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A decision support system for public logistics information service management and optimization

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ABSTRACT

Transportation optimization usually aims at minimizing the empty load ratios (ELRs) of vehicles. Most Chinese vehicles for logistics are owned by individual entrepreneurs. Because China is very large, transport distances are typically long, and thus the ELR is very high. The ELR is the primary reason for high transport costs, considerable pollution, and high energy consumption. Many Chinese local governments try to build public transport information services that decrease the ELR. This work proposes a decision support system (DSS) for public logistics information service management and optimization (PLISMO) for vehicle drivers and owners, logistics customers and related logistics service providers and management institutes. The dynamic and real-time matching model between goods and vehicles, and the enabling technologies are important issues for the DSS for PLISMO. Therefore, intelligent positioning technologies are employed to acquire and manage the vehicle status. A model matching vehicles with goods is developed based on an assessment model of transport capability and service priority criteria. A multi-objective real-time scheduling model is devised to minimize the ELR. Based on the concepts and decision-making models for PLISMO, a DSS is created and the architecture of the system is investigated. The effectiveness of the DSS and decision-making models is demonstrated by a case of finished vehicle logistics (FVL). Analytical results show that the proposed DSS can reduce the ELR and logistics cost. This system helps governments construct DSSs for general PLISMO.

1. Introduction

The Chinese economy has been transformed from a planned economy into a market economy. In the planned economy, door-to-door transport was common, and the supplies of goods were planned. Moreover, transport capability was short, such that logistics resources (e.g., vehicles) were utilized fully. After reforms, transport restrictions by the government were eliminated. At this time, China's automobile industry and its entire domestic economy began developing rapidly. Therefore, logistics requirements gradually increased, and transport capacity was challenged.

In the last ten years especially, while China's economy has boomed, logistics resources owned by companies or individuals have been abundant. However, due to the unbalanced distribution of logistics demands in China and the asymmetry of information, logistics resources and their capacity are not fully utilized. The empty load ratio (ELR) is high, such that transport resources are wasted and the environment is polluted. The ELR is the ratio of mileage without load to total mileage in the context of a full or less-than-full truck load. The ELR commonly measures the efficiency of a route and waste. According to statistics, the ELR in China was low during the planned economy, and was high, almost reaching 50%, during the market economy; with the evolution of logistics requirements, transport capacity, and information technology, the ELR is dropping to roughly 40%. Notably, different vehicle types may have different ELRs (e.g. taxis have lower ELRs than trucks) and different areas with unbalanced logistics requirements and transport capacities have different ELRs. In China, as an economic indicator and environmental indicator, the ELR can be further minimized.

According to the report "The development of highway and waterway transportation industry: Statistical bulletin for 2012" (economic data are primarily from bulletins released by China's Ministry of Transport on the website http://www.moc.gov.cn) released by China's Ministry of Communications, by the end of 2012, China had built 4.2395 million km of road, an increase of 131.1 thousand km from 2011; the number of vehicles was 1339.89 million, an increase of 6.0% from 2011; road freight transport was 31.885 billion tons of goods, an increase of 13.1% from 2011, and turnover of goods was 5.953486 trillion tons km, an increase of 15.9% from 2011; average transport distance was 186.72 km; and investment in road construction was 1.451249 trillion Yuan, an annual increase of 0.3%. These statistics show that road transport has an important role in rapid development; second, the volume of goods and turnover rate is so large that there is ample room for optimization.

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The architecture of a decision support system (DSS) for public logistics information service management and optimization (PLISMO) and its decision-making models for vehicle drivers and owners, logistics customers and service providers, and related management institutes are proposed to reduce the ELR and improve the match degree between vehicles and demands. Strategies, models, algorithms, and system architecture are designed. This work mainly contributes to the architecture of the PLISMO and its organizational mechanisms, the service matching model for vehicles and demands, the real-time scheduling model that predicts travel and minimizes the ELR, and the design of the prototype system for the PLISMO. Finally, the models and algorithms are verified by a case of finished vehicle logistics (FVL).

The remainder of this paper is organized as follows. Section 2 presents a literature review on public logistics service information system and routing problems with consideration of minimizing ELR. Section 3 describes the current situations in China. In Section 4, the DSS and models are developed. Section 5 elucidates a demonstrative case of FVL. Finally, the paper is concluded and directions for future research are given.

2. Literature review

(1) Public logistics service information system

Public logistics service information system (PLSIS) is generally used to share transport resources among customers and carriers. Hang [1] implemented a taxi calling system based on intelligent mobile terminal, by which passengers and taxi drivers can exchange information anytime. This system analyzes the randomly appeared personalized passenger transport demand and timely transfers it to the appropriate service provider, so as to fully use the existing taxi service. Taniguchi et al. [2] developed a persuasive communication program that provides public-transport-oriented choice for students. By a PLSIS, arrival information can be shared timely among customers and service providers related to logistics. Rahman et al. [3] noted that actual bus arrival times often deviated from the posted schedules due to a variety of factors; hence, providing real-time bus information can improve service quality.

Logistics systems can be assessed and optimized by integrating their PLSISs. The operational performance of public transport networks is an important aspect of urban planning and development. Mesbah et al. [4] explored the operational performance of public road transport using spatial and historical analysis at a network-wide level. The results help to find solutions for improving the public transport system. Tang and Thakuriah [5] investigated the effects of real-time bus information system on ridership. To take account of other factors that might affect bus ridership, they used data on unemployment levels, gas prices, local weather conditions, transit service attributes, and socioeconomic characteristics in the proposed method. De Borger and Fosgerau [6] studied the interaction between pricing, frequency of service and information provision by public transport firms offering scheduled services under various regulatory regimes. Cheng [7] noted that more and more passengers using public transport system plan their trips by using PLSISs which are provided as website services. Farag and Lyons [8] noted that investments in and growing availability of various services provided by PLSISs make them popular. Policymakers and information service providers could benefit from a well understanding of factors affecting information use. Moreover, their study provided insights into the use of the PLSISs by applying attitude theory. Tibaut et al. [9] examined the interoperability of passenger information systems in Europe, and asserted that local information systems of public transport service providers should be interoperable with a nation's passenger information system.

Many PLSISs utilize data and function of intelligent transport systems. Jakubauskas [10] applied intelligent transport systems and services to create a multimodal public transport system aimed at improving its efficiency. Lei and Church [11] defined an extended GIS data structure to handle temporal elements of transit service, and developed a framework for supporting transit service analysis and planning.

Developments are already underway for the integration of information systems across different public transport modals and between PLSISs covering different regions. An integrated information service has a great potential to inform and influence travel choices. Lyons [12] considered the prospect of providing travelers with multimodal information that integrates the driver information with public transport service information. PLSIS is a way to coordinate and integrate different transport modals. The European Commission launched a consultation on the 'Development of Integrated Ticketing for Air and Rail Transport', in 2008, with the objective of examining the organizational and technical opportunities related to the introduction of integrated ticketing as an important factor to generate demand for intermodal air–rail services. Amsler [13] proposed solutions for integrated ticketing for air and rail transport that coordinate with urban public transport.

Many public information systems are developed for supplier selection [14], investment [15], trading [16], field service scheduling [17], and disaster management [18]. These systems are not focused by this work.

(2) Routing problems with consideration of minimizing ELR

With the increasing availability of real-time information and communication systems in logistics, the need for appropriate planning algorithms arises. Customers in transport markets increasingly expect quicker and more flexible fulfillment of their orders, especially in the electronic marketplace. Fleischmann et al. [19] considered a dynamic routing system that dispatches a fleet of vehicles according to customer orders arriving at random during the planning period by using dynamic travel time information. Routing in a stochastic and dynamic (time-dependent) network is a crucial transportation problem. With the utilization of perfect online information of continuous real-time link travel time, Ardakani and Sun [20] proposed a new variant of adaptive routing problem, and developed an adaptive approach to tackle the continuous dynamic shortest path problem. Boriboonsomsin et al. [21] presented an eco-routing navigation system that determines the most eco-friendly route between a trip origin and a destination by using advanced traveler information systems. Mendoza et al. [22] developed a DSS that integrates commercial systems with a distance-constrained routing module. Suzuki [23] developed a DSS that helps motor carriers route vehicles. These vehicles visit all customers in time (without violating time-windows), and utilize the cheapest gas stations (cheapest truck stops in a region) as refueling points during a tour. Pillac et al. [24] designed an event-driven framework that anticipates unknown changes in a dynamic VRP.

ELR, empty trip, and empty movement are usually considered in optimizing vehicle routing solutions, and their effects on logistics are analyzed in literature. Empty vehicle traffic plays a critical role in the operating performance of vehicle systems [25]. Utilizing an empty backhaul vehicle on its way back to its domicile after a normal delivery trip has attracted many logistics carriers and third party logistics companies [26]. Johnson [27] presented analytical models to predict empty vehicle travel distance under popular vehicle dispatching rules for systems facing stochastic trip demands. Holguín-Veras and Thorson [28] developed new mathematical formulations that depicted the flow of empty commercial vehicles as a function of a given matrix of commodity flows based on probability principles and spatial interaction