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Optimising truckload operations in third-party logistics: A carbon footprint perspective in volatile supply chain

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ABSTRACT

With government and customers driving third-party logistics seeking opportunities to improve operation efficiencies and mitigating carbon emissions in the supply chain, third-party logistics firms have been striving to improve their truckload utilization and vehicle routing operations, especially in emission-regulated countries and volatile business environment. Traditional literature has focused on either truckload utilization or vehicle routing operations but seldom integrating carbon emission mitigation in their daily trucking operations. This paper delineates the operation review of three third-party logistics firms in Hong Kong and develops an organisation-based carbon emission measurement metrics for logistics operations. The truckload utilization and routing performance are reviewed, followed by a correlation analysis on the truckload utilization against truck capacity, loading volume, fuel consumption, truck size, travelling distances and number of destinations. An integrated carbon-driven multi-criteria model is developed achieving carbon emission reduction initiatives, time and distance cost penalty, minimizing number of trucks, and improving truck utilization. The integrated mathematical model has been developed into a simulation system which has been tested with evaluated results. The mathematical model is enhanced for the set of cargo items and vehicle fleet with additional factors of arrival time slots and weight. The model assists traffic planners to reduce cargo planning time and optimize the truckload operations. Further development will be focused on adding the dimensions of pallet loading operations and exception rules for customer loading requirements.

1. Introduction

Increasing pressure from customers and government for greenhouse gas (GHG) emission mitigation as well as motivation towards corporate social responsibility underpins a driving force in third-party logistics (3PL) firms. Not only do they aim at reducing operation costs but also quantifying and reducing carbon emission activities in warehouse and truck operations. Carbon emission reduction initiatives in logistics and transportation operations were discussed in the World Economic Forum in July 2013 (Le Quéré et al., 2014; Doherty et al., 2013). Government in the United States issued an Executive Order in March 2015 to cut Federal Government's GHG emission 40 percent over the next decade and encourage Federal suppliers to set similar goals to bring GHG reduction commitment across the supply chain. The combined total GHG reduction commitment, together with the suppliers, including IBM, General Electric, Honeywell, ADS Inc., and Hewlett Packard, could be up to 5 million metric tons between 2008 and 2020 (The White House, 2015). In October 2014, the Singapore Stock Exchange (SGX) announced a sustainability-reporting mandate across all listed

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companies, including those in the logistics and transportation sector (Shah and Cheam, 2014). The Hong Kong Stock Exchange (HKEx) also announced that companies could voluntarily provide sustainability reports with best practice recommendations (HKEx, 2012).

Facing the global sustainability trend on carbon reduction initiatives carried out by leading logistics firms, other 3PL firms face fierce challenges in tackling the competition on pricing strategy, operations costs, corporate image and marketing, fuel price fluctuation, and operation efficiencies while exploring opportunities to mitigate carbon emissions in daily operations (Mohammed et al., 2017; Chanchaichujit et al., 2016; Konur, 2014; Ji et al., 2014; Pan et al., 2013). Hong Kong-based logistics corporations usually focus on profit margin and cost efficiency but find difficult to incorporate emission mitigation in their trucking operations, considering limited knowledge, resource and available tools. To meet the needs of improving operation efficiency and reducing carbon emission during the consolidation of thousands of boxes into trucks each week, 3PL firms require a systematic and intelligent system to plan for loading various boxes on different pallets and packed into the trucks for cargo delivery, with consideration of box size, arrival time, truck size, pallet size, and destinations (Levesque, 2011). This paper presents an analysis on the operation reviews of three global 3PL firms in Hong Kong and investigates the statistical relationship between dominant factors in carbon emission associated operations parameters. The performance measurement and sustainability reporting of 3PL firms are discussed. Upon the statistical analysis and sustainability performance measures, a carbon-driven bin packing model is developed, followed by simulations on three scenarios. A sensitivity analysis is carried out to evaluate the changes of time factors towards the carbon emission savings. Future development initiatives are recommended.

2. Truckload operations in third-party logistics

A new 3PL business model for logistics and physical distribution evolved in U.K. in the early 1990s (Kimura, 1998). The evolution of 3PL in simulating companies outsourcing logistics services to third-party operators in UK has been driven by factors in operation globalization, focusing of core business, and new business search by transport companies under deregulation and increased competition. Ackerman and Wise (1985) presented the early state of third-party warehousing in the Council of Logistics Annual Conference. Lieb (1992) described 3PL as the use of external companies to perform logistics functions that have traditionally been performed within an organization. The functions performed by the third-party can encompass the entire logistics process or selected activities within that process. In the early 2000s, 3PL is included in contract logistics and defined as multiple logistics services provided by a single vendor on a contractual basis (Lewis and Talalayevsky, 2000; Razzaque and Sheng, 1998). Aicha (2014) reviewed the outsourcing of logistics activities and the selection of 3PLs in the past two decades with the consideration of logistics services in transportation, distribution, warehousing, inventory management, packaging and reverse logistics. In recent years, globalization, offshoring, and complex supply chain network have incited the expansion of firms specializing in transport and logistics services (Williams, 2014; Selviaridis and Spring, 2007; Kholer, 2001). Companies tend to outsource logistics activities in order to focus on their core competencies, such as manufacturing, wholesaling and retailing. The role of 3PL is becoming more prominent in the 21st century as a professional logistician in providing services, including warehousing, cargo consolidation, distribution, customs, documentation, multi-modal transportation, and supply chain management (Jaafar and Rafiq, 2017; Mehmann and Teuteberg, 2016; Ajakaiye, 2012; Chin et al., 2010).

Whether a 3PL firm can fully utilize the spaces in trucks affects its operation costs and carbon emissions. Improving truckload utilization lowers operation cost, increases revenue, lessens the number of trucks used, and reduces congestion and pollution for the society (Centobelli et al., 2017; Abate, 2014; Van de Klundert and Otten, 2011; Min and Jong, 2006). Various analysis and modelling on truckload utilization have been carried out. Samuelsson and Tilanus (1999) developed a model to provide estimates on various measures for capacity utilization in regional less-than-truckload (LTL) distribution, considering the dimensions of time, distance, speed, and capacity. Hubbard (2001) described capacity utilization as high when trucks are hauled with a series of full loads with the support of computation tools and wireless networking applications. The utilization of each truckload is highly depended on the agglomeration of complementary demands into individual trucks. Tyan et al. (2003) evaluated the freight consolidation policies of global 3PL and developed a mathematical programming model to assist the evaluation of consolidation policies. Baykasoglu and Kaplanoglu (2011) proposed a multi-agent based load consolidation decision making approach for LTL orders to solve the complex interrelated factors including loading sequence, capacity limit, route selections, and cargo consolidation. Abate (2014) reviewed the capacity utilization in trucking considering the empty running and load factor. A joint econometric modelling framework is proposed for the truck utilization as a function of haul, carrier, and truck characteristics. Other truckload utilization literature includes Van de Klundert and Otten (2011), Baykasoglu et al. (2013), and Baykasoğlu and Kaplanoğlu (2015). Most of the literatures focused on modeling the truckload utilization based on time, distance, speed and capacity. A few of them successfully integrate truckload, utilization, departure and arrive time, and vehicle emission during the truckload planning and put them into real practices. There are lack of literature developing systematic and structured methodologies in carbon mapping and reporting in truckload operations of 3PL. These 3PL firms lack knowledge and skills in calculating and mitigating carbon emission in the warehouse and truck operations. This paper addresses these issues by building a framework and method in carbon reporting in logistics firms, analysing critical factors on truck load utilization, and developing novel optimisation model to improve truckload utilization and reduce the carbon emitted from truck operations.

3. Performance measurement in truckload utilization, carbon emission, and operation cost

Due to the extensive use of logistics services, there is a growing concern among customers and governments about greenhouse