Computers in Industry 81 (2016) 138–151

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

A rail-road PI-hub allocation problem: Active and reactive approaches

Faiza Walha[a], Abdelghani Bekrar[b,*], Sondes Chaabane[b], Taicir Moalla Loukil[c]

[a] LOGIQ, University of Sfax, Sfax, Tunisia
[b] LAMIH, UMR CNRS 8201, University of Valenciennes and Hainaut-Cambrésis, UVHC, Le Mont Houy, 59313 Valenciennes Cedex, France
[c] Faculty of business administration, Tabuk University, Tabuk, Saudi Arabia

ARTICLE INFO

Article history:
Received 8 May 2015
Received in revised form 21 April 2016
Accepted 22 April 2016
Available online 28 April 2016

Keywords:
Physical internet
Rail-road allocation
Cross-docking
Heuristic
Simulated annealing
Multi-agent system

ABSTRACT

This research concerns an allocation problem in the context of the physical internet aimed at improving rail-road π-hub efficiency by optimizing the distance travelled by each container to the dock, as well as the number of trucks used. To achieve this, heuristic, metaheuristic and Multi-agent-based approaches are proposed. When given the sequence of all the containers in the train, the proposed heuristic approach can assign these containers to outbound doors. Then, the Simulating Annealing (SA) method improves this allocation by minimizing the distance travelled. In addition, a multi-agent system model is proposed to generate reactive solutions which take dynamic aspects into account.

The experimental results show that the proposed SA yields an improvement of about 2.42–7.67% in relation to the solution generated by the heuristic; it provides good results within a reasonable time. Conversely, the multi-agent-based approach provides good solutions in case of perturbations or unexpected events.

1. Introduction

The Physical Internet (PI, denoted π) is defined as "an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation,interfaces and protocols" [1]. In this structure, goods are shipped in standard size containers in the same way as data packets in the Digital Internet, where networks are connected using standard packets of data under the TCP-IP protocol. In order to exploit the Physical Internet, Montreuil et al. [2] proposed three key types of physical elements: π-containers, π-movers (π-vehicles, π-carriers, π-conveyors and π-handlers) and π-nodes (π-transits, π-switches, π-bridges, π-sorters, ***π-hubs***, π-composers, π-shops, π-bridges . . .).

The mission of the ***π-hub*** is to transfer π-containers from the incoming π-movers to the outgoing π-movers. Ballot et al. [3] developed a new, specific "road-rail π-hub" for the purpose of transferring containers from trucks to trains ("road → rail"), and vice-versa ("rail → road"), as well as from one train to another ("rail → rail"). The road-rail π-hub is plagued by three main problems:

- The road → rail problem: some π-containers must be transferred from π-trucks to railcars using the road-rail π-sorters.
- The rail → rail problem: some π-containers must be transferred from railcars to other railcars using the rail-rail π-sorters.
- The rail → road problem: some π-containers must be transferred from railcars to outgoing π-trucks using the rail-road π-sorters.

In this paper, the last problem ("rail → road") is considered. The main performance objective of the "rail → road" zone is to minimize the number of trucks used and the distance travelled by each container to reach the docks. However, many specific constraints are considered: 1) The position of both containers and trucks in relation to the docks tends to change over time. 2) The position of the containers in relation to the docks is important when the objective is to minimize the number of containers moving through the routing zone. 3) The size of the containers placed on each truck should not exceed the capacity of the truck. 4) All containers put on a specific truck are heading for the same destination.

This paper is organized as follows. In Section 2, a literature review is presented. Section 3 describes the problem considered. Proposed approaches to solve the allocation problem are detailed in Section 4. Computational results and experiments are presented in Section 5. Finally, a conclusion is drawn and future prospects are addressed.

* Corresponding author.
E-mail addresses: walha.faiza@gmail.com (F. Walha), abdelghani.bekrar@univ-valenciennes.fr (A. Bekrar), sondes.chaabane@univ-valenciennes.fr (S. Chaabane), taicir.loukil@fsegs.rnu.tn (T.M. Loukil).

http://dx.doi.org/10.1016/j.compind.2016.04.007
0166-3615/

Notations

N Number of containers.
M Number of dock positions
D Number of destinations
P Number of docks
i Indices of containers, $i = 1, \ldots, N$
p Indices of docks. $p = 1, \ldots, P$.
lc_i Length of container i, $i = 1, \ldots, N$.
T Number of periods in planning horizon
K Capacity/length of trucks
d_{ip} Distance travelled by container i, to reach dock p. $i = 1, \ldots, N$. $p = 1, \ldots, P$
cd Total distance travelled defined as the sum of all distances travelled by all the containers to reach the docks

2. Literature review

2.1. The cross-docking platform

Cross-docking is a distribution system where freight is received and prepared in order to be transferred to another location, typically by trucks, shipping containers or rail. Most of the existing research is on truck-to-truck applications [4]. In these cross-docking hubs, freight is shipped from inbound trucks to outbound trucks on the same day, or overnight without storage. The cross-docking problem is classified into three levels: strategic, tactical and operational (see Refs. [5] and [6]). Different problems are studied: cross-dock location, layout design, vehicle routing, inner transport scheduling, truck scheduling, and dock-door assignment.

In the dock-door assignment problem, the purpose is to assign destinations to outbound dock-doors of the cross-dock, with the aim of minimizing the distance travelled for the material-handling equipment. When the number of trailers exceeds the number of docks available, the first are parked until at least one dock becomes available. The assignment can be of medium-term, short-term, or a combination of both [7]. In the medium-term, each door is assigned to an input or output destination for a specific period of time (usually 6 months). In the short-term model, each door is assigned to an input or output destination based on the current flow of goods.

In Ref. [8], the authors compared the existing literature review with industry practices. They propose a different classification of cross-docking. For the dock-door assignment problem, the authors classify the existing papers as "truck-to-door assignment problems". McWilliams [9] developed a dynamic algorithm to solve the problem of load balancing in the cross-docking context. This consists in scheduling a set of incoming trucks, with a heterogeneous set of packets, to a set of unloading doors. The proposed method can be applied to manual and automated systems. In automated systems, freight is moved using conveyors, as with our problem, and the objective is to minimize the total transfer time. Tsui and Chang [10] formulate an assignment issue as a bi-linear programming problem, where the goal is to minimize the distance travelled by the forklifts. The same authors [11] propose a branch-and-bound algorithm to solve the dock-door assignment problem. Oh et al. [12] solve the assignment problem in a mail distribution centre. Miao et al. [13] develop a similar heuristic search and an adapted genetic algorithm to solve truck scheduling problems so as to minimize the operational cost of shipments. In Refs. [14–16] some heuristics and metaheuristics are proposed to minimize the total processing time. Golias et al. [17] developed a memetic algorithm where they demonstrate the advantages of scheduling inbound and outbound trucks simultaneously.

2.2. The classical road-rail hub

The road-rail terminal is a special transhipment node where gantry cranes tranship containers from trains to trucks, and vice versa. These containers are collected, rearranged, unloaded,

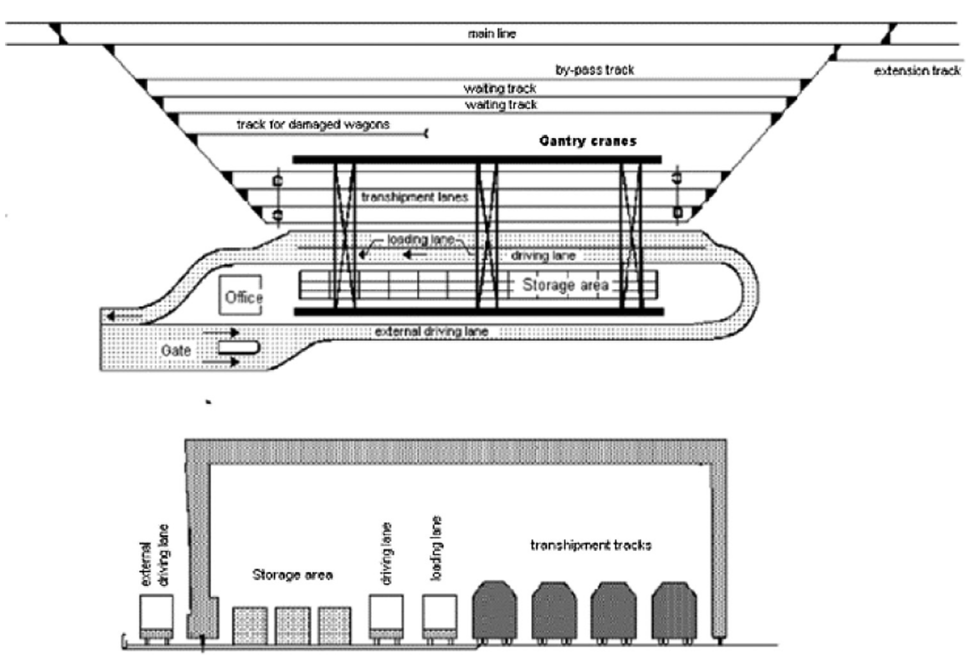

Fig. 1. Layout and cross-section of the rail–road terminal equipped with three gantry cranes [19].