Journal of Air Transport Management xxx (2016) 1–11

Contents lists available at ScienceDirect

Journal of Air Transport Management

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

Multi-criteria decision-making for complex bundling configurations in surface transportation of air freight

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ARTICLE INFO

Article history:
Received 6 February 2016
Accepted 7 February 2016
Available online xxx

Keywords:
Air cargo
Freight
Logistics chain
Multi-criteria decision-making
Best worst method (BWM)
Bounding configuration

ABSTRACT

Airlines typically carry out freight transportation in a hub and spoke structure, where the movements between the outstations and the hub are served by trucks. To transport freight efficiently, air carriers must consider bundling options for shipments that are delivered at outstations and have to be moved to the hub. There are three options when it comes to bundling freight: on 'through unit load devices' (T-ULD) (all freight for the same flight at the hub), on 'mixed unit load devices' (M-ULD) (freight for different flights at the hub) and loose freight in trucks. The optimal freight bundling configuration for carriers, taking into account their main KPIs (key performance indicators), is unknown. This research formulates the problem as a multi-criteria decision-making (MCDM) problem, allowing carriers to decide which configuration is optimal for a given outstation. The selected KPIs (cost, (un)loading time, and quality) are formulated as mathematical functions. A new MCDM, called best worst method (BWM), is then used to identify the best configuration with respect to the three KPIs. The proposed methodology is applied to KLM Cargo to identify the best configuration for the selected outstations that supply freight to the KLM hub at Schiphol Airport. This case study shows that there are different optimal freight bundling configurations for different outstations and that trucking costs and freight handling tariffs are among the key factors in deciding which configuration is optimal.

1. Introduction

Air cargo, which is defined as any property (e.g.: freight, mail, express parcels) transported by a full-freight aircraft, a combi-aircraft, or under the main deck of a passenger aircraft (Domingues et al., 2014), has at least two advantages over surface transportation (sea, road and rail), the first of which is the speed of the transportation, which is required for specific goods, such as perishable goods or goods that require next morning delivery (e.g. newspapers). The second advantage is the low risk for damage or loss, which means that high-value, time-sensitive goods with a high value-to-weight ratio are suitable for air transportation (Zhang and Zhang, 2002; Ohashi et al., 2005).

The air freight transport chain has different stages, starting at the shipper, leading via forwarders and the carrier (in our case the airline) towards the consignee. The logistics chain of air freight is visualized in Fig. 1 (adopted from Petersen, 2007). Shippers, the clients of the air cargo transporting service, are positioned at the start of the logistics chain (Popescu et al., 2010). They use freight forwarders to transport their shipment to a carrier. Other services being offered by freight forwarders include securing freight, storing freight, consolidating freight, organizing value added services and loading freight trucks. The carrier moves the shipment with airplanes to the respective destination airport, from which forwarders transport and deliver the freight shipment to the consignee, the recipient of the shipment (Petersen, 2007).

Fig. 2 shows an example of a high-level overview of the air freight transport chain. Usually, carriers contract Third Party Logistics Service providers (3PL) in the country or continent of origin to collect freight from freight forwarders and send it to the airport, together with other shipments. The same typically applies to the destination airport, but then in reverse order, as outlined in Fig. 2.

Here we briefly describe the actors involved in this chain:

Shipper: Shipper is the owner or supplier of the freight. It is also called 'consignor', its ultimate goal is to send shipment to the 'consignee'.

Forwarder: Forwarder is the actor that arranges the transport of the freight from shipper to origin outstation or from destination

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http://dx.doi.org/10.1016/j.jairtraman.2016.02.006
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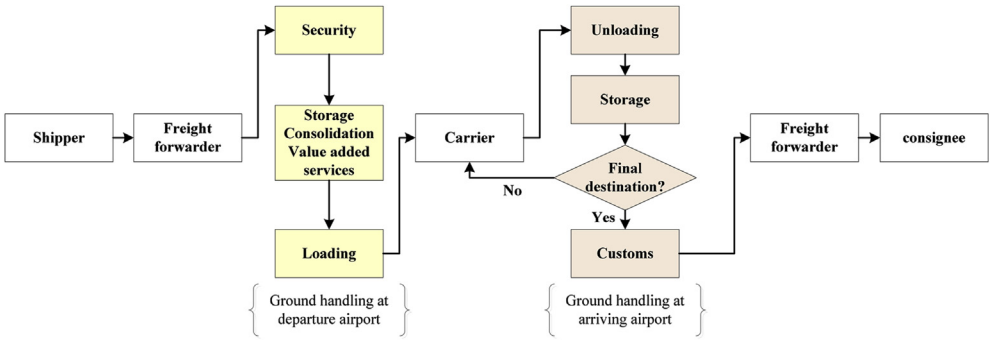

Fig. 1. Air cargo handling process.

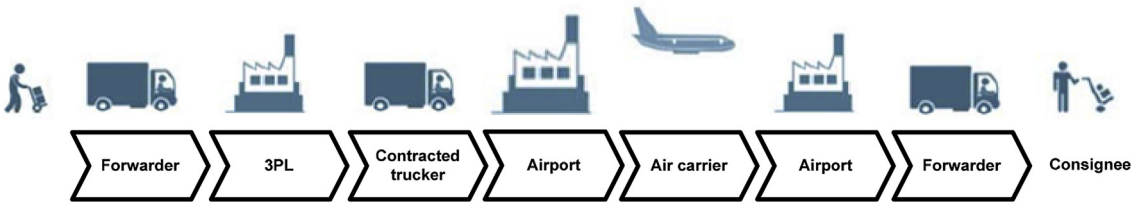

Fig. 2. Air freight transport chain.

airport to consignee. Forwarders often consolidate shipments, so they combine shipments designated for the same flight, in order to get a better price from the carrier. They also provide additional services, such as custom declarations and registrations of dangerous goods.

Outstation: Outstation is a place where an airline receives freight from forwarders or shippers. Outstation is usually operated by Third Party Logistics Service providers (3PL). Airlines usually contract these 3PL companies to process freight for airports.

Road carrier: A road carrier is a trucking company which transports freight from outstation to hub under an airway bill. Air carriers usually outsource their trucking activities to trucking companies. These trucks function as an airline service between outstations and the hub. These trucks comply with all requirements to transport air freight.

Hubs: Hubs receive freight from either trucks originated from outstations or directly from the shipper. Once arrived and accepted in the hub, the palletized freight is stored, ULD's are decomposed to shipment level or (re)built on pallets for the correct. The main goal of the hub is that the shipments are built on the correct ULDs and are ready for carriage before the deadline of the flight.

Air carrier: Air carrier is the airline on which the ULDs are loaded and transported to the destination.

Consignee: Consignee is the final receiver of the shipment.

Air freight transport chain might be of some other forms. What we presented above, is the framework we use in our study.

To transport air freight to an airport hub it needs to be palletized on unit load devices (ULDs). The most common ULDs are containers and big metal plates, on which freight can be bundled and tied down. For transportation by truck, the 3PL typically has three options in terms of the transport of shipments to an airport:

- *Through-ULD* (*T-ULD*); this type of ULD contains shipments for the same flight from an air cargo hub. This type is desirable for carriers, but only possible when there is enough freight volume at the outstation for a specific destination to build T-ULDs.
- *Mixed-ULD* (*M-ULD*); ULD that contains shipments for multiple flights.
- *Loose freight*; instead of palletizing freight, shipments are placed on a skid inside a truck.

T-ULDs are restricted by the specifications of the aircraft: if, for example, only belly freight can be accommodated on an aircraft, which is the primary form of carrying air cargo at many large airports (Merkert and Ploix, 2014), the T-ULD pallet cannot exceed 10 m^3 in volume. M-ULDs, on the other hand, are not restricted by aircraft specifications, because these pallets are disassembled upon arrival at the airport hub, as they do not contain shipments for one and the same flight. These ULDs can contain approximately 15 m^3 of freight during transport by truck towards the hub. Transporting palletized shipments has two advantages: (*i*) it reduces the time needed to load and unload the trucks, and (*ii*) it lowers transport and storage cost, because palletized freight uses space more effectively. Disadvantages of transporting palletized shipments are: (*i*) the costs of palletizing freight, (*ii*) the need for moving equipment between hub and outstation, and (*iii*) the requirements of this equipment (Morabito et al., 2000). M-ULDs have an additional disadvantage, in that they also need to be disassembled upon arrival at the airport, because they contain shipments for multiple flights.

Carriers have three different optimization alternatives at their disposal when it comes to transporting palletized freight from a 3PL to an airport. These optimization alternatives apply to a situation in which all freight is palletized. These alternatives are:

1) *Increase the number of T-ULDs for non-constraint destinations*: lower the minimum required volume for building T-ULDs at the outstation for shipments to non-constraint destinations. Because the freight capacity of flights to non-constraint destinations is not completely utilized, it is not necessary to build T-ULDs that utilize all the available cargo space of the ULD. This configuration will increase the number of T-ULDs and reduce the number of M-ULDs.
2) *Transport shipments loose*: shipments with short connection time that are placed on a M-ULD can also be transported loose in trucks instead of palletized. Upon arrival at the airport hub,

Please cite this article in press as: Rezaei, J., et al., Multi-criteria decision-making for complex bundling configurations in surface transportation of air freight, Journal of Air Transport Management (2016), http://dx.doi.org/10.1016/j.jairtraman.2016.02.006