several customers focus, today, on environmentally solutions in the transport industry. For all these reasons, intermodal transportation has attracted the attention of researchers and industry operators. The location of intermodal terminals is among the most challenging issues in the scientific literature. We study in this paper the Intermodal Terminal Location Problem in incomplete networks. The remainder of this article is organized as follows: we provide the state of the art in the section 2, problem description is given in the section 3, we propose several extensions of the original formulation in the section 4 and we conclude in the section 5.

2. STATE OF THE ART

The scientific literature on Intermodal Location Problems is relatively recent, but the number of articles dealing with this subject is steadily increasing. Arnold et al. (2001) modeled the intermodal transshipment centers location as a linear program and proposed several extensions of the basic version. Artmann and Fischer (2003) studied the sustainability issues of the traffic shift from road to rail. Bontekoning et al. (2004) provided a review synthesis about intermodal transportation in the field of operations research. Limbourg and Jourquin (2009) proposed an iterative heuristic based on the p-median problem and on the multimodal assignment problem. Sorensen et al. (2012) proved that the intermodal terminal location problem is NP-hard and proposed efficient heuristics to solve it. Tsamboulas et al. (2007) developed a methodology for the policy measures assessment for modal shift to intermodal transportation. Lin and Lin (2014) proposed a simplified version of the Sorensen model and proposed two efficient math-heuristics to solve it. Oudani et al. (2014) solved the problem using a genetic algorithm and proposed a new intermodal cost evaluation. Lin and Lin (2018) proposed a two-stage matheuristic approach to solve the problem. They proposed a program reformulation of the problem and test it using randomly generated data set. Abbassi et al. (2018) proposed a bi-objective model for transportation of agricultural products from Morocco to Europe and developed heuristics to solve it. Recently, Mostert et al. (2018) proposed a bi-objective mathematical model minimizing the transportation and environmental costs objectives. Abbassi et al. (2019) studied the robust intermodal freight transport problem and proposed two solutions approaches for solving the problem. To the best of our knowledge, the current paper is the first to consider the terminals network incompleteness.

3. PROBLEM DESCRIPTION

3.1 The incomplete version motivation

As in hub location problems, most studies in intermodal terminal location problems assume a complete inter-terminals network, that is, every terminal pair is interconnected. In the incomplete network studied here, we relax this assumption. In fact, assuming a complete network increase the total investment cost and connecting all terminals directly may also become unnecessary and expensive.

Fig. 1 shows a small incomplete intermodal terminal network with 3 terminals and 4 customers. The induced graph by terminals is not complete. For instance, there is no rail link between terminal $T_1$ and $T_3$.

3.2 Mathematical formulation

Let be the following parameters:

$I$ : set of customers.
$K$ : set of potentials sites for intermodal terminals.
$l$ : number of links between located terminals.
The total goods to be transported form
that through the terminals
sum of the amount routed directly from
routing goods by road and by using the intermodal rail-
The objective function (1) minimizes the total cost for
Let be the following decision variables:
be modeled as follows:
The incomplete intermodal terminal location problem may
Subject to :
- the unit cost for intermodal transportation from
- the amount of goods to be transported from the
- the unit unimodal cost for routing goods from
- the cost for location of the terminal k.
- the capacity of the terminal k.
Let be the following decision variables:
- if the inter-terminals link between
- the cost for location of the terminal
- the capacity of the terminal
- the amount of goods transported by road from the
the amount of goods transported by road from the
the amount of goods to be transported from the
The objective function (1) minimizes the total cost for
Instead of minimizing the number of terminals to be

3.3 Exact solutions
The model is validated by implementation in CPLEX
12.6 solver. To report numerical results, we used the in-
stances randomly generated by Sörens et al. Customers
and potentials sites coordinates are randomly generated
between (0, 0) and (10^4, 10^4). The goods demands are
generated from the interval [0, 500]. The investment cost
\( f_k \) in the interval [0, 5.10^5] and potentials sites capacities
are drawn from [0, 10^4]. After that, cost \( c_{ij} \) is equal
the euclidean distance between the customers \( i \) and \( j \) while
\( e_{ik}^{1/m} = c_{ik} + \frac{1}{2} e_{km} + c_{mj} \). The exact solutions for some
instances are reported in the table 1. Optimal solutions for
larger instances (more than 90 customers and 40 potential
location) are not found in 1 hour.

4. EXTENSIONS

4.1 Minimizing the number of inter-terminals links
Instead of minimizing the number of terminals to be
located, we consider the problem of minimizing the number
of links between a given $q$ number of terminals to be located. This problem can be modeled as follows:

$$\begin{align*}
\text{Min} & \sum_{i,j \in I} \sum_{k,m \in K} c_{km} x_{ij}^k m + \sum_{i,j \in I} c_{ij} w_{ij} + \sum_{k,m \in K} c_{km} z_{km} \\
\text{Subject to:} & \quad (2) - (3) - (4) - (5) - (6) - (7) - (8) - (9) - (10) \\
\sum_{k \in K} z_{kk} &= q
\end{align*}$$

We report in the table 2 optimal solutions of this version for some instances with different values of number of terminals.

4.2 Minimizing the handling cost in terminals

This version aims to minimize the operational handling cost in terminals. We denote $t_{km}$ the handling cost in terminal $k$ to terminal $m$ (we consider this cost as asymmetric i.e $t_{km} \neq t_{mk}$). This problem may be formulated as follows:

$$\begin{align*}
\text{Min} & \sum_{i,j \in I} \sum_{k,m \in K} c_{km} x_{ij}^k m + \sum_{i,j \in I} c_{ij} w_{ij} + \sum_{k,m \in K} (t_{km} + t_{mk}) z_{km} \\
\sum_{k \in K} z_{kk} &= q
\end{align*}$$

Subject to:

$$\begin{align*}
(2) - (3) - (4) - (5) - (6) - (7) - (8) - (10)
\end{align*}$$

We report in the table 3 optimal solutions of this version for some instances with different values of number of inter-terminals links.

4.3 Intermodal ($p,l$)–terminal location problem

In this version both the number $p$ of the terminals to be located and the number $l$ of the inter-terminals links are given. This problem can be modeled as follows:

$$\begin{align*}
\text{Min} & \sum_{i,j \in I} \sum_{k,m \in K} c_{km} x_{ij}^k m + \sum_{i,j \in I} c_{ij} w_{ij}
\end{align*}$$

Subject to:

$$\begin{align*}
(2) - (3) - (4) - (5) - (6) - (7) - (8) - (10)
\end{align*}$$

We report in the table 4 optimal solutions of this version for some instances.
Table 4. Exact solutions

| Instance     | Cost ($\times 10^7$) | Time (s) |
|--------------|-----------------------|----------|
| 10C10L2T2TL  | 6.24                  | 2.31     |
| 10C10L4T4TL  | 9.12                  | 0.35     |
| 10C10L6T6TL  | 9.82                  | 0.53     |
| 10C10L8T8TL  | 9.74                  | 0.55     |
| 10C10L10T10TL| 9.74                  | 0.47     |
| 20C20L4T4TL  | 54.9                  | 171.67   |
| 20C20L8T8TL  | 45.2                  | 250.65   |
| 20C20L12T12TL| 41.9                  | 3456.65  |
| 40C40L4T4TL  | *                     | *        |
| 40C40L8T8TL  | *                     | *        |
| 40C40L12T12TL| *                     | *        |
| 50C50L8T8TL  | *                     | *        |
| 50C50L12T12TL| *                     | *        |
| 50C50L16T16TL| *                     | *        |
| 60C60L8T8TL  | *                     | *        |
| 60C60L12T12TL| *                     | *        |
| 60C60L16T16TL| *                     | *        |
| 60C60L20T20TL| *                     | *        |

5. CONCLUSION

In this paper, we proposed a general version of the classical Intermodal Terminal Location Problem (ITLP) when the induced graph by located terminals is not necessarily complete. We formulate the problem as 0-1 linear program and proposed several extensions. We reported numerical results on data set instances given in the literature using CPLEX solver. As perspectives, we envision:

1. To develop efficient heuristics to solve larger instances
2. To combine the problem with routing problems
3. To study a hybrid hub intermodal terminal location problem considering incomplete networks

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