Computers & Operations Research 51 (2014) 1–10

Contents lists available at ScienceDirect

Computers & Operations Research

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

A flow allocation strategy for routing over multiple flow classes with an application to air cargo terminals

Dongsheng Xu [a], Cai Wen Zhang [a,*], Zhaowei Miao [b], Raymond K. Cheung [c,1]

[a] Department of Management Science, Business School, Sun Yat-sen University, Guangzhou, China
[b] Department of Management Science, School of Management, Xiamen University, Xiamen, China
[c] Department of Industrial Engineering and Logistics Management, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

ARTICLE INFO

Available online 28 March 2014

Keywords:
Network flow
Flow allocating strategy
Material handling system
Multiple flow classes
Terminal operations

ABSTRACT

Advances of information technology have enabled the utilization of automated material handling systems in the logistics industry. The increasing costs of labor in developing countries have accelerated this trend. Major cargo terminals are now installing more and more integrated automated shipment handling systems in order to increase their operational efficiency which can be measured by the average shipping times or the facility throughput, for example. Routing is clearly an important decision category that has significant impact on the operational efficiency. In this paper, motivated by a project with one of the busiest air cargo terminals in the world, we investigate a routing optimization problem for multiple flow classes with different levels of priority. We propose a flow allocation (FA) routing strategy in which when a shipment arrives at a decision point, a set of allocation ratios will be employed to direct it to the next location. These ratios are determined by solving a mathematical model that explicitly considers the congestion effect and the characteristics of the multi-commodity network. Comprehensive simulation experiments demonstrate that the proposed FA routing strategy significantly outperforms the one currently in use.

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1. Introduction

Advanced automated warehouses and distribution centers are playing an increasingly important role in global supply chains for their merits of reduced labor costs, high space utilization rate and high speed of goods movement. Recent trends show that some major air cargo terminals and distribution centers have started to adopt large-scale integrated automated shipment handling systems (IASHSs), which are composed of multiple automated storage and retrieval systems (ASRSs) and various processing stations. The operations in a stand-alone ASRS are already quite complex, let alone those in an IASHS. Therefore, optimization of the operations plays a critical role in improving its efficiency.

In this paper, we are concerned with a specific operational management problem in an IASHS, motivated by an industrial project with a major air cargo terminal—the Hong Kong Air Cargo Terminals Limited (Hactl for short). Established in 1976, Hactl has been actively seeking innovative facilities to provide world-class services. Today, Hactl is one of the world's leading air cargo terminal operators. Hactl is currently serving almost 90 international airlines and 1000 freight forwarders together with its wholly owned subsidiary—the Hong Kong Air Cargo Industry Services Limited (Hacis). The main cargo handling facility in Hactl is the Super Terminal 1 which provides services 24 h a day and 365 days a year. The Super Terminal 1 uses a highly automated and complex IASHS as shown in Fig. 1 to achieve competitiveness.

In this IASHS, there are thousands of pieces of equipment which enable fully automated material handling operations. Hactl categorizes the equipment into two groups by functionality. The first group is referred to as the *critical equipment* which is connected with multiple input channels for picking up the shipments and multiple output channels for dropping off the shipments. Examples include stacker cranes (similar to storage/retrieval machines) which move both horizontally and vertically, automatic guided vehicles which move horizontally, hoists which move vertically, and turntables which change the moving directions of shipments at intersections horizontally. The second group is called the *linkage equipment* that provides connections between the critical equipment and the system entry/exit points (SEPs). Examples include conveyors and sets of consecutive powered rollers. The linkage equipment can also serve as buffers for shipments when they are waiting to be processed by the critical equipment.

* Corresponding author.
E-mail address: zhangcw@mail.sysu.edu.cn (C.W. Zhang).
[1] This paper is dedicated to the memory of Prof. Raymond K. Cheung, whose passing has left us deeply saddened.

http://dx.doi.org/10.1016/j.cor.2014.03.015
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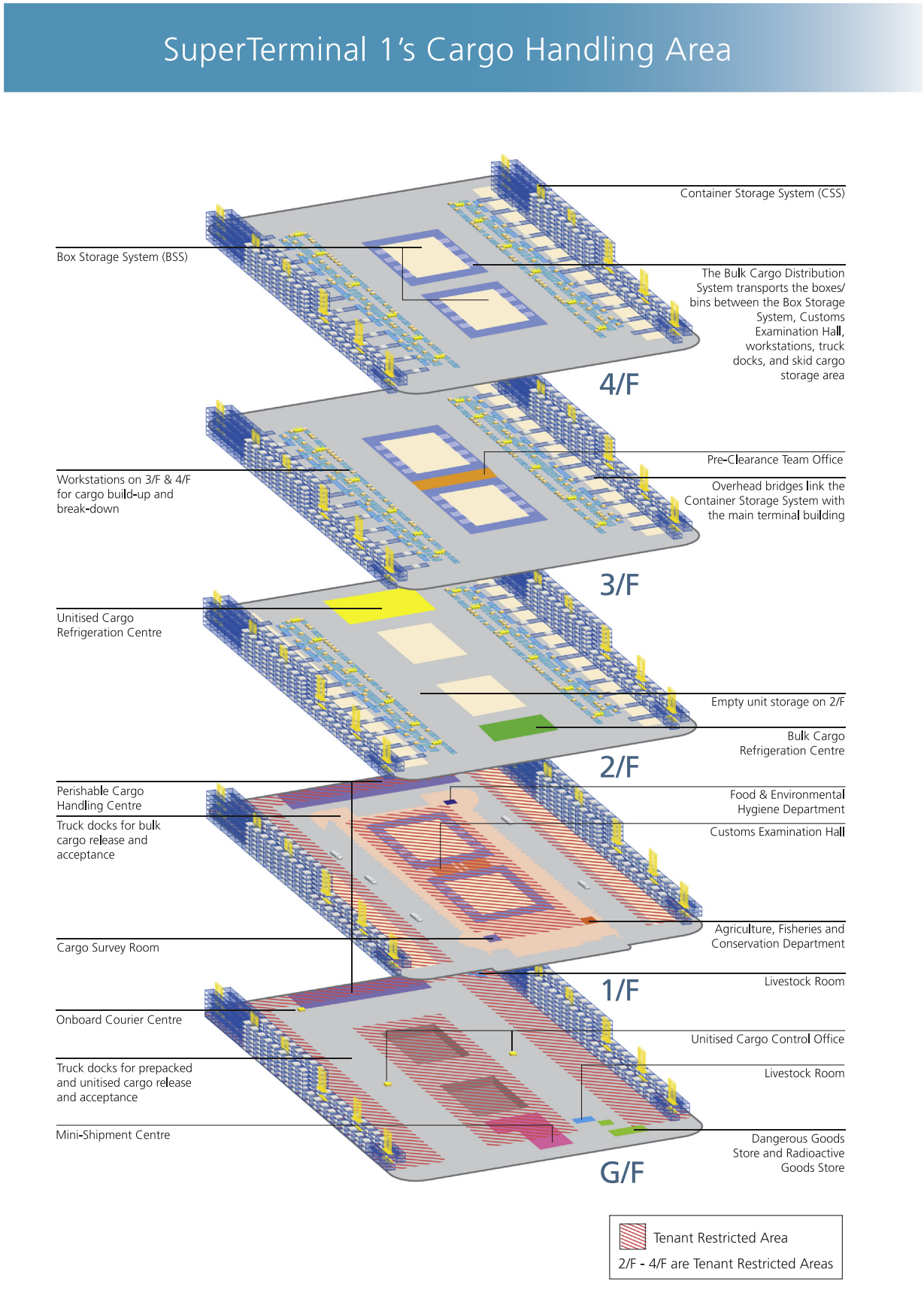

Fig. 1. A schematic of the Super Terminal 1.

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