Performance Analysis of Road-Rail Intermodal Transport: A Case Study in Southern China

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Intermodal transportation is a shipping method utilizing a combination of two or more different shipping modes to offer many advantages over traditional truckload freight, including lower cost, environmental friendliness, and high efficiency, that may have immense potential in China. When using road-rail intermodal transportation, truckload freight in containers or carriers are used for the origin pick-up and destination delivery to and from the railway terminals, while the railway is utilized for the long-haul portion. Based on the transportation setting in a largest private shipping company in China, this study evaluates the operational value and managerial concerns when assessing the implementation of road-rail intermodal transport in Southern China. A quantitative analysis on operational benefit shows 49.7% cost saving and 56.3% reduction of CO_2 emissions. A qualitative analysis leads to an assessment framework that helps understand the evaluation process of a private logistics company in China when adopting road-rail intermodal transport.

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I. INTRODUCTION

Intermodal transport involves the transportation of freight in an intermodal container or vehicle, using multiple modes of transportation (e.g., rail, truck, and ship), with container or carrier swapping to simplify freight handling when changing modes (Caris, Macharis, and Janssens, 2008) and (OECD, 2002). Intermodal freight transport has received increased attention due to problems of high shipping costs, road congestion, air pollution, and global warming concerns (Konings, Priemus and Nijkamp, 2008). A growing recognition of the strategic importance of speed and agility in logistic services is forcing firms to reconsider traditional freight shipping approaches that heavily rely on trucking transport (Morlok, Sammon, Spasovic, and Nozick, 1995). As a consequence, research interest in intermodal freight transportation issues is growing.

From an economic perspective, a cost benefit over road trucking is the key benefit for road-rail intermodal transport use (Stull, 2008). By reducing the trucking distance, intermodal transport may also reduce insurance costs due to high accident rates on roadways, and thereby reduce damages and loss. In highly populated areas, such as Southern China, intermodal transport may effectively avoid highway congestion and further reduce the carbon footprint. In addition, China's relocation of manufacturing to the inland provinces and the growth of domestic consumption pose challenges for logistics. Transportation distances increase, while the highways become increasingly congested. Seeking a solution, the Chinese government and logistics companies have identified that road-rail intermodal, or domestic container logistics, is one of the ways to address these challenges (Cole, 2008).

We use the shipping information and routing plans obtained from S.F. (Shun-Feng) Express in this study. Founded in 1993 and based in Shenzhen China, S.F. Express is China's largest private logistics firm and provides logistics distribution and domestic/international express service solutions in China and East Asia and reaches revenues of USD 3.5 billion in 2014. In this case study, Guangdong province and Hubei province in Southern China are chosen. In 2014, the GDPs of Guangdong province and Hubei province were 1.1 trillion (similar to the GDP of Mexico) and 0.45 trillion (similar to the GDP of Norway), respectively. In each province, one capital city and 5 satellite cities are included in our study. The population of the two capital cities, Guangzhou city in Guangdong province and Wuhan city in Hubei province, are both around 11 million people. The average population of each of the 5 satellite cities in Guangdong province and the 5 satellite cities in Hubei province is around 2 million people.

Following the framework of the case study method discussed in (Ellram 1996) and (Eisenhard 1989), we want to explore the answer to two correlated research questions that represent a logistics company's operational and non-operational considerations when assessing the implementation of road-rail intermodal transportation: "For a logistics company in China, what are the operational benefits to adopt road-rail intermodal transportation?" and "Given the operational benefits, what are the non-operational considerations of a logistics company in China when evaluating roar-rail intermodal transportation?" Hendric and Ellram (1993) stated that empirical data collected from a case study can be applied to a mixture of quantitative analysis and qualitative analysis. In this study, we use quantitative data to evaluate the operational benefits in numerical and quantifiable terms. To analyze the non-operational concerns, we use qualitative data extracted from interviews with senior managers in S.F. Express to create an understanding of relationships or interactions during the assessment of implementing road-rail intermodal transport for a private logistics company in China.

With one single sample in this case study, this research is largely exploratory and explanatory in nature. The purpose of this research is to put forward a set of evaluations on both operational value and non-operational considerations of adopting intermodal transport in China. The paper is organized as follows. A base model of operational cost and CO_2 emissions using existing truck transportation is analyzed in Section II to compare side-by-side with the results of road-rail intermodal scenarios proposed in Section III. In addition to the comparison of operational cost analysis, Section IV identifies and analyzed the non-operational factors when assessing the feasibility to implement road-rail intermodal transport in a private logistics company in China. Conclusions and directions of future research are addressed in Section V.

II. BASE MODEL: TRADITIONAL TRUCK TRANSPORTATION

Before applying intermodal transport, S.F. Express transports freight from cities in Hubei province to cities in Guangdong province solely by truck. In the following analysis, the Hubei province is denoted as X. The indexes for cities in Hubei province are: x_0 for the capital city Wuhan, and x_1, x_2…, x_5 for the 5 satellite cities surrounding Wuhan city in Hubei province. Similarly, the Guangdong province is denoted as Y. The indexes for cities in Guangdong province are: y_0 for the capital city Guangzhou, and y_1, y_2…, y_5 for the 5 satellite cities surrounding Guangzhou city in Guangdong province.

2.1. Shipping from Cities in Hubei Province to Cities in Guangdong Province

Current routing practices in S.F. Express are described in Fig. 1. In each city of Hubei province, S.F. Express collects all freight bound for Guangdong province, regardless of the destination city, then dispatches trucks directly from each city in Hubei province to the capital city Guangzhou, which serves as its distribution hub in Guangdong province. The S.F. Express station in Guangzhou city then sorts the inbound freight from all cities in Hubei province and reloads on trucks before delivering to each destination city in Guangdong province. Fig. 2 describes the enlarged routing map from Guangzhou city station to the surrounding 5 satellite cities.

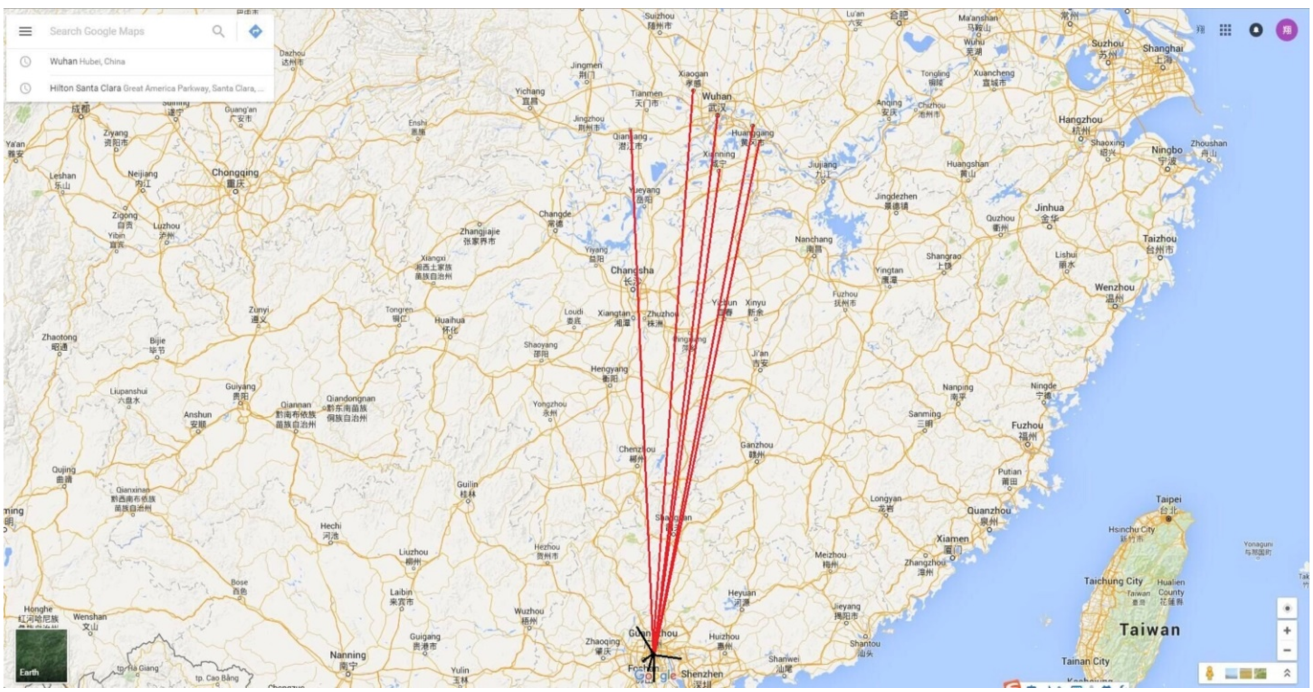

FIGURE 1. ROUTING FROM CITIES IN HUBEI TO CITIES IN GUANGDONG.

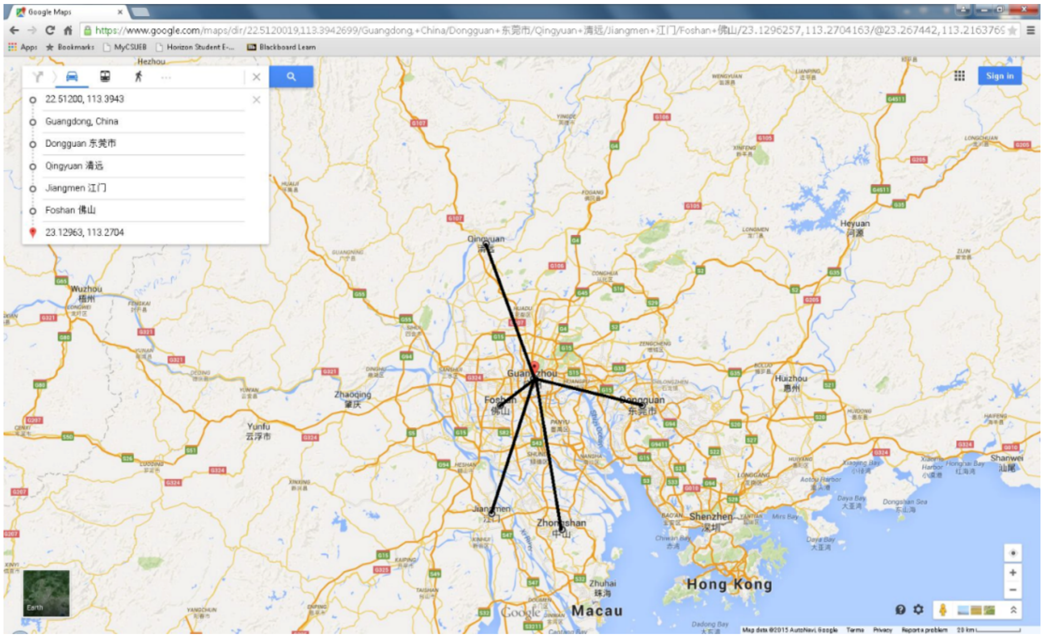

FIGURE 2. ENLARGED ROUTING FROM GUANGZHOU CITY TO SATELLITE CITIES.

TABLE 1. DISTANCES BETWEEN CITIES IN HUBEI AND GUANGZHOU CITY.

(In km-Hwy)	Wuhan x_0	Huangshi x_1	Qianjiang x_2	Xianning x_3	Xiaogan x_4	Huanggang x_5
Guangzhou y_0	1020	990	967	946	1068	1004

TABLE 2. DISTANCES BETWEEN GUANGZHOU CITY AND ITS SATELLITE CITIES.

(In km-Hwy)	Guangzhou y_0	Dongguan y_1	Zhongshan y_2	Qingyuan y_3	Foshan y_4	Jiangmen y_5
Guangzhou y_0	0	67	87	78	34	93

In general, the benchmark where road-rail intermodal starts to be competitive against road-only transport is at approximately 1000 kilometers. For road ramps that connect railway terminals, the typical distance is about 150 kilometers or less. Table 1 summarizes the distances $S(x_i, y_0)$ in km-highway between each city x_i in Hubei province and Guangzhou city y_0. The distances $S(y_0, y_j)$ between Guangzhou city y_0 and each of its satellite city y_j are shown in Table 2.

Table 3 shows the weekly freight weight, indicated as $W(x_i, y_j)$ in tons, from each city x_i of Hubei province to each city y_j of Guangdong province. Typical load weight of road-rail intermodal container or carrier is designed at 20 tons capacity, which is mainly limited by trucking capacity and highway regulations. Please note that the numbers are disguised and simplified for confidentiality. To describe the current routing practice in S.F. Express, we calculate the weekly freight weight $W(x_i, Y)$ as the total amount of weekly shipping from each Hubei city x_i to Guangdong province Y that is consolidated in Guangzhou city, where

$$W(x_i, Y) = \sum_{j=0}^{5} W(x_i, y_j). \quad (1)$$

Similarly, the weekly freight weight $W(X, y_j)$ in tons is the weekly shipping demand from Hubei province X, which is consolidated in Guangzhou city then delivered to each Guangdong province city y_j.

$$W(X, y_j) = \sum_{i=0}^{5} W(x_i, y_j) \quad (2)$$

Although the freight information in Table 3 is disguised and simplified, the overall delivery frequency is aligned with current S.F. Express operations, in which about 50 trucks (in 20-ton load) are dispatched from Wuhan city to Guangzhou city, and about 10 trucks weekly from each satellite city x_i to Guangzhou city. Out of 50 trucks (1,000 tons) from Wuhan to Guangzhou, approximately 25 trucks (500 tons) stay in Guangzhou, and 5 trucks (100 tons) head to each of the five satellite cities of Guangzhou. Similarly, out of 10 trucks from each satellite city of Wuhan to Guangzhou, 5 trucks stay in Guangzhou, and 1 truck (20 tons) heads to each of the five satellite cites of Guangzhou.

TABLE 3. WEEKLY FREIGHT WEIGHT FROM CITIES IN HUBEI TO CITIES IN GUANGDONG.

(In tons)	Guangzhou y_0	Dongguan y_1	Zhongshan y_2	Qingyuan y_3	Foshan y_4	Jiangmen y_5
Wuhan x_0	500	100	100	100	100	100
Huangshi x_1	100	20	20	20	20	20
Qianjiang x_2	100	20	20	20	20	20
Xianning x_3	100	20	20	20	20	20
Xiaogan x_4	100	20	20	20	20	20
Huanggang x_5	100	20	20	20	20	20

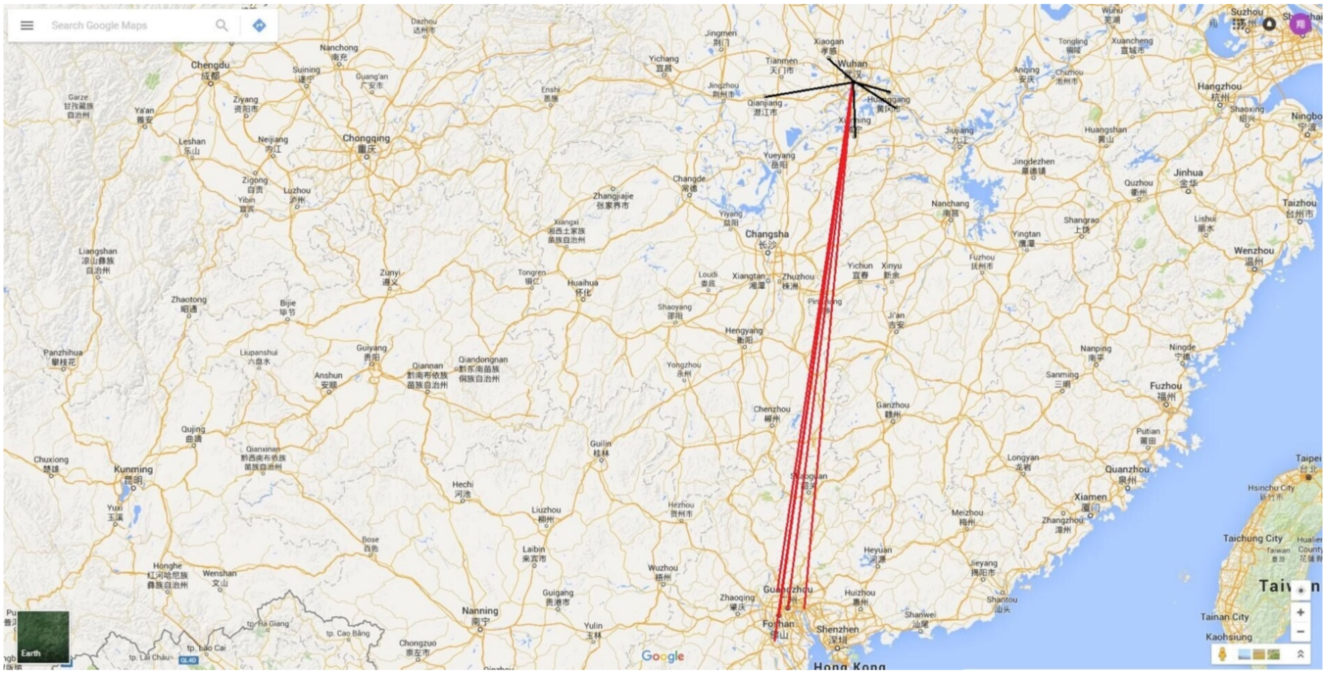

FIGURE 3. ROUTING FROM CITIES IN GUANGDONG TO CITIES IN HUBEI.

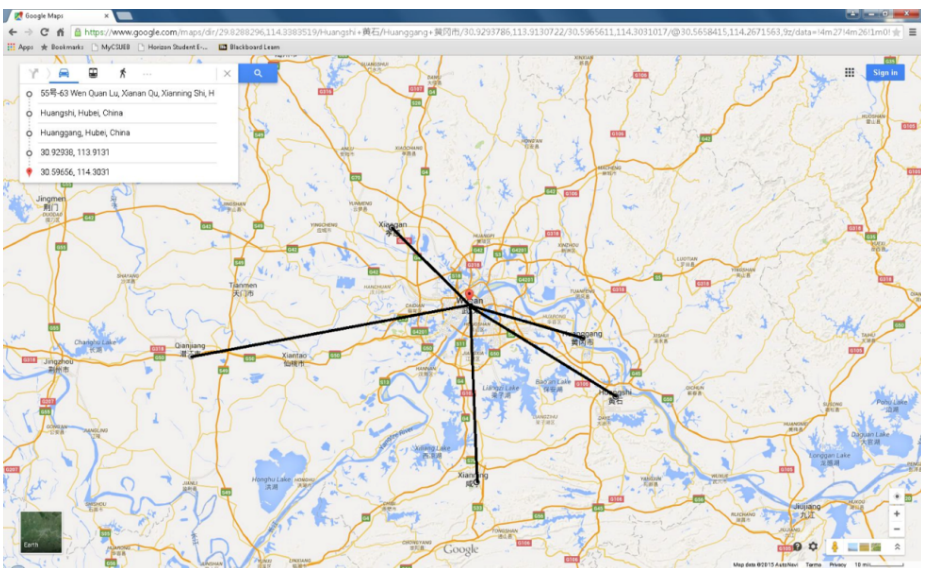

FIGURE 4. ENLARGED ROUTING FROM WUHAN CITY TO SATELLITE CITIES.

2.2. Shipping from Cities in Guangdong Province to Cities in Hubei Province

Following the similar routing concept described in Section 2.2., to ship freight from cities in Guangdong province to cities in Hubei province, the routing practice in S.F. Express (see Fig. 3 and 4) is to collect all freight bound for Hubei province, then dispatch trucks directly from each city in Guangdong province to the capital city Wuhan, which serves as the distribution hub in Hubei province. The S.F. Express station in Wuhan city then sorts all inbound freight from all cities in Guangdong province and reloads on trucks for delivering to each destination city in Hubei province.

Table 4 summarizes the distances $S(y_j, x_0)$ in km-highway between each city y_j in Guangdong province and Wuhan city x_0. The distances $S(x_0, x_j)$ between Wuhan city x_0 and each of its satellite city x_i are shown in Table 5.

Table 6 shows the weekly freight weight, indicated as $W(y_j, x_i)$ in tons, from each city y_j of Guangdong province to each city x_i of Hubei province. To match the routing practice of S.F. Express, we calculate the weekly freight weight $W(y_j, X)$ as the total amount of weekly shipping from each Guangdong city y_j to Hubei province X that is consolidated in Wuhan city, where

$$W(y_j, X) = \sum_{i=0}^{5} W(y_j, x_i). \quad (3)$$

Similarly, the weekly freight weight $W(Y, x_i)$ in tons represents the weekly shipping demand from Guangdong province Y that is consolidated in Wuhan city, then deliver to each Hubei province city x_i.

$$W(Y, x_i) = \sum_{j=0}^{5} W(y_j, x_i) \quad (4)$$

TABLE 4. DISTANCES BETWEEN CITIES IN GUANGDONG AND WUHAN CITY.

(In km-Hwy)	Guangzhou y_0	Dongguan y_1	Zhongshan y_2	Qingyuan y_3	Foshan y_4	Jiangmen y_5
Wuhan x_0	1020	1050	1101	968	1045	1104

TABLE 5. DISTANCES BETWEEN WUHAN CITY AND ITS SATELLITE CITIES.

(In km-Hwy)	Wuhan x_0	Huangshi x_1	Qianjiang x_2	Xianning x_3	Xiaogan x_4	Huanggang x_5
Wuhan x_0	0	103	278	97	72	83

TABLE 6. WEEKLY FREIGHT WEIGHT FROM CITIES IN GUANGDONG TO CITIES IN HUBEI.

(In tons)	Wuhan x_0	Huangshi x_1	Qianjiang x_2	Xianning x_3	Xiaogan x_4	Huanggang x_5
Guangzhou y_0	500	100	100	100	100	100
Dongguan y_1	100	20	20	20	20	20
Zhongshan y_2	100	20	20	20	20	20
Qingyuan y_3	100	20	20	20	20	20
Foshan y_4	100	20	20	20	20	20
Jiangmen y_5	100	20	20	20	20	20

When comparing Table 6 with Table 3, one may find that the round-trip shipping demands between Guangdong province and Hubei province are symmetrical. This is actually very similar to the data we obtained from S.F. Express. The reason for this is that the trucks of S.F. Express in the Hubei-Guangdong routes run a long multi-day cycle with long layovers in hub stations. As a result, there is adequate waiting time to fill the truck load. Because S.F. Express normally runs the Hubei-Guangdong routes at near capacity in all legs, the demand information is quite symmetrical between Table 3 and Table 6. The overflow demand usually becomes the bread and butter of smaller shipping companies.

2.3. Cost Analysis of Traditional Truck Transportation

Using the information described above, the total weekly cost of traditional truck transportation $TCTT$ can be calculated as follows. To prevent the data integrity from being affected by fluctuations in the currency exchange rate, throughout this paper, we will use Chinese Yuan in cost calculation to keep the numbers consistent as they are obtained from various information sources in China. Let CTT_1 be the weekly cost of trucking freight from each city in Hubei province to consolidate in Guangzhou city; CTT_2 be the weekly cost of distribute Hubei freight from Guangzhou city to other cities in Guangdong province; CTT_3 represent the weekly cost of carrying from each city in Guangdong province to consolidate in Wuhan city; CTT_4 be the weekly cost of distributing Guangdong freight from Wuhan city to other cities in Hubei province. The unit cost for highway transportation is estimated as A_1 = 0.129 Yuan/km-ton. Then we get the following:

$CTT_1 = [\sum_{i=0}^{5} \mathrm{S}(x_i, y_0) * \mathrm{W}(x_i, \mathrm{Y})] * A_1$ = [2,015,000 km-ton] $* A_1$ = 259,935 Yuan

$CTT_2 = [\sum_{j=0}^{5} \mathrm{S}(y_0, y_j) * \mathrm{W}(X, y_j)] * A_1$ = [71,800 km-ton] $* A_1$ = 9,262 Yuan

$CTT_3 = [\sum_{j=0}^{5} \mathrm{S}(y_j, x_0) * \mathrm{W}(y_j, \mathrm{X})] * A_1$ = [2,073,600 km-ton] $* A_1$ = 267,494 Yuan

$CTT_4 = [\sum_{i=0}^{5} \mathrm{S}(x_0, x_i) * \mathrm{W}(Y, x_i)] * A_1$ = [126,600 km-ton] $* A_1$ = 16,332 Yuan.

As a result, the total weekly cost using traditional truck transportation becomes

$TCTT = CTT_1 + CTT_2 + CTT_3 + CTT_4$ = 553,023 Yuan per week.

Please note that in this analysis, the sorting and loading-unloading costs are not included. This is because the S.F. Express's hub operations in Guangzhou city and Wuhan city also serve as hubs to support its national level logistic network in China and, therefore, the cost of hub operations is treated as overhead. The actual cost of truck shipping between Hebei province and Guangdong province would be slightly (3 to 5%) higher. However, the liaison of S.F. Express is satisfied with using this conservative cost estimate as a baseline when comparing against the cost of using road-rail intermodal transport to be implemented in the future.

III. OPERATIONAL VALUE OF IMPLEMENTING ROAD-RAIL INTERMODAL TRANSPORT

Recognizing the huge potential of road-rail intermodal transport in China, the Ministry of Transportation in China has established demo road-rail intermodal terminals in both Wuhan city and Guangzhou city in 2014. The purpose of the demo intermodal terminals is to improve facility design, equipment selection (Rodrigue, 2013), operations procedures, and collecting data to benchmark those intermodal terminals in developed counties (Li, 2010). The China government has identified intermodal transport as a strategic economic development project in its 13th 5-year national development plan to be carried out from year 2016 to 2020. The goals of adopting intermodal transport are to improve the transportation efficiency (Douglas, 2013), and to reduce highway congestion, air pollution, as well as greenhouse gas emissions (López-Navarro, 2014).

3.1. Intermodal Transport Model and Cost Analysis

Fig.5 illustrates the routing plan of road-rail intermodal transport to connect cities in Hubei provinces with cities in Guangdong province. Take the freight transportation from cities in Hubei provinces to the cities in Guangdong province for example: Trucks collect freight from each city in Hubei province and ship to the railway hub in Wuhan city. The railway distance between Wuhan city and Guangzhou city is $S_R(x_0, y_0)$ = 1,069 km. The unit cost for railway transportation is estimated as A_2 = 0.03 Yuan/km-ton. To swap the intermodal container or carrier between the truck and train, the loading and unloading cost at the intermodal terminals are L = 9 Yuan/ton and UL = 9 Yuan/ton, respectively.

CIT_1 is the cost for collecting freight from each city in Hubei province and ship to the railway intermodal terminal in Wuhan city. CIT_2 is the cost of using rail to ship freight from Wuhan city to Guangzhou city. CIT_3 is the cost of loading and unloading the freight in intermodal terminals located in Wuhan city and Guangzhou city. CIT_4 is the cost of delivering freight from Hubei province, now consolidated in Guangzhou city intermodal terminal, to each city in Guangdong province. CIT_5 is the cost for collecting freight from each city in Guangdong province and ship to the railway intermodal terminal in Guangdong city. CIT_6 is the cost of using rail to ship freight from Guangzhou city to Wuhan city. CIT_7 is the cost of loading and unloading the railway freight in Guangzhou city and Wuhan city. CIT_8 is the cost of delivery all the freight from Guangdong province, now consolidated in Guangzhou city intermodal terminal, to each city in Hubei province. CIT_9 represents the costs when the return portions of truck pickup and delivery with empty load. The unit cost of road transportation with empty load is set at 85% of unit cost with full load due to less fuel consumption and insurance rate. The following are the specific calculations of all costs using road-rail intermodal transport.

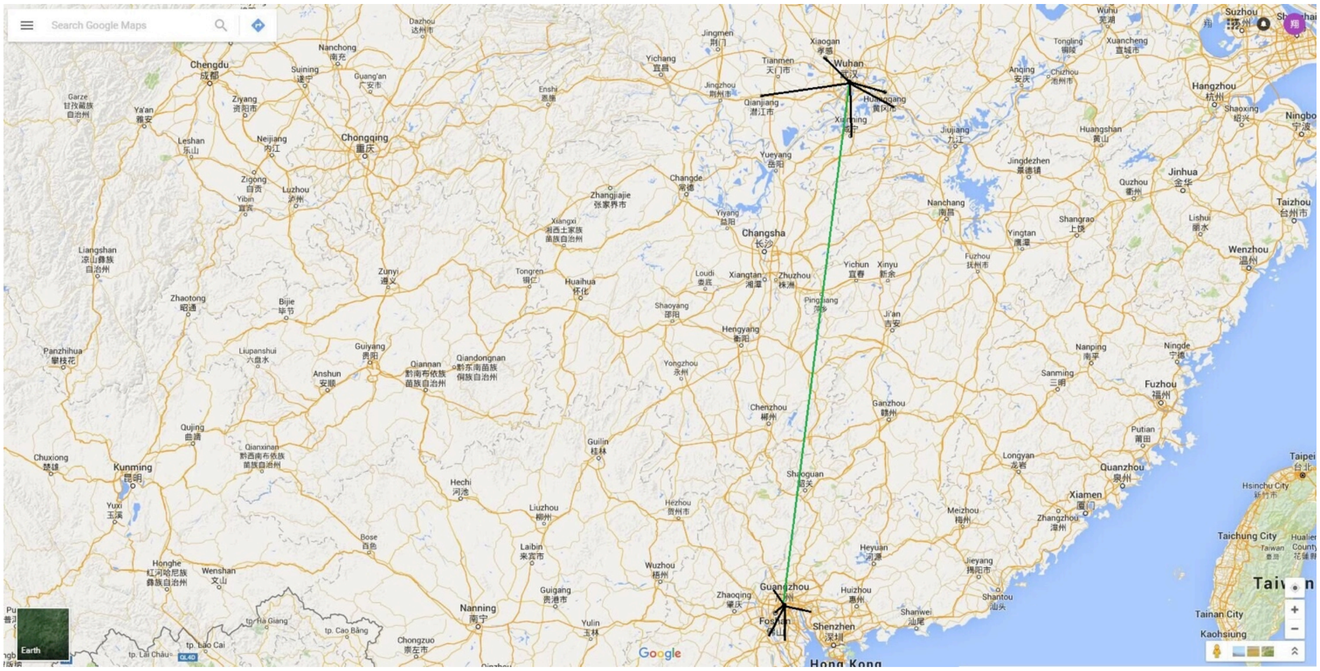

FIGURE 5. INTERMODAL ROUTING BETWEEN CITIES IN GUANGDONG AND CITIES IN HUBEI.

$CIT_1 = [\sum_{i=0}^{5} \mathrm{S}(x_0, x_i) * \mathrm{W}(x_i, \mathrm{Y})] * A_1 =$ [126,600 km-ton] $* A_1$ = 16,332 Yuan
$CIT_2 = S_R(x_0, y_0) * [\sum_{i=0}^{5} \mathrm{W}(x_i, Y)] * A_2 =$ [2,138,000 km-ton] $* A_2$ = 64,140 Yuan
$CIT_3 = (L + UL) * [\sum_{i=0}^{5} \mathrm{W}(x_i, Y)] = (9 + 9) *$ [2,000 tons] = 36,000 Yuan
$CIT_4 = [\sum_{j=0}^{5} \mathrm{S}(y_0, y_j) * \mathrm{W}(X, y_j)] * A_1 =$ [71,800 km-ton] $* A_1$ = 9,262 Yuan
$CIT_5 = [\sum_{j=0}^{5} \mathrm{S}(y_0, y_j) * \mathrm{W}(y_j, \mathrm{X})] * A_1 =$ [71,800 km-ton] $* A_1$ = 9,262 Yuan
$CIT_6 = S_R(x_0, y_0) * [\sum_{j=0}^{5} \mathrm{W}(y_j, X)] * A_2 =$ [2,138,000 km-ton] $* A_2$ = 64,140 Yuan
$CIT_7 = (L + UL) * [\sum_{j=0}^{5} \mathrm{W}(y_j, X)] = (9 + 9) *$ [2,000 tons] = 36,000 Yuan
$CIT_8 = [\sum_{i=0}^{5} \mathrm{S}(x_0, x_i) * \mathrm{W}(Y, x_i)] * A_1 =$ [126,600 km-ton] $* A_1$ = 16,332 Yuan
$CIT_9 = 0.85 * (CIT_1 + CIT_4 + CIT_5 + CIT_8)$

Here we consider two scenarios based on the road-rail intermodal routing plan described in Fig. 5. First is the best scenario or the cost lower bound, when the delivery and pickup truck runs can be combined that leads to 100% utilization of truck capacity. Let $TCIT_{lower}$ represent the total weekly cost of this best scenario of intermodal transportation. Accordingly,

$TCIT_{lower} = \sum_{n=1}^{8} CIT_n$ = 251,468 Yuan per week

Second is the cost upper bound in a worst-case scenario, when the delivery or pickup truck run returns with an empty load that leads to 50% utilization of truck capacity. Let $TCIT_{upper}$ represent the total weekly cost of this worst-case scenario of intermodal transportation. Accordingly,

$TCIT_{upper} = \sum_{n=1}^{9} CIT_n = 294{,}978$ Yuan per week

3.2. Intermodal Model with Routing Enhancement

To improve the vehicle utilization rate, the common approaches are to solve as vehicle routing problem (Ziliaskopoulos and Wardell, 2000) or scheduling problem using simulation (Gambardella, Rizzoli, and Funk, 2002). Based on our preliminary simulation result of routing enhancement with various time window setting, it is typical to reach the truck capacity utilization rate in 70% to 80% range. For example, when using the three-stop routing examples described in Fig. 6 and Fig. 7, the average reduction of weekly empty truck load are 82,500 km-ton among cities in Hubei province and 46,400 km-ton among cities in Guangdong province. As a result, the average total cost when using road-rail intermodal transport with routing enhancement is 278,351 Yuan per week. In the next section of performance comparison, the result of intermodal transport with routing enhancement is adopted as an intermediate scenario when evaluating the cost saving and reduction of CO_2 emission.

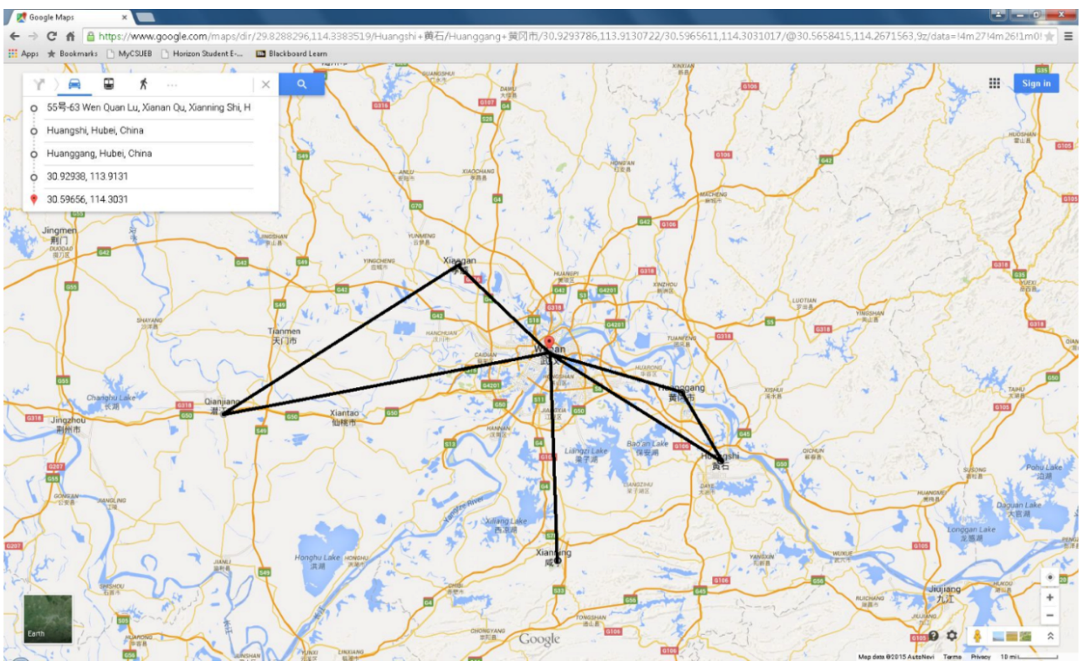

FIGURE 6. EXAMPLE OF ENHANCED ROUTING IN HUBEI PROVINCE.

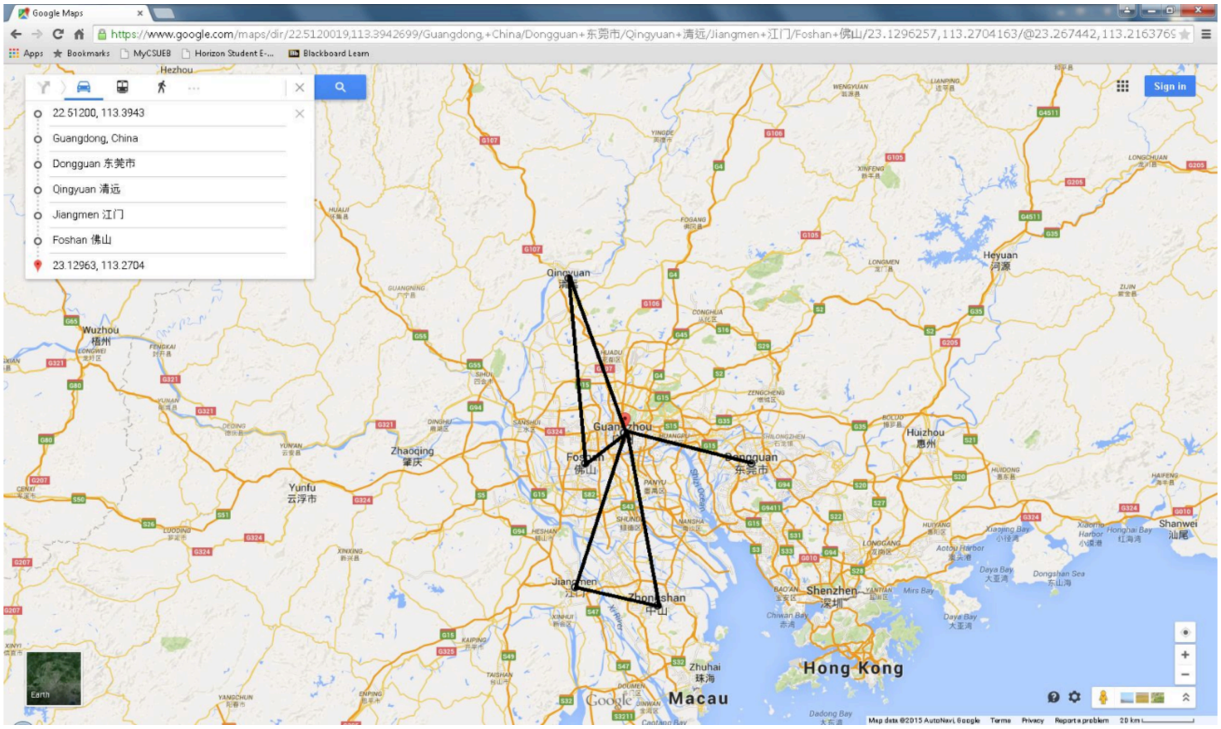

FIGURE 7. EXAMPLE OF ENHANCED ROUTING IN GUANGDONG PROVINCE.

To evaluate the value and benefit of road-rail intermodal transport over traditional truck transport, Table 7 summaries the cost, cost saving, and reduction of CO_2 emissions of each transportation plan discussed above. The emission factors for truck and railway transportation are found in (Xie, 2011). When considering the environmental impact, intermodal transport enjoys the reduction of CO_2 emission by the range of 51.9% to 61.1%, with an intermediate scenario of 56.3% reduction. This environmental benefit is critical to help China reduce its increasingly severe air pollution and to control greenhouse gas emissions, while maintaining economic growth. The cost saving of road-rail intermodal transport ranges from 46.7% to 54.5%. The intermediate scenario (intermodal with enhanced routing) saves costs by 49.7%.

IV. NON-OPERATIONAL FACTORS FOR EVALUATING ROAD-RAIL INTERMODAL TRANSPORT

This section applies qualitative research methods using structured interviews with senior managers in S.F. Express to explore the answer to the research question: "Given the operational benefits, what are the non-operational considerations of a logistics company in China when evaluating roar-rail intermodal transportation?" Pilot interviews and informal discussion were conducted with executives of S.F. Express before performing the cost and CO_2 analysis to compare road-rail intermodal transport with traditional truck transport. After presented with the cost and CO_2 analysis to S.F. Express, five senior managers, including VP Operations, VP Finance, Director of Scheduling and Route Planning, GM of Wuhan Hub, and GM of Guangzhou Hub, were interviewed either in person or via conference calls.

TABLE 7. PERFORMANCE COMPARISON ON COST AND CO_2 EMISSION.

	Traditional Truck Transport	Intermodal Worst Scenario	Intermodal Best Scenario	Intermodal with Enhanced Routing
Weekly Cost (Yuan)	553,023	294,978	251,468	278,351
Weekly Cost (USD)*	86,410	46,090	39,292	43,492
Annual Cost (Yuan)	28,757,196	15,338,856	13,076,336	14,474,252
Annual Cost (USD)	4,493,312	2,396,696	2,043,178	2,261,602
Annual Saving (Yuan)	0	13,418,340	15,680,860	14,282,944
Annual Cost Saving (USD)	0	2,096,616	2,450,134	2,231,710
Cost Saving %	**0.0%**	**46.7%**	**54.5%**	**49.7%**
Weekly CO_2 Emission (Ton)**	238.4	114.7	92.6	104.2
Annual CO_2 Emission (Ton)	12,395	5,963	4,816	5,419
Annual Reduction of CO_2 Emission (Ton)	0	6,431	7,579	6,976
CO_2 Emission Reduction %	**0.0%**	**51.9%**	**61.1%**	**56.3%**

* The exchange rate is set at 1 USD = 6.4 Chinese Yuan.
** The CO_2 emission factors are estimated at 0.0556 kg/km-ton for truck transportation and 0.0165 kg/km-ton for railway transportation.

As a large private logistics company in China, S.F. Express executives consider the operational cost savings as the most important element when evaluating the feasibility to implement road-rail intermodal transport vs. existing trucking approach. Overall, the assessment on operational benefits is very positive. The executives are impressed by the results of 49.7% savings in transportation costs and 56.3% reduction of CO2 emissions when compared with existing truck transport.

Other than the operational benefits, the interview results indicate that when evaluating road-rail intermodal transport, the most important non-operational factor is associated with China government's policies and incentives. This result is not surprising because China is still controlled by a strong centralized government and many business decisions are strongly influenced by the economic planning led by the China government. Transportation normally accounts for 8% to 12% of the cost of a product. Consequently, the savings created by road-rail intermodal transport are significant. In fact the high cost of trucking transport contributes to China's domestic logistics costs, accounting for roughly 18% of China's GDP. In comparison, U.S. and EU logistics costs account for 8.5% and 10% of the nation's GDP. Therefore, the road-rail intermodal transport gains much obvious support backed by China's logistics policies and incentives. China government realizes that its economic growth needs more effective and efficient transport service to retain its edge as a global manufacturer, particularly as Southeast Asia and Mexico look to grab some of its dominant share of global sourcing. In addition, reduced transportation costs will make products more affordable to Chinese consumers, allowing government leaders to realize their goal of shifting the export-reliant economy to one based more on services and domestic consumption.

Despite the significant potential in operational cost saving, environmental benefit, and positive China government support, when interviewing the managers in S.F. Express, the following challenges and concerns have been raised regarding implementing road-rail intermodal transport:

1) **Capacity limit and slow timeline of building railway intermodal terminals.** One major obstacle to increased intermodal transport is that the investments have to be undertaken by rail infrastructure owners and local terminal operators, who may have different objectives from the logistic service companies and may cause bottlenecks of establishing intermodal infrastructure.
2) **Compatibility of information systems to acquire visibility of railway operations.** Another major obstacle to increase intermodal is the total absence of cross-firm IT-infrastructure between the road and rail transportation industries. Typically transportation service providers mainly have their in-house-developed IT-system, and this system is regarded as one of the competitive advantages of the firm that they may not be willing to share.
3) **Scheduling and lead time uncertainty related to railway operations.** First and foremost, intermodal competitiveness is tied to operational effectiveness and efficiency at the railway terminals. The terminal must meet the requirements of connecting the road transportation networks. However, the mindsets of railway operators need to change from internal-processes-oriented to the supply chain collaboration type. The railway and terminal operations need to provide transparency in the logistics network.
4) **May affect S.F. Express's competitive advantage and strategic positioning.** In the past, S.F. Express has invested heavily in road transport and trucking operations. To adopt intermodal transport, S.F. Express would be required to share railway capacity and intermodal terminals with smaller competitors that would weaken S.F. Express's current competitive advantages in the trucking network. In addition, reduced trucking fleet size and hub operations may require writing off existing investments made by S.F. Express.
5) **Need to implement additional intermodal transport technologies**. Road-rail intermodal transport requires a set of technologies and process enhancement in order to carry out its full value and benefit. This is true especially in the areas of routing improvement, scheduling improvement, incentive contract design, as well as in railroad terminal equipment, standardization of containers and carriers to extend road-rail intermodal transport to include waterway intermodal mode.

A framework to evaluate the feasibility of implementing road-rail intermodal transport with specific assessment items is proposed in Table 8. Based on what we learned in this case study with S.F. Express, a logistics company in China will first evaluate the operational cost and benefit associated with intermodal transport. Among the non-operational factors, the government policies and incentives are most influential during the assessment. Other non-operational factors may include available infrastructure capacity, compatible information system, smooth connection with railway operations, potential change of competitive positioning, and how to incorporate proper supporting technologies or equipment to enhance the efficiency of intermodal transport.

TABLE 8. EVALUATION FRAMEWORK AND ASSESSMENT ITEMS IN S.F. EXPRESS.

Consider to implement road-rail intermodal transport

Evaluation Items in S.F. Express		
(Operational)	(Non-Operational)	
Cost and benefit analysis	Government policies and incentives	Capacity limit and slow timeline of building railway intermodal terminals
		Compatibility of information systems to acquire visibility of railway operations
		Scheduling and lead time uncertainly related to railway operations
		May affect S.F. Express's competitive advantage and strategic positioning
		Need to implement additional intermodal transport technologies
(very positive)	*(positive)*	*(areas of concern)*
(Current assessment status in S.F. Express)		

Decide to implement road-rail intermodal transport

V. CONCLUSIONS AND FUTURE RESEARCH

Due to global competition in logistics services and the focus on environmentally friendly transport, intermodal transportation is increasingly receiving attention. Long distance service by railway transportation reduces costs and is by far the most environmentally friendly solution. Using trucks for pick-up and delivery ensures the flexibility to serve a variety of locations and to deploy transportation capacity to match seasonal or fluctuating logistic demand. Combining the use of containers, intermodal transport can further control transshipment times and handling cost. In China, severe air pollution and increasingly congested highways offer excellent conditions for road-rail intermodal container transportation. In addition, the relocation of production facilities from the coastline to Central and Western China will increase average transport distance and further raise the attractiveness of combined rail solutions which have a competitive edge over medium to long distances. China's Ministry of Transportation has embarked on an extensive investment program in its medium and long-term plan. The growth of road-rail intermodal transport in China is expected to be exponential in coming years.

In this study, both numerical data and qualitative data have been collected from S.F. Express, a large logistics company in China. Numerical data is then utilized to evaluate the operational benefits in numerical terms, while qualitative data extracted from interviews with senior managers in S.F is used to analyze the non-operational factors in decision making. Based on the analysis results, an evaluation framework is proposed to create an understanding the assessment process of implementing road-rail intermodal transport in a private logistics company in China.

Expanding from this exploratory study, in the future we expect to investigate the following research questions: "How would the road-rail intermodal transport affect the competitive positioning of both logistics industry leaders and followers in China?" and "How would the government policy and incentive design promote healthy competition to reduce logistics cost and improve logistics efficiency in China?" In addition, more operational studies may focus on scheduling and routing improvement within intermodal transport networks to achieve higher efficiency. Other investigations may be made into contracting issues that involve multiple transportation operators and multiple decision makers when involving joint investment and collaborative operations.

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