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ORIGINAL PAPER

The use of freight apps in road freight transport for CO_2 reduction

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Abstract
Purpose The purpose of this study was to investigate how a smart phone freight application service (Apps) could reduce CO_2 emissions in road freight transport and to identify the core problems for improvements.
Methods This research uses a multiple-case-study approach to examine several existing freight apps in the Chinese market. The study was conducted using multiple data collection techniques, including interviews, production observation, first-hand experience, and online-search summaries.
Results Inspired by a full analysis of case studies, a hierarchical conceptual framework was developed to provide an overarching view of how existing apps achieve environmental benefits, which deepens our understanding of the interrelationship between freight Apps utilization and CO_2 reduction. Freight apps provide a mechanism that auto-match the consignor's demand and the carrier's supply based on mobile Internet. The efficient way to find the right truck and complete the delivery process enhances the decrease of truck's empty travel distances and improvement of average vehicle loaded, then leading to an improvement of efficiency and a decline in carbon emission in freight industry. And then the identification of returning pick-up and route planning was conducted to further improve apps for CO_2 reduction.
Conclusions The influences to freight movement system by apps focused on reconstructing the demand and supply with integration technology, and resulted in a more efficient transaction using matching technology and advanced fleet management with optimization technology. When with inter-urban Full Truck Load, freight apps enable carriers to search for demand for returning a pick-up with decreasing empty running mileages, which then has environmental benefits through reducing CO_2 emissions. However, when in urban Less-than-Truck Load, by strengthening the average vehicle utilization on laden trips, another determinant of route planning of delivery & collection reduced CO_2 emissions. In order to further promote development of apps, in inter-urban Full Truck Load of long-distance transport, sufficient number of users and suitable matching conditions ensured carriers schedule an order to guarantee the return pick-up at an appointed time or grab several orders to achieve a larger non-empty return trip. In this "always-laden" transport plan, consideration should be given to the carriers' search and waiting costs before starting the next freight service. Meanwhile, route planning of delivery & collection based on real-time traffic information in Less-than-Truck Load required sharing high-level of data, complicated-adaptable models and the efficient computing power. These valuable aspects would be a great challenge for follow-up development of freight apps in aiding CO_2 emission reduction.

Keywords Road freight transport · CO_2 reduction · Freight app · Evaluation framework · Further improvement

This article is part of Topical Collection on Smart cities and transport infrastructures

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1 Introduction

1.1 Background

Road transport currently dominates freight movement in China, accounting for approximately 76% of lifted tons [1]. Subsequently, road transport contributes to 85% of total CO_2

emissions for domestic freight transport [2] and approximately 6.8% of total domestic CO_2 emissions in China, which only accounted for 34% of the total freight turnover in 2011. Given the serious challenges of global warming plus the increasing concerns about energy shortage, both the government and stakeholders of freight movement have been intensely exploring methods to reduce energy use and CO_2 distances for inner-city delivery as well as the use of alternative fuels and resource collaboration for emissions. Common measures under the ASIF (activity, structure, intensity and factor) model include, for instance, the increased vehicle load factors, which reduce emissions per ton-kilometer [3]. The work of Mckinnon [4] and Tacken et al. [5] indicates that the practices to reduce CO_2 generated from road transport sectors can be clustered into the following four main elements: modal split, vehicle fuel efficiency, carbon intensity of fuel used and road freight transport network optimization and consolidation.

Concurrent with the rapid development of information and communication technologies (ICT) in recent years, companies in the freight transport industry have moved to make use of an increasing number of applications based on ICT in an effort to improve the performance of their processes. The studies of Marchet et al. [6] and Perego et al. [7] provide a detailed summary of four classes of transport-related technologies: transport management applications; supply chain execution applications; field force automation applications; and fleet and freight management applications. More recently, the attention of scholars has concentrated on improving the environmental friendliness and sustainability of road freight transport using ICT-based applications. Klunder and Malone et al. [8] developed three types of ICT-based solutions for energy use and CO_2 emission in road transport.

Inspired by the success of taxi-calling apps in the global market, over 200 freight mobile apps have come into Chinese market in recently years. According to the different users, some main types of freight apps are shown in Table 1. As the ICT-based applications of logistics platform, the freight apps has a similar business model to taxi-calling apps, which reduce the logistics cost and accelerate the service response [10]. The freight apps improve the efficiency of social

Table 1 Major types of freight app use in China

Type	Functions	Typical product
Apps in logistics parks	Both cargo owners and drivers can use it. Cargo owners can publish and manage the source of goods, and select the drivers. Drivers can publish the source of cars and find the goods. Generally, such Apps do not involve in the specific transaction, but only provides the information interaction function, and third-party payment, insurance, oiling and other value-added services.	Apps of Linan Logistics and Chuanhua logistics
Apps for cargo owners	Only applicable to cargo owners. Provide query, ordering, tracking, account checking, inquiry and other functions for the cargo owners.	Chewang platform, Kaopu platform, Lulu Dispatch, OTMS, Yunmanman, and Good logistics
Apps for truck management	Provided for logistics companies having own vehicles or needing to manage out-sourced vehicles. Have management functions of vehicle archiving, vehicle dispatching, tracking, etc.	G7 truck management version, Lulu truck management, and Aidijie motorcade
Apps for Drivers	Provided for the drivers. Functions include publishing the source of trucks, finding the goods, feedback of the transportation process, etc.	G7 freight personnel version, Guanchebao, Haoduoche, Yunmanman, and Kuaile cart
Apps for transportation enterprises	Mainly provided for use by cargo owners or potential cargo owners. Functions include order placing and delivery, inquiry and tracking, account checking and settlement, business advertisement, etc.	Apps of Huayu and Deppon
Apps for in-city distribution	Provides intra-city order placing and delivery by standard vehicle type.	Blue Rhino, No.1 truck, No.1 Huode, Shendun Express and Huolala

Source: Derived from [9]

logistics to saving fuel consumption and carbon dioxide emissions per ton-kilometer. Hence, it is necessary to conduct a systematic study to deepen our understanding about the role played by freight apps in CO_2 reduction.

1.2 Definition of freight apps and objective of study

The freight apps is the mobile phone application software service that provides freight distribution, management and other services to freight stakeholders. The freight apps are the evolving applications of Electronic Transport/Logistics e-Marketplace (ET/LM) of a new technology innovation, which classified as ICT-based applications using mobile communication and Internet technology. The freight apps also created the new business model. Table 2 provides pros and cons of both freight apps and ET/LM. As logistics platform become mobile, the achievement of mobile information management process in freight movement system build an information exchange bridge for cargo owners and drivers using mobile internet, promoting a match between trucks and cargos by improving the integration and utilization level of freight resources in the field.

The purpose of this paper is to investigate how freight apps influence CO_2 reduction and identify the challenges that need to be addressed to ensure their success with improvement. Our contributions are twofold: from a theoretical perspective, a structured conceptual framework was developed to deepen our understanding about the role played by freight apps in CO_2 reduction, and from a practical perspective, the research describes how to accomplish environmental benefits through improvement at the level of returning pick-up and route planning. Consequently, our proposed research questions are as follows:

- *RQ1*. What is the use of the freight apps on CO_2 reductions in road freight transport?
- *RQ2*. What are the main aspects for further development in CO_2 reduction?

The rest of this paper is organized as follows. Literature relating to this subject is reviewed in next section. Section 3 describes the research method used in this study. Section 4 outlines the framework to evaluate the impact of mobile apps for CO_2 reduction. The main aspects for further development for freight apps in CO_2 emissions reduction are presented in Section 5. Section 6 offers the conclusions and outlines the limitations of this research and suggestions for future research.

2 Literature review

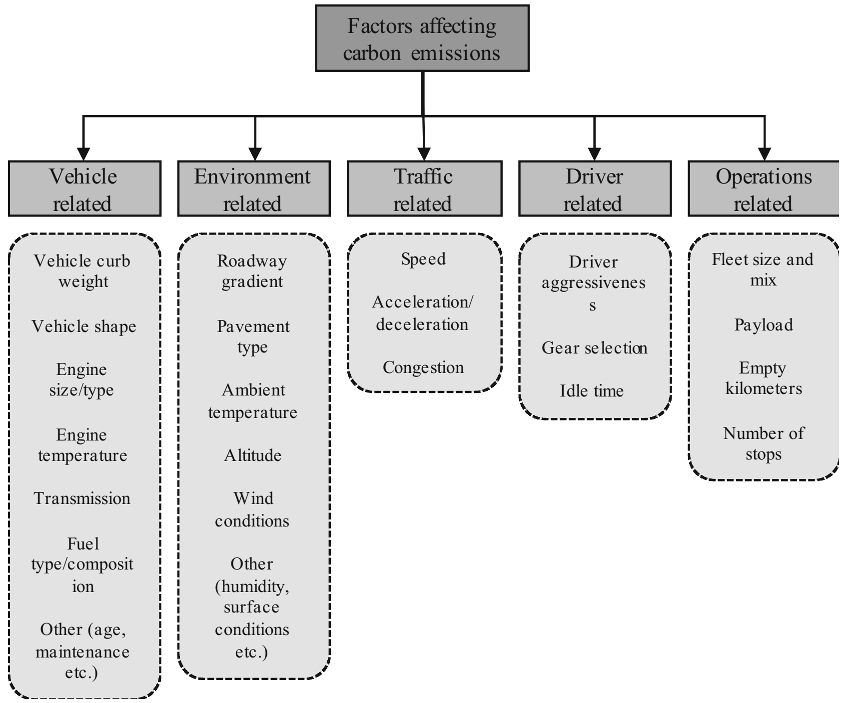
2.1 Factors affecting CO_2 emissions in road freight transport

Carbon emissions are related to many factors that have been researched by scholars. Demir and Bektas et al. [11] summarized these works into five categories: vehicle, environment, traffic, driver and operations. Figure 1 provides a clear data semantics and structural description. When a vehicle moves, an engine must provide power to overcome the effects of inertia, wind resistance, and road slope, etc. However, several factors were considered separately when we concentrate on the means of ICT-based applications for carbon reduction in road freight transport. CO_2 emissions are distance-dependent [12]. Speed that additionally determines travel time is also an important one because it affects inertia, rolling resistance, air resistance and road slope [13]. Fleet size and mix has an impact on carbon emissions, as small vehicles which have smaller engines consume less fuel than larger vehicles. This is supported by Demir et al. [13] who have assessed, for a certain amount of payload, the difference between a medium and heavy-duty vehicle may be up to 14 l of fuel on a 100 km road segment. Bektas and Laporte et al. [14] have studied the effect of payload on carbon emissions that vehicle payload can be an important factor of routing decisions. Also, reducing empty kilometers always leads to a lesser CO_2 emissions, which should be avoided whenever possible.

Table 2 A comparative between freight apps and ET/LM

Type	Freight apps	ET/LM
Pros/Emphasis	• Mobility of logistics platform • Logistics socialization • Integrated to meet the long tail demand • Eliminate barriers to achieve information sharing	• Logistics facilities standardized • Transport unit standardized • Decreasing the stocks and the physical distribution costs • Reduce investment in fixed assets
Cons/Aporia	• The cultivation of the number of users • The change of shippers' and providers' behaviors • Facticity of information • Profit model	• Logistics function are out of control • Giving up the exploitation of professional logistics • The uncertainty of long-term relationship with customers

Fig. 1 Factors affecting carbon emissions. Source: [11]



2.2 ICT-based applications for CO_2 reduction in road freight transport

Information and Communications Technology (ICT) is an extended term for information technology (IT) which stresses the role of unified communications and the integration of telecommunications (telephone lines and wireless signals), computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information [15]. Scholars discussed ICT-based application classification in road transport. Giannopoulos [16] provided a comprehensive overview of various ICT systems used in transport. McKinnon [17] examined eight carbon-saving measures for logistics, which argue for telematics as a CO_2 reduction solution. Bask and Spens et al. [18] emphasized the use of a smart transportation management system, which includes smart freight systems (such as radio-frequency identification (RFID), general packet radio service and web technology), smart vehicle systems (including the in-truck good identification systems and vehicle systems) and smart infrastructure. One important work by Wang and Sanchez et al. [19] provided good summaries of ICT-related applications in road transport through a synthesis of the literature. A hierarchical approach was used to offer the deployment at four levels as shown in Table 3. The table also outlines the key clarify applications and systems used that had a potential impact on CO_2 emissions for each level.

2.3 The impact of ICT-based applications for CO_2 reduction

ICT-based applications have been identified as having the potential to reduce the CO_2 emissions of road vehicles. Hilty et al. [35, 36] pointed that the effects in the target of carbon emissions must also be evaluated from a life cycle perspective called “linked life cycles approach”, if ICT is viewed as an enabling technology to improve or be substituted for processes in sectors (“Green by IT/ICT”). The linked life cycle approach modified the life cycle of ICT-based production in the ways for optimizing the design, production, use, and end-of-life of other products. Wang et al. [19] empirically investigated the direct positive impact on CO_2 emissions reduction for ICT solutions by adopting a multiple case study with three leading UK grocery retailers. The findings highlight opportunities to further reduce CO_2 emissions, which are perceived as lying beyond retailers’ own distribution networks for the underutilization of shared information with competitors, which reflects the necessity of the integration of the same type of information. Termed as the Electronic Logistics Marketplace (collaborative ELM), Wang and Potter et al. [34] highlighted that the ELM has potential for growth in optimizing supply chain networks and enabling vertical collaboration between shippers and a carrier.

However, only a few ICT-based applications have specifically addressed environmental aspects as significant results and quantitative data are still missing in practice [37]. The fact had been confirmed by the main literature reviews in the research of Lieb et al. [38], Lin et al. [39] and Evangelista [40].

Table 3 A hierarchical categorisation of ICT use in transport and logistics operations

Levels for use of ICT	Key references	Key applications and systems
Level1 – vehicle and load	Baumgartner et al. [20], Stefansson and Lumsden [21], Zeimpekis and Giaglis [22].	On-vehicle or in-cab ICT systems managing individual vehicles or loads; typical applications include: Digital tachograph, which works by digitally storing data on the driver and vehicle in its memory, and also on a credit card-sized plastic card known as the "driver smart card". It is an electronic system for recording driving and rest times for drivers and co-drivers of trucks that are driven under EC driver' hours rules. Telematics, which is made up of three components: an on-board computer, a satellite receiver/GPS, and a communications device. These are normally combined into a single piece of equipment within the vehicle, supported by office-based equipment and software. It is the wireless backbone of vehicle and load management and helps to monitor the movement of vehicles, fuel consumption and communicate with drivers
Level 2 – company	Botta-Genoulaz et al. [23], Gupta and Kohli [24], Baumgartner et al. [20], Helo and Szekely [25], Marchet et al. [6], Yusuf et al. [26].	Enterprise systems deployed to manage specific business processes: Best of breed functional systems: a typical application is transportation management system (TMS) which usually offers the following functions; Planning and scheduling: daily route and resource planning and strategic what-if scenarios analysis for long term business plan; Execution and monitoring: driver communication, real time or retrospective tracking, management reporting and financial settlement; Fully integrated systems: a typical application is Enterprise Resource Planning (ERP) system which integrates all of a company's major business processes (from order processing to product distribution) within a single family of software modules
Level 3 – supply chain	Brown et al. [27], Evangelista et al. [28], Sweeney et al. [29], Buxmann et al. [30]	Inter-organisational systems managing mainly the dyadic business activities between two organisations. Typical applications include: Customer relationship management (CRM) system, allowing business to carry out b2b sales on the web and provides support for marketing and customer service; Supplier relationship management (SRM) or Supply chain management (SCM) system, designed to deal with the procurement of the components a company needs to make a product or service and the movement and distribution of components and finished products throughout the supply chain
Level 4 – network (multiple supply chains)	Auramo et al. [31], Davies et al. [32], Wang et al. [33], Wang et al. [34].	Network systems usually involve multiple participants and communications are simultaneously conducted between two or more companies. Typical applications include: Open electronic logistics marketplaces, mainly for sport trading of transport services between shippers and carriers. Such systems can be used for identifying backhaul opportunities; Closed electronic logistics marketplaces, for long-term logistics provision and execution. Such systems integrate shippers (consignors), carriers and customers (consignees) and can be used for horizontal transport collaboration between shippers or between carriers Network systems usually involve multiple participants and communications are simultaneously conducted between two or more companies. Typical applications include

Source: [19]

Relatively little research has been using a quantitative approach to model the effect. Boulter and Smit [41] considered the state of ITS in Australia and reviewed its effect on emissions. A framework has been developed, and the power-delta-power (PΔP) model was used to evaluate the effects of some types of ITS on emissions. Nagao and Hara et al. [42] constructed estimation models for the scenario based on the basic model and estimated the reductions in CO2 emissions by using statistical data for 2013 in Japan.

While many aspects of ICT-based application have been considered, only a few studies investigate the development and application of mobile apps in road freight transport. Nemoto and Visser et al. [43] built a framework to evaluate the impacts on urban logistics systems by describing the nature of influencing the ICT, which considers several scenarios in the mobile environment. An experimental co-operative pick-up system to match transport demand and supply was conducted [44], and the result did not imply that the pick-up system should be viewed negatively in the future. However, these studies focus on technologies and are only based on the Internet, fixed phones or pagers. With the mobile Internet environment, the freight apps have influenced the freight movement system by changing the shippers' and providers' of road transport behaviors [45]. In particular, from the perspective of CO_2 reduction, the literature fails to offer a common structured comprehensive view of freight apps in road freight transportation, and the existing freight apps products in Chinese market provide a condition for the study of this problem.

3 Research method

A multiple-case-study research method is suitable when attempting to address "what" and "how" research questions in the context of contemporary events [46], and Barratt et al. [47] highlights that this method is mainly used to develop new theories. Robert K. [48] shows the case study takes a typical case as the material to solve the current "how" and "why" research questions through specific analysis and anatomy and these research methods do not require a strictly controlled research approach. A common criticism associated with case study research is the potential lack of objectivity, considering that researchers may lose their independence through heavy involvement with the case [19]. To improve the validity of case studies, Barratt and Choi et al. [47] used multiple data collection techniques, i.e., interviews, system demonstrations, site observation and archival documents. This triangulation shows higher reliability of data and more effect structures of the target. The collection techniques applied in this paper also aim at triangulating the data and achieving a better result of contextual data.

The freight app products are at the core of freight movement; as a result, when selecting the cases, selecting the appropriate freight apps has become the key. The following two conditions based on research regarding the choice of cases are as follows: (1) Freight apps can represent the current situation of Chinese road freight and logistics industry markets and the future directions, and they have been adequate to influence the industry. (2) Freight apps must be fully functional, and they must have been used by a number of related enterprises and drivers. Considering the data availability and market survey, seven typical freight apps that are currently used in the Chinese market were introduced as suitable cases for research, which was greatly promoted in the logistics field and received large investments for the market share. Table 4 summarizes their backgrounds and indicates the scale of their businesses.

With case 1, the case study involved an interview of five truck drivers and shippers using freight apps; they were asked about the use of the app since it was installed. Because the purpose is to know the process of using the app, the choice of five samples was sufficient. This offered the opportunity to collect the data required for this particular research. The same method was also used for study cases 2–7, which allowed the cases to be compared with one another using cross-case analysis. The usage process data were also summarized based on the information available from the apps' own websites and from web sites of China's Industry Development Association as well as academic articles [45, 49]. By installing seven freight apps on the author's smart phone, the information collected via production observation is demonstrated to be sufficient to fulfill the needs of this research as a validation of the case findings. The firsthand experience data were obtained by the paper contributors, who installed seven apps to simulate the shippers and discussed their own experiences.

A mechanism that matches the consignor's demand and the carrier's supply based on mobile internet was developed in Fig. 2 to examine the general characteristics according to analysis of cases studies. Type A is the traditional electronic board type wherein consignors and carriers freely input cargo information, transport requirements, truck information, and available time. After checking with the condition, the intentional consignor and carrier negotiate and develop a contract. In a mobile Internet environment, the mode to match cargos and

Table 4 A summary of case examples' background

NO. of case	Road freight apps	Financing amount	No. of registered drivers	No. of coverage area
Case 1	1HHD.com	Several million CNY	50,000	10 cities
Case 2	Loji.com	8.6 billion CNY	1.3 million	41 service stations
Case 3	Lanxiniu.com	200 million CNY	10,000	12 cities
Case 4	Yihaohuoche.com	Several billion CNY	20,000	16cities
Case 5	Huolala.cn	137 million CNY	50,000	12 cities
Case 6	56xiaomi.com	68 million CNY	80,000	6 cities
Case 7	Ymm56.com	Several billion CNY	3.5 million	200 cities

CNY Chinese Yuan. All data based on the year of 2015

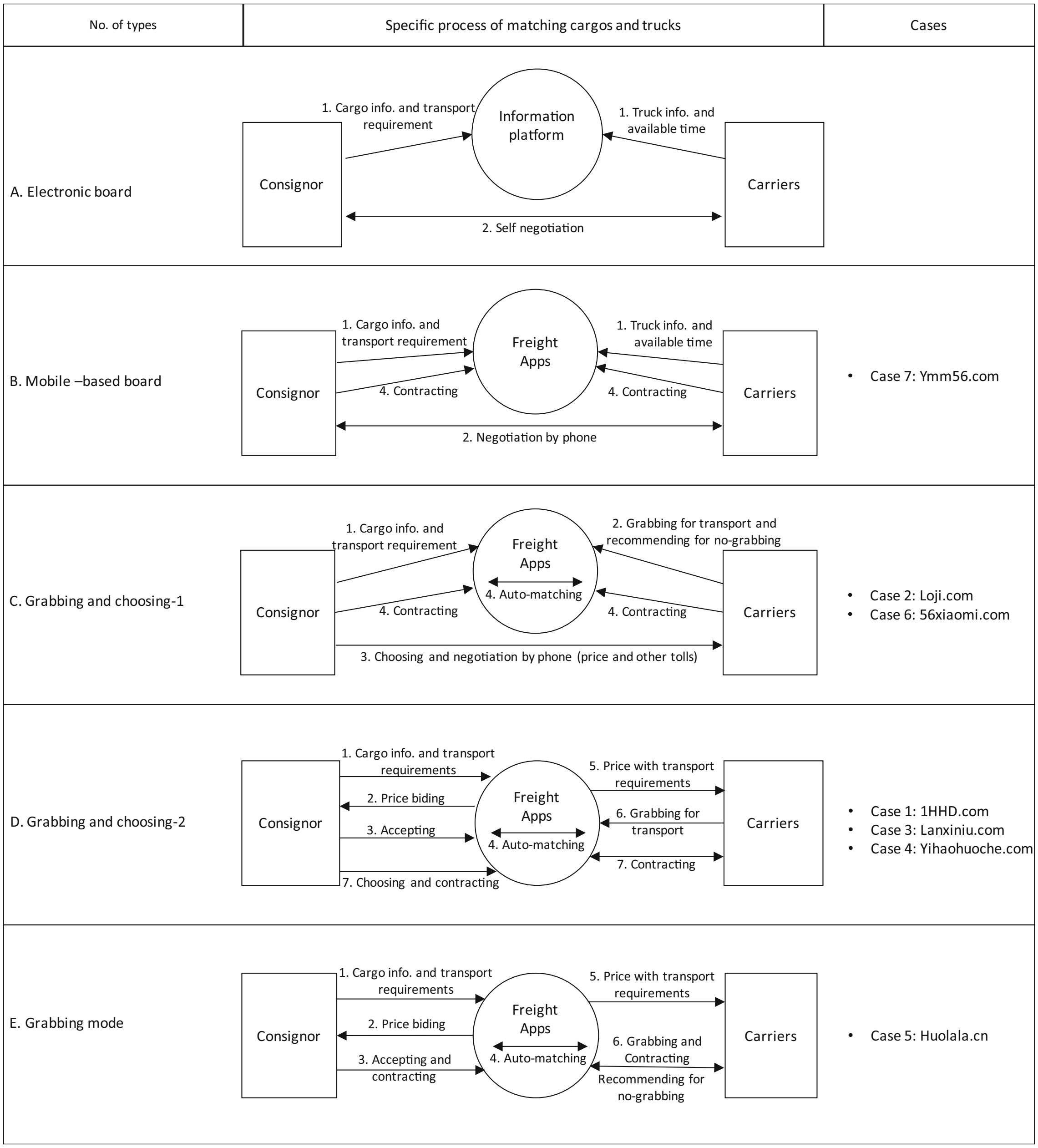


Fig. 2 Mode types to match cargos and trucks

trucks has been transformed to types B-F (Fig. 2). In this situation, most companies develop two apps for different users, including a shippers' version and a drivers' version. The UI (user interface) design and function of road freight apps are similar. With cases 1, 3, 4, and 5, the interaction of drivers and consignors is realized through a real-time map with a GPS location system, and the remaining cases are in the form of a list. When the consignor needs a freight service, a series of information, including the receiving address, delivery time, truck requirements and additional conditions, will be filled. Only the drivers meeting the criteria can receive the order. In case 7 of type B, the drivers can also take the initiative to release the empty truck message and wait for shippers. The rule of "first come, first served" is determined when the information is pushed to eligible stakeholders. The place of receipt is quickly located, and the consignor also has the right to choose a carrier's suitability according to historical orders and credit evaluation in cases 1, 2, 3, 4, and 6. The freight apps also provide fully real-time navigation and route planning guidance, and this is very important for environmental sustainability in the urban Less-than-Truck Load (LTL), which will be discussed further in the following section. If there is no driver to grab the shippers' order, the technology provider of apps would dispatch to the truck in cases 2, 5 and 6. The actual process of loading and unloading is often completed by mobile phone in case 7. Full cycles of circulation for goods are recorded and the consumer can also give an estimate after the order is completed. Apps also provide the reference price according to past statistical data from the completed order to somewhat prevent crazy quotes in markets. The efficient way to find the right truck and complete the delivery process enhances the improvement of efficiency and information symmetry of the freight industry.

4 Framework to evaluate the impacts of freight apps for CO_2 reduction

4.1 Mobile-internet-based freight movement system

Before we analyze the impact of freight apps on the freight movement system, the four major stakeholders shown in Fig. 3 are introduced. The consignors who send cargos and the consignees who receive cargos hope that the cargos reach the intended destination within a pre-defined time window. The common aim is to achieve the most convenient business operation by decreasing the opportunity cost, simplifying the business operation and reducing loss and damage. The consignor and consignee are often the same person. In China, most carriers belong to small or medium-sized companies. The carriers try to minimize the total cost (order cost, transaction cost, transport cost, management cost, etc.) while satisfying the transport requirements. The government has the responsibility to minimize social cost in the mobile-internet environment by providing freight infrastructure and implementing effective policies.

Freight apps may influence the multiple links in the freight movement system. The directions should be concerned in Fig. 4 when assessing the impact of a freight app on the movement system. The freight apps make it possible to re-integrate fragmented supply and demand (Cr2Cr and Ca2Ca in Fig. 4) in a wider time and space (App-integrating). The apps change the Cr2Ca and Ca2Cr (Fig. 4) interaction processes using an innovative communication method between demands and supply such that loosely scattered freight demand is integrated (App-matching). A more efficient organization of freight apps-based transactions contributes to strengthening stakeholders by enabling easier communication with a larger number of suppliers, which is neither the consignor nor the consignee. The apps also make delivery & collection operations more efficient and environmentally sustainable by optimizing routes based on a series of demand points, full use of unloading space and real-time traffic information (App-routing).

4.2 Freight movement system influenced by apps for CO_2 reduction

The availability and summary of case study analysis to perform a full analysis of freight apps for CO_2 reduction with the framework presented in Fig. 5 are associated with the ones Nemoto [43] and Liimatainen et al. [50] used. The framework had to be modified because of differences both in the subject investigated and in the usefulness of the terminology. Overall, the framework consists of eight aggregates, seven indicators, several determinants and one key indicator, with the core consist of two types of factors (Route planning of delivery & collection in urban Less-than-Truck Load and Return pick-up in Full Truck Load).

In the right part of the framework (Fig. 5), the structure diagram of processes responsible for the generation of CO_2 emissions tells us that the links are related to the operations of the freight movement system. The modal split influences the CO_2 intensity because it results in the total level of road transport (tons). The modal split is not discussed further in this paper. The amount of road (ton-kilometers) is affected by the level of cargos transported on roads and the length of trips. At the same time, road ton-kilometers are converted to kilometers

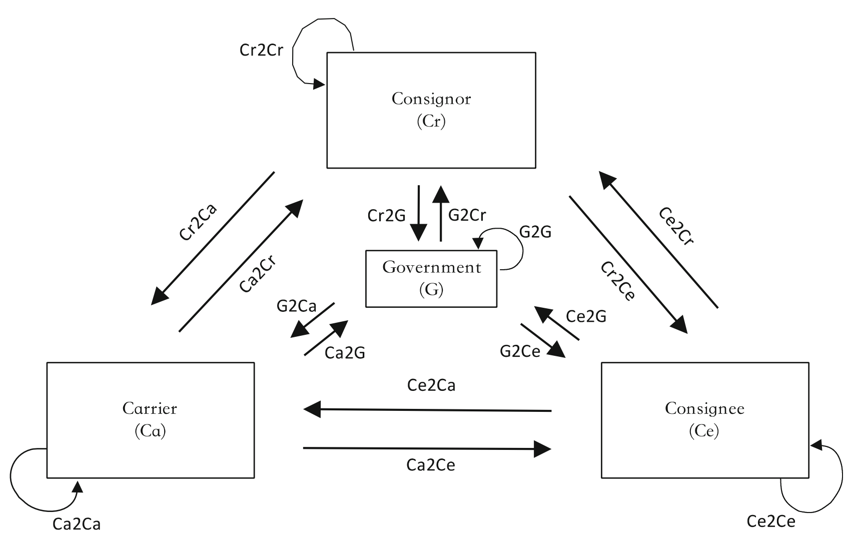


Fig. 3 Stakeholders in the freight movement system. **Cr: Consignor, Ca: Carrier, Ce: Consignee*

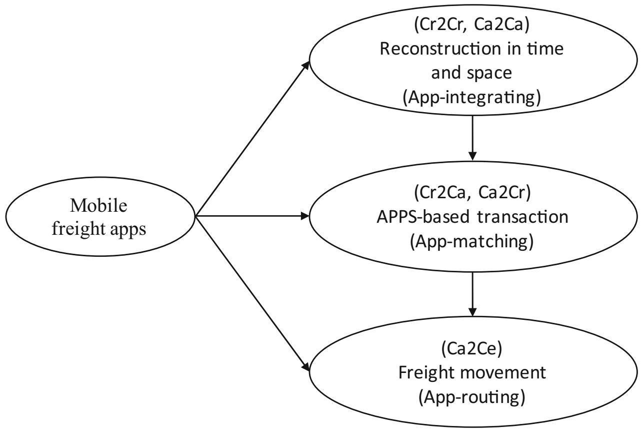


Fig. 4 Freight apps and freight movement system

by dividing them by the average load on laden trips. The larger the average loads are, the fewer vehicles and vehicle-kilometers are needed for transport. For the volume limit of cargos and the delivery and collection frequency, the trucks rarely have full loads. Empty running should be used to calculate the total vehicle-kilometers of trucks, as the most important factor of the freight's high emissions may be returning empty in long-distance trips in China. Finally, to calculate the total CO_2 emission of road freight transport from the total energy consumption, the amount of vehicle-kilometers is divided by the average vehicle energy consumption.

The framework also presented factors that affecting CO_2 emissions in road freight transport, which were summarized in literature review section. Several factors were separately considered in framework's entity block diagram when our study concentrate on the means of freight apps for carbon reduction in road freight transport. Suitable value of payload, empty kilometers and fleet mix were considered to be the most optimized by freight apps.

The use of freight apps for CO_2 emissions focuses on reconstructing the demand and supply with integration technology, which results in a more efficient transaction using matching technology and advanced fleet management with optimization technology. When considering the impact of existing apps for CO_2 reduction, it is notable that the target of connecting cargos and trucks focuses on different aspects between "inter-urban Full Truck Load (FTL)" and the "urban Less-than-Truck Load (LTL)". Less than load is the transportation of relatively small freight, and refers to the weight or volume of the cargo is not sufficient for a full truck. Full Truck Load refers to the weight of cargo that is more than 3 tons, or less than 3 tons, but its character, volume, shape requires a road freight transport of more than 3 tons.

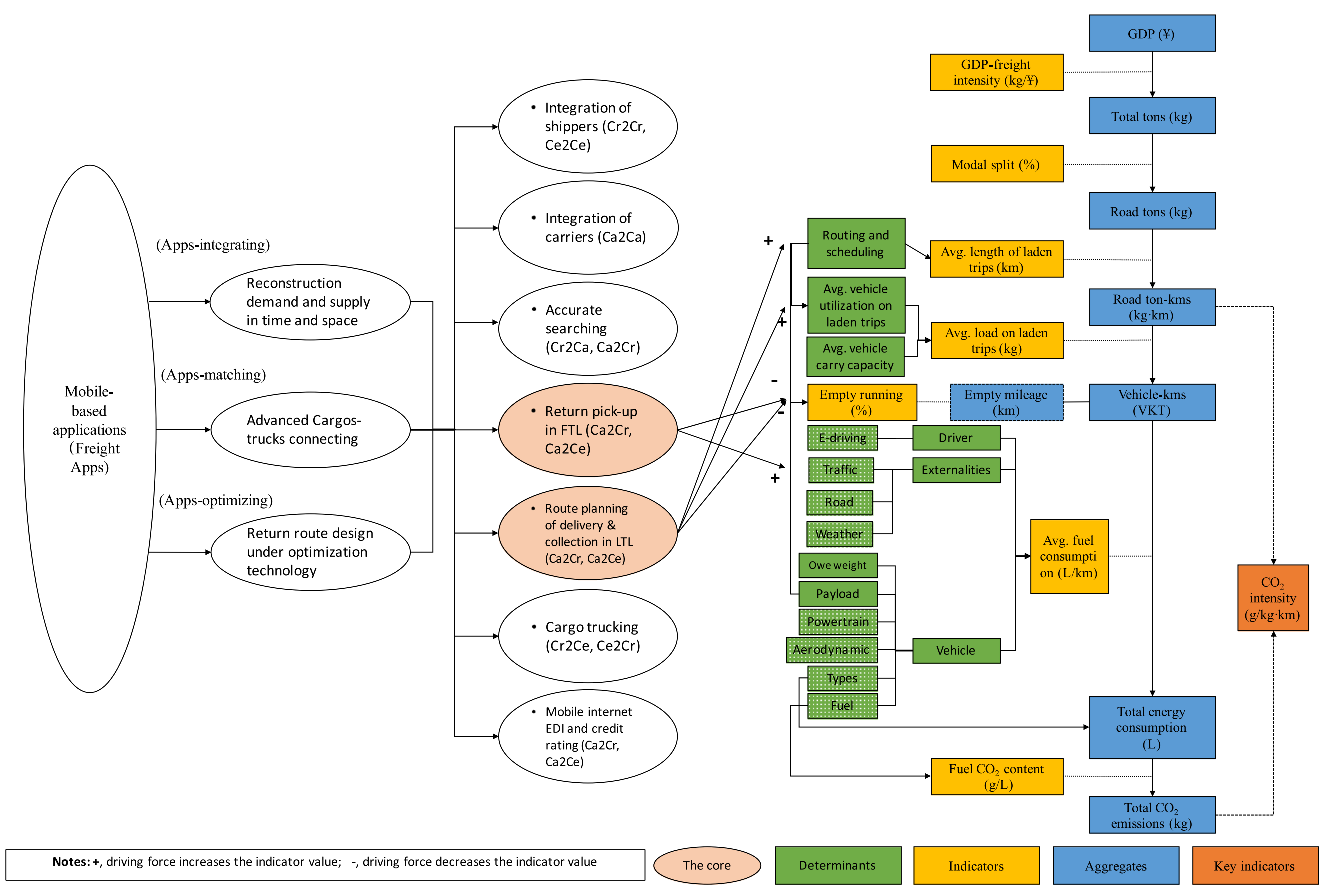


Fig. 5 Framework for analyzing freight apps for CO_2 reduction. Source: Modified from [43, 50]

When matching cargos and trucks with inter-urban FTL, carriers have a strong incentive to acquire a business opportunity of cargo information. To prevent their trucks from returning without any backhaul, the appeal of an apps' matching function is fully confirmed. The freight apps enable them to search for demand in a short period of time. This is also the key determinant (Fig. 5) for returning a pick-up with decreasing empty running mileages, which then has environmental benefits through reducing CO_2 emissions. However, when in urban LTL, the function of real-time navigation and route planning guidance plays a more important role in accommodating inter- and intra-organizational communications at a network level. By strengthening the average vehicle utilization on laden trips, another determinant (Fig. 5) of route planning of delivery & collection that not only enjoys a higher economy of scale benefits, but also reduces the energy consumption and CO_2 emission of the entire organization network. Because these are the levels of improvement, attention has been paid to the promotable efficiency strengthening and environmental savings to the use of freight apps in case studies. It is intuitive to suggest that this research's contributions are the identification of freight apps as a beneficial tool, which could help realize the reduction of CO_2 emissions in the Chinese freight organization with further development. These developments are discussed further in next section.

5 The main aspects for further development

Given the lack of prospective observations in road transport, it is practical to determine what driving factors may be available to improve freight apps at the level of returning for pick-up and route planning. We envisage that exploring reconstruction and matching between supply and demand could lead to further reductions in CO_2 emissions through the mechanisms described in this section.

5.1 Returning pick-up in FTL

In inter-urban Full Truck Load of long-distance transport, the carriers often have no scheduled cargos for their return trip (Fig. 6a). By using the freight apps' truck-cargo matching system, carriers could schedule an order to guarantee the return pick-up at an appointed time (Fig. 6b) or grab several orders to achieve a larger non-empty return trip (Fig. 6c). The matching conditions should include, in addition to the trip's origin and destination, the time to load and the type of vehicle. As a result, the implementation of a "point-to-point" scheme requires a certain number of potential consigners who require the same conditions to join the freight apps before auto-matching is attained. Inspired by the scenarios of backhaul improvement, when the social capital focuses on the promotion of matching mode innovation in China, consideration should be given to the carriers' search and waiting

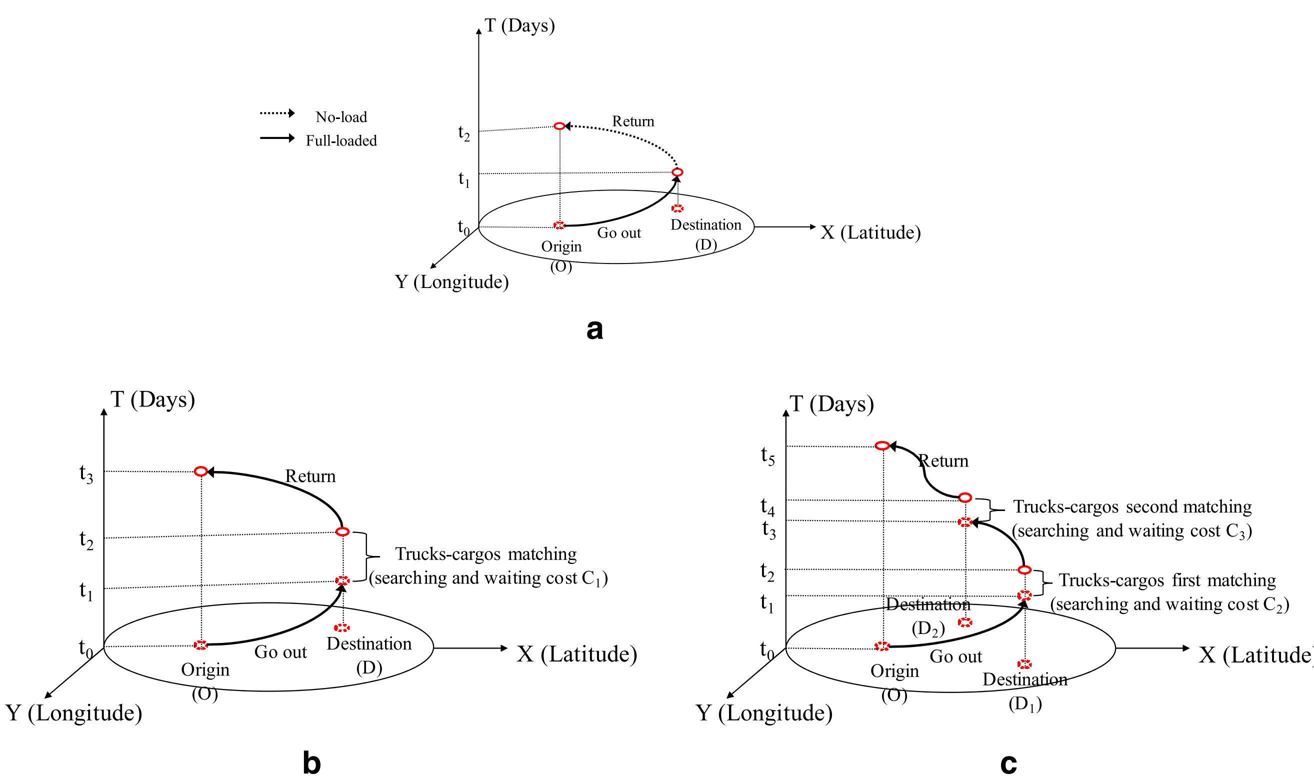


Fig. 6 Scenarios of backhaul improvement. Source: Modified from 51

costs (C_1, C_2 and C_3 in Fig. 6) before starting the next freight service. A potential solution for enhancing the frequency of usage would be strengthening the value of searching as well as changing the waiting cost and behavioral acceptance mode of the truck-cargo matching system.

5.2 Route planning of delivery & collection in LTL

Route planning of delivery & collection based on real-time traffic information seems to be the most complicated and dynamic process, especially as multiple drops and pick-ups are integrated into one round trip (Fig. 7). Improvement of the embedded route planning in freight apps, based on navigation and push-guidance, can cause the truck-cargo stowage to reach a reasonable volume, weight and loading sequence of demand points, and there is stowage area for more trucks that are the fully loaded, which can reduce the number of trucks out in the parking lot. The realization of the optimization technology for route planning increases the demand on sharing high levels of data with a reasonable delivery time for the requested information, including the details of the delivery, real-time traffic, and real-world events, which are necessary for conducting efficient "always-laden" transport plans in response to the increase in the average vehicle utilization for CO_2 reduction.

5.3 Risks in further development

So far, because of extensive subsidies from finance, freight apps are widely used in China's market. In the long-term sustainable development, we need to pay more attention to demands of users. Transport behavior change of shippers and drivers to apps need continuous intervention for long time in order to get significant efficacy. So, in the condition of the gradual disappearance of subsidies, how to ensure sufficient number of users, which is a prerequisite for cargo-truck matching, should be considered. Another concern is whether the use of apps is charged. The company that exploited apps gets profit from use charge or a percentage of each order. Technically, much emphasis of freight apps' function is placed on cargo-truck matching mechanism. Implementation of freight movement practice in offline world only through mutual estimation is also need to be investigated. These risks need to be addressed and finally accepted by the user.

6 Conclusion

While the intent to implement environmentally friendly and sustainable processes continues to grow, the contribution that road transport makes to the nation's carbon footprint and the potential for their reduction through the use of freight apps have not been investigated in depth, and its impact is largely unclear. Seven leading freight apps in the Chinese market underwent a full analysis, and a clear conceptual framework was developed to provide an overarching view into how existing apps accomplish environmental benefits, thus deepening our understanding of the potential role freight apps could play in reducing CO_2 emissions. Then our research identified improvement at the level of returning pick-up and route planning to accomplish carbon emissions benefits.

We find that freight apps provide a mechanism that automatch the consignor's demand and the carrier's supply based on mobile internet. The efficient way to find the right truck and complete the delivery process enhances the improvement of efficiency and information symmetry of the freight industry. The influences to freight movement system by apps have

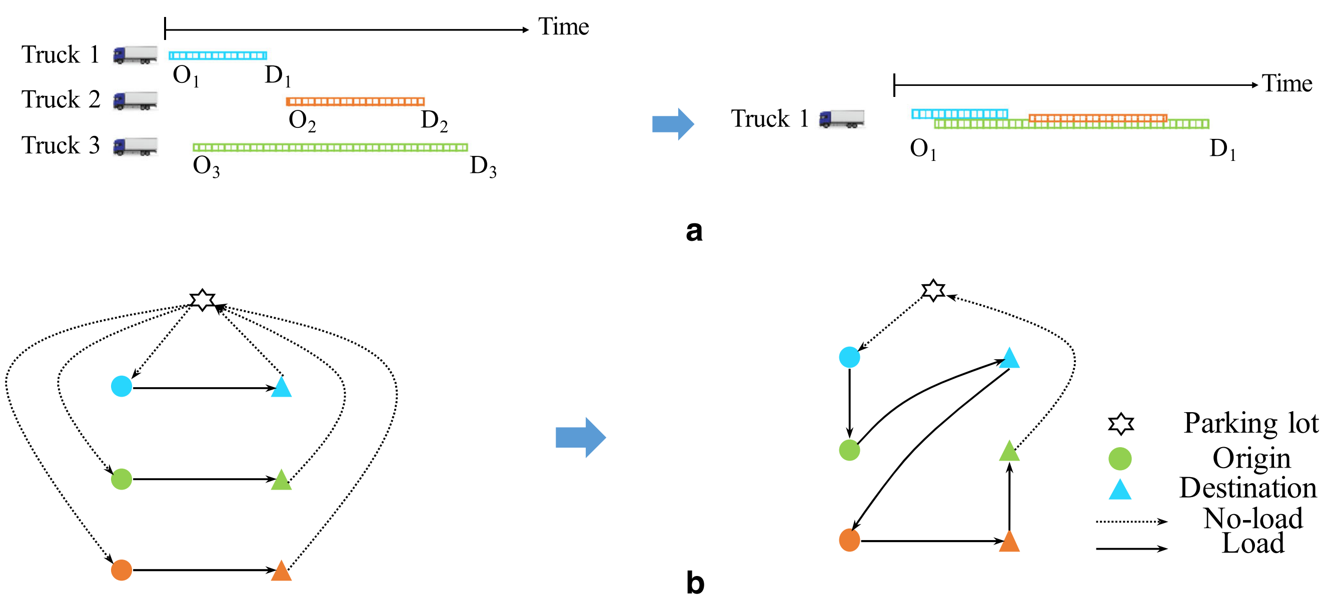


Fig. 7 Optimization technology of route planning for delivery &collection

three principally aspects: re-integrate fragmented supply and demand in a wider time and space; an innovative communication method to match cargos and trucks; delivery & collection operations more efficient and environmentally sustainable by optimizing routes based on a series of demand points, full use of unloading space and real-time traffic information.

The framework clearly presented the use of freight apps for CO_2 reduction, which focused on reconstructing the demand and supply with integration technology, and resulted in a more efficient transaction using matching technology and advanced fleet management with optimization technology. Factors of payload, empty kilometers and fleet mix were separately considered when concentrating on the means of freight apps for carbon reduction. We talked about the target of connecting cargos and trucks focuses on different aspects between "inter-urban Full Truck Load" and the "urban Less-than-Truck Load". When with inter-urban FTL, freight apps enable carriers to search for demand for returning a pick-up with decreasing empty running mileages, which then has environmental benefits through reducing CO_2 emissions. However, when in urban LTL, by strengthening the average vehicle utilization on laden trips, another determinant of route planning of delivery & collection that not only enjoys a higher economy of scale benefits, but also reduces the energy consumption and CO_2 emission of the entire organization network.

In order to further promote development of apps, in inter-urban Full Truck Load of long-distance transport, sufficient number of users and suitable matching conditions ensured carriers schedule an order to guarantee the return pick-up at an appointed time or grab several orders to achieve a larger non-empty return trip. In this "always-laden" transport plan, consideration should be given to the carriers' search and waiting costs before starting the next freight service. Meanwhile, route planning of delivery & collection based on real-time traffic information in LTL required sharing high-level of data, complicated-adaptable models and the efficient computing power. These valuable aspects would be a great challenge for follow-up development of freight apps in aiding CO_2 emission reduction.

In terms of future work, we will attempt to utilize the historical e-waybill data and trajectory data to conduct a quantitative benefit analysis of the fraying truck-cargo that matches the system. We also aim to improve the sophisticated scheduling technique based on freight apps, which we think would really help to support environmental sustainability and CO_2 reduction.

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Compliance with ethical standards

Competing financial interests The authors declare no competing financial interests.

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