Decision-Making Process for Developing Urban Freight Consolidation Centers: Analysis with Experimental Economics

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Abstract: The concept of freight consolidation center (FCC) has emerged in recent years. Although several case studies have indicated that FCCs are beneficial to the operation of urban transportation systems, the implementation of this concept has proven difficult because the construction and operation of a FCC involves the coordination of different, and conflicting, stakeholders. Unlike other traditional approaches, this paper investigates the FCC development issue using experimental economics. First, profit functions are defined for involved stakeholders; based on those profit functions, four players—carriers, operators, government, and residents—bid on rent, financial incentives, and wages to maximize their own profits. Eight scenarios are analyzed and compared to determine potential influential factors and appropriate conditions for FCC decision making. Results show that public–private partnership lowers rent and increases wages, which leads to higher carrier, operator, and resident profits. A central location lowers rent, wages, financial incentives, and all stakeholders' profits. A larger carrier size benefits all stakeholders. In conclusion, the appropriate conditions for FCC development are public–private partnerships in noncentral locations with large carrier sizes. **DOI:** 10.1061/(ASCE)TE.1943-5436.0000632.

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Introduction

Freight transport contributes significantly to urban economic activities. Yet it also causes or intensifies congestion, noise, and pollution, which are becoming increasingly prominent problems. To improve the efficiency and reduce the negative impacts of freight transport, the concept of freight consolidation centers (FCC) has been proposed. A FCC is a facility that consolidates freight deliveries from outside and transships to local receivers using smaller trucks with full loads. The overall purpose of FCCs is to decrease the number of truck deliveries, increasing truck load factors and reducing congestion and pollution (Best Urban Freight Solutions 2007; Browne et al. 2005). It addresses the so-called last mile problem, which is often the most expensive part of a delivery given that economies of scale diminish after a vehicle leaves the road network (Lewis et al. 2010).

Despite the advantages that FCCs possess, the implementation of a FCC is often difficult, involving multiple stakeholders in the freight transport system. Based on several FCC case studies, Lindholm (2010) proposed a Sustainable Urban Transport Plan (SUTP) freight transport model to identify basic elements and potential factors that could influence the decisions involved in FCC development. The basic element of FCCs, including types of goods and vehicles, facilities, and infrastructure, were identified. Influential external factors, such as financial and institutional constraints and concerns over land use, noise, and air pollution, were also given. In reality, other external factors, such as location and organization type, were also found to influence FCC development. For example, a reasonable location could save travel time and distances and enhance delivery efficiency while reducing externalities such as traffic congestion and pollution. Other locations could make the freight transport situation, with all of its ramifications, worse. As for organization type, if the FCC is self-sustaining with no government financial incentives, then government will have little impact on FCC operation. On the other hand, if the FCC receives financial support from the government, the interactions between involved stakeholders will be further complicated. This paper investigates the ways in which these various factors can affect FCC development and stakeholder benefits.

Existing FCC studies focus primarily on specific case studies and logistics supply chain analysis. A thorough literature review of FCC examples and preliminary evaluation by Browne et al. (2005) suggests that a FCC has great potential if it meets these criteria: availability of funding, strong public involvement, and limited congestion and pollution. Panero et al. (2011) provided detailed FCC case studies in Europe and discussed their transferability to the United States. Major FCC case studies, such as La Petite Reine in France, Heathrow Airport in the U.K., and Tenjin Joint Distribution System in Japan, have been carefully studied in terms of operation, financial profile, and social benefits and costs; these analyses have provided important references for this paper.

In terms of studies in logistics and supply chains, Kayikci (2010) developed a conceptual model to facilitate decision making on where to locate a FCC, applying a combination of the fuzzy-analytical hierarchy process (AHP) and the artificial neural network (ANN) method. Based on the data, the most influential factor among multiple criteria was chosen, and the most appropriate location was selected. Moon et al. (2011) developed a joint replenishment and consolidation freight model.

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Based on mathematical models and four algorithms, results indicated that a quasi-stationary policy led to lower total costs compared to a stationary policy.

Method

Unlike traditional methods, this paper studies the FCC development problem using experimental economics. Experimental economics is a subarea of economics that studies human behavior in a laboratory context. It allows researchers to control the decision setting to mimic decision-making processes (Riedl, working paper, 2009). Some researchers question the validity of the approach because a laboratory context is different from a real decision context, and players in the experiment cannot fully represent the whole population (Duflo 2006). However, the experimental economics approach has two important advantages: replicability and control (Davis and Holt 1993). Replicability allows other researchers to reproduce an experiment and validate its results. In addition, researchers can control the experimental context to investigate major factors in the decision process. FCC research requires various kinds of data that are not always available. In the absence of data, the experimental economics approach becomes increasingly important to generate synthetic data and analyze decision results.

The applicability of experimental economics has already been proven by several applications in freight transportation. Holguín-Veras and Thorson (2003) used experimental economics to study the urban freight transportation market. Participants acted as competing truck companies to earn as much profit as possible. Cost functions for truck companies were defined to measure the profit and relation between players. The estimated number of stops, load factors, and time durations were well aligned with theoretical ones. As with the studies discussed earlier, this paper will apply experimental economics to the FCC decision problem. A profit function is derived from empirical data for each type of stakeholder: carrier, operator, government, and resident. As in a real collaboration process, four players, representing these four types of stakeholder, try to derive the most benefit from FCC development. In the experiment, such a benefit is mimicked by a bonus allocated to the players. To obtain the highest possible bonus, players must bid wisely to maximize profits, while making necessary compromises to achieve group consensus. Eight scenarios are tested to determine the effects of organizational type, location, and carrier size on stakeholders and, ultimately, on the FCC development decision. Results from this study will help identify potential factors in the FCC development decision process and provide guidance for future studies.

Experimental Design

The goal of the experiment is to assess how different FCC conditions affect stakeholder decisions. The experimental results are expected to provide insights into the decision-making process of FCC development in practice. Four players representing carriers, operators, government, and residents participate in the experiment. The experiment runs for eight sessions, each representing a FCC proposal with a specific organization type, location, and carrier size conditions. Each session contains five rounds of bidding. Players are allowed to consult with each other to determine the optimal bidding prices. If no agreement is reached within five rounds, the session is considered an undesirable FCC proposal.

In each round, participants may receive a cash bonus based on their performance maximizing profit and achieving consensus. When a player's bid maximizes his or her profit, a $2 bonus is earned. If a player's bid is profitable but not maximally, the bonus will be proportional to the ratio of actual profit earned to maximum possible profit. For example, if, according to the profit function, the maximum possible profit of the operator is $1,000, and the operator earns $800 in one round, he or she might be given $1.60 as a bonus. However, the player will only get the bonus if consensus from all stakeholders is achieved. Otherwise, the player gets no bonus. Such an incentive mechanism is designed to mimic what happens in reality: stakeholders care most about their own benefit and would only accept a FCC proposal that is beneficial to them. However, if no consensus is reached (i.e., the FCC proposal is not approved), nobody gets anything.

To characterize the interactive relations between stakeholders, a profit function is defined for each stakeholder. As a starting point, most parameter values of these functions come from the La Petite Reine (LPR) freight consolidation center case study in France (Panero et al. 2011). Started in 2001, this FCC has grown to be one of the largest urban distribution systems in Europe, distributing nearly one-quarter of a million parcels per year. It uses small cargo cycles to transship goods from trucks to local receivers within 15 km of the FCC, thereby increasing efficiency and reducing congestion and pollution. It runs with minimal government support and charges relatively low rent. Additional revenue comes from advertising space on its cargo cycles. In general, it is a representative FCC that operates successfully and provides reasonable empirical parameter values.

Carriers

In this study, carriers are considered as an aggregate identity with one delivery route; this homogeneous assumption is implied for all involved carriers. Adapted from Arnott et al. (1993), the profit function for carriers consists of cost savings due to reduced delivery distance and time from using the FCC, minus total rent paid to the FCC. It is also assumed that a truck would have to circle around the city to make all of its deliveries if the FCC were not present. The route is thus a circle, with a radius equal to the average FCC delivery distance. Therefore, the profit function for carriers could be expressed as

$$P_c = N(2\pi\lambda\Delta D + 2\pi\alpha\Delta T) - Vr_c \tag{1}$$

where P_c = total profit for the carrier ($); N = number of deliveries per year; ΔD = reduced distance traveled per delivery (km); ΔT = reduced travel time per delivery (h); r_c = rent for the carrier ($/parcel); V = freight volume (parcel); α = value of time ($/h); and λ = unit cost related to delivery distance, including fuel cost, insurance, and maintenance ($/km). The estimated parameter values are presented in Table 1.

Operator

The operator's revenue comes primarily from the rent (Panero et al. 2011). In the case of strong public involvement, financial incentives from government may be a part of the operator's revenue. The operation cost of the FCC is calculated by the FCC labor cost and its percentage of total costs. When there is only one operator, the profit function for the operator could be expressed as

$$P_o = Vr_o + f_o - nw_oh/l \tag{2}$$

where P_o = operator profit ($); f_o = financial incentive for operator ($); l = labor cost as a percentage of total operation cost;

Table 1. Parameter Values for Carrier Profit Function

Parameters	Values: Original value	Values: Value in 2012
α	\$5/h (Arnott et al. 1993)	$5 \times 1.59 \times 55/24 =$ \$18.22/h [U.S. Bureau of Labor Statistics (BLS) 2012; Holguín-Veras et al. 2010]
λ	\$0.49/km (Holguín-Veras and Polimeni 2006)	\$0.56/km (BLS 2012)
ΔD	5 km (small carrier size) (Panero et al. 2011)	15 km (large carrier size) (Panero et al. 2011)
ΔT	$5\ \text{km}/(25\ \text{km/h}) = 0.2$ h (Panero et al. 2011)	$15\ \text{km}/(25\ \text{km/h}) = 0.6$ h (Panero et al. 2011)
N	50,000 (small carrier size) deliveries per year (Panero et al. 2011)	150,000 (large carrier size) deliveries per year (Panero et al. 2011)
V	250,000 (small carrier size) (Panero et al. 2011)	750,000 (large carrier size) (Panero et al. 2011)
r_c^*	Variable	

Note: The original values are converted into current values by multiplying the inflation factor (BLS 2012). For α, commuter time value is converted to trucker time value by multiplying 55/24 (Holguín-Veras 2010). ΔD is the distance traveled by cargo cycles from a FCC and ΔT is the time it takes. For consistency, major parameters are from the La Petite Reine (LPR) FCC case study in France (Panero et al. 2011). r_c^* indicates that rent is set as the variable for a carrier in the experiment.

n = number of employees; w_o = operator wage rate (\$/h); h = working hours per year (h); r_o = rent for operator (\$/parcel); and V = freight volume (parcel).

The estimated parameter values are presented in Table 2.

Government

Government in this study refers to the aggregate of public agencies that work for the benefit of the entire region potentially impacted by the FCC. The net benefit of government thus consists of reduced externalities due to pollution and toll revenue (Panero et al. 2011). The externalities of major pollutants, such as carbon dioxide and nitrogen oxide, are converted into monetary values using their emission prices. As for the quantification of congestion externalities, marginal-cost pricing on network users has been generally agreed upon as a valid measure (Yang and Huang 1998; Tsekeris and Vob 2009), which provides a basis for road tolls (Zhao and Kockelman 2006). It is thus assumed that congestion caused by truck deliveries is equivalent to the amount of tolls paid by trucks. The net benefit function for government could be expressed as

$$P_g = a\Delta CO_2 + b\Delta NO_x + tN - f_g \tag{3}$$

where P_g = government net benefit (\$); t = toll price (\$); ΔCO_2 = reduced carbon dioxide (ton); ΔNO_x = reduced nitrogen oxide (ton); a = CO_2 price (\$/ton); b = NO_x price (\$/ton); N = number of deliveries per year; and f_g = financial incentive for the government (\$). The estimated parameter values are presented in Table 3.

Table 2. Parameter Values for Operator Profit Function

Parameter	Value
n	10(small carrier size)/30(large carrier size) (Panero et al. 2011)
h	13 h/day × 6 days/week × 50 weeks = 3,900 h/year (Panero et al. 2011)
l	0.83 (Panero et al. 2011)
f_o^*	Variable
w_o^*	Variable
r_o^*	Variable

Note: For consistency, major parameters are from the La Petite Reine FCC case study in France (Panero et al. 2011). f_o^*, r_o^*, and w_o^* indicate that financial incentive, rent, and wage rate are set as variables for the operator in the experiment.

Table 3. Parameter Values for Government Profit Function

Parameter	Values
t	\$30 (Holguín-Veras and Polimeni 2006)
ΔCO_2	22 ton (Panero et al. 2011)
ΔNO_x	200 kg = 0.2 ton (Panero et al. 2011)
a	\$20/ton (Johnson et al. 2011)
b	\$300/ton (Federal Energy Regulatory Commission 2012)
f_g^*	Variable

Note: It is assumed that five-axle trucks are used to make peak hour deliveries, which corresponds to \$30 toll charges and \$150 parking fines (Holguín-Veras and Polimeni 2006). For consistency, major parameters are from the La Petite Reine (LPR) FCC case study in France (Panero et al. 2011). f_g^* indicates that financial incentive is set as the variable for the government in the experiment.

Residents

Many FCC case studies indicate that residents living close to a FCC are often the major opponents of FCC development for a number of rational concerns. Although a FCC creates employment in the local area, the concentrated freight transportation involved may negatively impact the local community in terms of increased noise, reduced community vibrancy, and safety. In an free market, it is also reasonable to assume that these externalities will be reflected in land price changes. Lin and Ben (2009) used an improved hedonic price model to study the impact of industrial land agglomeration (such as FCC construction) on land price. The profit function for local residents could thus be expressed as follows:

$$P_r = nw_r h + A\left(\frac{P_0 \mu A_c}{A}\right) = nw_r h + P_0 \mu A_c \tag{4}$$

where P_r = residents profit (\$); μ = land price elasticity (\$/percentage change in industrial land); A_c = FCC size (m^2); A = community area (m^2); P_0 = original land price (\$/m^2); n = number of employees; w_r = wage rate (\$/h); and h = working hour per year (h). The estimated parameter values are presented in Table 4.

Table 4. Parameter Values for Resident Profit Function

Parameters	Values
μ	−0.257 (Lin and Ben 2009)
A_c	600 m^2 (Panero et al. 2011)
P_0	$44.2€/m^2 \times 1.2287\,\$€ = \$54.3/m^2$ (Abelairas-Etxebarria and Astorkiza 2012; Google Finance 2012)
w_r^*	Variable

Note: Land area value comes from La Petite Reine FCC case study in France (Panero et al. 2011). w_r^* indicates wage rate is set as the variable for residents in the experiment.

Experiment Implementation

Four graduate students are recruited to perform the experiment. They are randomly assigned the roles of carrier, operator, government, and resident. In each scenario, players choose their own values of variables within given ranges to maximize their profit, with the understanding that their potential bonus will be proportional to the achieved profit and can only be earned when consensus is achieved. A total of three variables are used in the experiment: rent (r) charged by the operator and paid by carriers; financial incentive (f) provided by the government and received by the operator; and wage rate (w) negotiated by the operator and resident. Group consensus is reached if the bids' differences for all three pairs of variables are within 5%. During each round the players are allowed up to 2 min to discuss, reconsider, and revise their bids. If no group consensus is reached within five rounds, the scenario is considered an undesirable situation for building a FCC.

Eight scenarios are created to test different organizational types, location choices, and carrier sizes. Organization type defines the partnerships and relevant financial incentives between operator and government. The major organization types include private (no financial incentive), public (full financial incentive), and public-private partnership (PPP) (partial financial incentive) (Panero et al. 2011). Since PPP is a more recent and effective organization, this paper tries to compare private and PPP organization types. A location is directly related to the service area provided by the FCC. For example, a location in an urban area has smaller delivery distances, whereas congestion and pollution problems may be more significant. Instead, a suburban location reduces delivery distances for carriers and carries less externality. In this paper, an outskirt location (reduced more travel distances than a central location) and a central location (suggesting shorter last-leg travel distance) are compared. Carrier size, indicated by the number of truck deliveries handled by the FCC, is relatively straightforward. To a certain extent, this factor represents the carriers' acceptance and utilization rate of the FCC. Three values are assumed here: small size with 250,000 parcels, 10 FCC workers, and 50,000 deliveries or large size with 750,000 parcels, 30 workers, and 150,000 deliveries (Panero et al. 2011). The complete scenario information is summarized in Table 5.

Results

The experiment was carried out successfully. Test scenarios were run before the formal experiment to familiarize players with the bidding process. Group consensus was achieved in all but the third and seventh scenarios. In Scenarios 3 and 7, both of which are privately operated and located in a central area, one or more players always had to lose money in order to achieve consensus. FCC factors, such as organizational type, location choice, and carrier size, seem to have direct effects on bidding prices and the profit earned by each player, which is analyzed by comparing different scenarios with control factors. The bidding and profit results in different scenarios are compared in Table 6.

According to Table 6, compared to purely private organizations, the PPP decreases the government's net benefit. For example, government net benefit decreases by 48.0% from \$1.5 million to \$0.78 million when the organizational type changes but the FCC remains located on the outskirts and the carrier size remains small (Scenario 1 versus 2). In Scenarios 5 and 6, when only the organizational type changes but the FCC remains on the outskirts and the carrier size is large, the government's profit decreases by 46.7%, from \$4.5 million to \$2.4 million. This result is in keeping with the negative relation between financial incentive and government profit indicated in Eq. (3). However, all other stakeholders' profits increase when the organizational type is PPP. The carrier profit increase in a range of 20.5% (Scenario 5 versus 6) to 72.4% (Scenario 1 versus 2). The operator profit increase is even more dramatic, ranging from 273.3% (Scenario 1 versus 2) to around 500% (Scenario 5 versus 6), even with lower rent. Rent decreases from 11.8% (Scenario 5 versus 6) to 27.3% (Scenario 1 versus 2). It seems that using financial incentives effectively lowers rent for carriers and stimulates the acceptance of the FCC among carriers. One interesting finding is that local residents also seem to benefit from a PPP, as indicated by the higher wages. It seems that the financial incentive received by the operator is partially used to cover labor costs, which leads to the increase in wages (Scenario 1 versus 2 and 5 versus 6). In general, the experiment suggests that, although the financial incentive from government does not increase the systemwide benefits, it helps redistribute benefits and make the FCC more attractive for carriers, operators, and local residents. In fact, the positive effect of public sector involvement in FCC

Table 5. Summary of Scenarios

	Parameter values			
Scenarios	Organization	Location	Carrier size	Variable range (\$)
1	Private ($f = 0$)	Outside ($\Delta D = 15$ km, $\Delta T = 0.6$ h)	Small ($V = 2{,}50{,}000$, $N = 50{,}000$ $n = 10$)	$r = 0$–3.87 $f = 0$ $w = 7.25$–30
2	Public-Private ($f <$ \$15,00,500)	Outside ($\Delta D = 15$ km, $\Delta T = 0.6$ h)	Small ($V = 2{,}50{,}000$, $N = 50{,}000$ $n = 10$)	$r = 0$–3.87 $f = 0$–$15{,}00{,}500$ $w = 7.25$–30
3	Private ($f = 0$)	Inside ($\Delta D = 5$ km, $\Delta T = 0.2$ h)	Small ($V = 2{,}50{,}000$, $N = 50{,}000$ $n = 10$)	$r = 0$–1.29 $f = 0$ $w = 7.25$–30
4	Public-Private ($f <$ \$15,00,500)	Inside ($\Delta D = 5$ km, $\Delta T = 0.2$ h)	Small ($V = 2{,}50{,}000$, $N = 50{,}000$ $n = 10$)	$r = 0$–1.29 $f = 0$–$15{,}00{,}500$ $w = 7.25$–30
5	Private ($f = 0$)	Outside ($\Delta D = 15$ km, $\Delta T = 0.6$ h)	Large ($V = 7{,}50{,}000$, $N = 1{,}50{,}000$ $n = 30$)	$r = 0$–3.87 $f = 0$ $w = 7.25$–30
6	Public-Private ($f <$ \$45,00,500)	Outside ($\Delta D = 15$ km, $\Delta T = 0.6$ h)	Large ($V = 7{,}50{,}000$, $N = 1{,}50{,}000$ $n = 30$)	$r = 0$–3.87 $f = 0$–$45{,}00{,}500$ $w = 7.25$–30
7	Private ($f = 0$)	Inside ($\Delta D = 5$ km, $\Delta T = 0.2$ h)	Large ($V = 7{,}50{,}000$, $N = 1{,}50{,}000$ $n = 30$)	$r = 0$–1.29 $f = 0$ $w = 7.25$–30
8	Public-Private ($f <$ \$45,00,500)	Inside ($\Delta D = 5$ km, $\Delta T = 0.2$ h)	Large ($V = 7{,}50{,}000$, $N = 1{,}50{,}000$ $n = 30$)	$r = 0$–1.29 $f = 0$–$45{,}00{,}500$ $w = 7.25$–30

Note: Variable range is different to ensure nonnegative profit. Rent range is given based on rent level of different case studies (Panero et al. 2011). The estimated freight volume and number of deliveries for large carriers are based on the study of Nemoto (1997). The wage rate is defined according to the minimum wage level (U.S. Dept. of Labor 2012) and an employee with a high annual income of \$100,000 working 40 h/week.

Table 6. Impacts of Different Factors on Bidding and Profits

Factors	Scenarios compared	Average bidding price (r: \$/parcel, f: million \$, w: \$/h)	Average profit (million \$)	Variable comparison	Profit comparison
Organization (private versus public-private)	1 versus 2 (outskirts, small carrier size)	r: 2.74 versus 1.99 f: NA versus 0.75 w: 12.32 versus 15.83	P_c:0.29 versus 0.48 P_g:1.50 versus 0.78 P_o:0.15 versus 0.56 P_r:0.49 versus 0.63 Total: 2.43 versus 2.44	Lower r Higher w	Higher P_c Lower P_g Higher P_o Higher P_r Similar total
	3 versus 4 (downtown, small carrier size)	r: NA versus 0.82 f: NA versus 0.66 w: NA versus 13.00	P_c:NA versus 0.12 P_g:NA versus 0.88 P_o:NA versus 0.32 P_r:NA versus 0.52 Total: NA versus 1.84	NA	NA
	5 versus 6 (outskirts, large carrier size)	r: 2.45 versus 2.16 f: NA versus 2.21 w: 11.75 versus 15.87	P_c:1.12 versus 1.35 P_g:4.50 versus 2.40 P_o:0.31 versus 1.85 P_r:1.43 versus 1.91 Total: 7.36 versus 7.52	Lower r Higher w	Higher P_c Lower P_g Higher P_o Higher P_r Similar system gain
	7 versus 8 (downtown, large carrier size)	r: NA versus 0.83 f: NA versus 2.19 w: NA versus 13.92	P_c: NA versus 0.36 P_g: NA versus 2.42 P_o: NA versus 1.05 P_r: NA versus 1.68 Total: NA versus 5.52	NA	NA
Location (outskirts versus downtown)	1 versus 3 (private, small carrier size)	r: 2.74 versus NA f: NA versus NA w: 12.32 versus NA	P_c:0.29 versus NA P_g:1.50 versus NA P_o:0.15 versus NA P_r:0.49 versus NA Total: 2.43 versus NA	NA	NA
	2 versus 4 (public-private, small carrier size)	r: 1.99 versus 0.82 f: 0.75 versus 0.66 w: 15.83 versus 13.00	P_c:0.48 versus 0.12 P_g:0.78 versus 0.88 P_o:0.56 versus 0.32 P_r:0.63 versus 0.52 Total: 2.44 versus 1.84	Lower r Lower f Lower w	Lower P_c Higher P_g Lower P_o Lower P_r Lower total
	5 versus 7 (private, large carrier size)	r: 2.45 versus NA f: NA versus NA w: 11.75 versus NA	P_c:1.12 versus NA P_g:4.50 versus NA P_o:0.31 versus NA P_r:1.43 versus NA Total: 7.36 versus NA	NA	NA
	6 versus 8 (public-private, large carrier size)	r: 2.16versus 0.83 f: 2.21 versus 2.19 w: 15.87 versus 13.92	P_c:1.35 versus 0.36 P_g:2.40 versus 2.42 P_o:1.85 versus 1.05 P_r:1.91 versus 1.68 Total: 7.52 versus 5.52	Lower r Similar f Lower w	Lower P_c Similar P_g Lower P_o Lower P_r Lower total
Carrier size (small versus large)	1 versus 5 (private, outskirts)	r: 2.74 versus 2.45 f: NA versus NA w: 12.32 versus 11.75	P_c:0.29 versus 1.12 P_g:1.50 versus 4.50 P_o:0.15 versus 0.31 P_r:0.49 versus 1.43 Total: 2.43 versus 7.36	Lower r Lower w	Higher P_c Higher P_g Higher P_o Higher P_r Higher total
	2 versus 6 (public-private, outskirt)	r: 1.99 versus 2.16 f: 0.75 versus 2.21 w: 15.83 versus 15.87	P_c:0.48 versus 1.35 P_g:0.78 versus 2.40 P_o:0.56 versus 1.85 P_r:0.63 versus 1.91 Total: 2.44 versus 7.52	Higher r Higher f Similar w	Higher P_c Higher P_g Higher P_o Higher P_r Higher total
	3 versus 7 (private, center)	r: NA versus NA f: NA versus NA w: NA versus NA	P_c:NA versus NA P_g:NA versus NA P_o:NA versus NA P_r:NA versus NA Total: NA versus NA	NA	NA
	4 versus 8 (public-private, downtown)	r: 0.82versus 0.83 f: 0.66 versus 2.19 w: 13.00 versus 13.92	P_c:0.12 versus 0.36 P_g:0.88 versus 2.42 P_o:0.32 versus 1.05 P_r:0.52 versus 1.68 Total: 1.84 versus 5.52	Similar r Higher f Higher w	Higher P_c Higher P_g Higher P_o Higher P_r Higher total

Note: NA = data unavailable.

Table 7. Qualitative Factor Impacts

Items	Scenarios compared	Bidding prices: Rent (r_c)	Financial incentive (f_g)	Wage rate (w_r)	Stakeholder profits/Net benefit: Carriers	Government	Operator	Residents	Total
Organization (change from private to PPP)	1 versus 2 3 versus 4 5 versus 6 7 versus 8	−	NA	+	+	−	+	+	AB
Location (change from outskirts to downtown)	1 versus 3 2 versus 4 5 versus 7 6 versus 8	−	−	−	−	AB	−	−	−
Carrier size (change from small to large)	1 versus 5 2 versus 6 3 versus 7 4 versus 8	AB	+	AB	+	+	+	+	+

Note: + = positive impact; − = negative impact; NA = not available; AB = impact ambiguous.

operation has been pointed out by several studies. For example, Holguín-Veras et al. (2008) suggested that financial incentives provided by the government are helpful in achieving an efficient collaborative freight operation, and van Duin et al. (2010) indicated that both carriers and operators could benefit from a FCC when operated properly.

In terms of the effect of FCC location, it was found that an FCC located in a city center is less attractive to all stakeholders except government. For carriers, a central location translates into lower savings in terms of travel distance and time (Scenario 2 versus 4 and 6 versus 8), even though rent and wages are lower. Carrier profits decrease by around 75% (in both Scenario 2 versus 4 and 6 versus 8) compared to the case of using a FCC on the outskirts. Because of the significant reduction in carriers' cost savings, operators seem to have less negotiating power when the FCC is located in the downtown of a city, as indicated by the lower rent. Although operators also pay lower wages in this case, it is not sufficient to offset the loss due to lower rent. Therefore, operator profits are also lower, which leads to lower wages and lower resident profits (Scenario 2 versus 4 and 6 versus 8). Government's net profit does not seem to be affected by location. In short, the experiment suggests that a central location is less attractive than an outskirt location for most stakeholders. As Panero et al. (2011) also concluded, for FCC location, "a location in the outskirts is often preferred or even legally stipulated anyway" (Panero et al. 2011, p. 17).

Analysis of carrier size (which can be considered as a proxy of FCC utilization rate) indicates that it is positively correlated with all stakeholders' profits. A larger carrier size increases both carrier cost savings and government profit. Of course, an operator's profit increases with carrier size, too: higher FCC utilization rates mean increased revenue for an operator. A large carrier size also attracts greater financial incentives but has insignificant effects on rent and wages. For example, rent drops from \$2.74/parcel in Scenario 1 to \$2.45/parcel in Scenario 5, but increases slightly from \$1.99/parcel in Scenario 2 to \$2.16/parcel in Scenario 6. Economy of scale is not significant here because the rent seems to be jointly determined by location, organization, and size factors. From the perspective of system gain, a slightly higher-than-proportional increase in total profits with respect to carrier size is observed. As the delivery volume increases by 200%, the system gain, evaluated as the total profits of all stakeholders, increases by 204% (average of Scenarios 1 versus 5, 2 versus 6, and 4 versus 8). In the optimal case where the organization type is PPP and the FCC is located on the outskirts, the system gain increases by 208%.

The impacts of organizational type, location choice, and carrier size on bid prices and profits are summarized in Table 7. Clearly, the most appropriate conditions for FCC development are a public-private partnership, a location on the outskirts, and a large carrier size.

Conclusions

This paper uses experimental economics to investigate the potential factors and their impacts on stakeholder profits in FCC development decisions. Four players—carriers, operators, government, and residents—bid on rent, financial incentives, and wages under different scenarios, always aiming to maximize their own profit and achieve consensus. A profit function and relevant parameter values are defined for each player based on previous findings. Results indicate that a PPP lowers rent and increases wages. PPPs also increase carrier, operator, and resident profits at the cost of lower government net benefit. A central location lowers rent, financial incentives, wages, and all stakeholders' profits. A large carrier size brings with it a greater financial incentive but does not seem to affect rent and wages. A large carrier size also increases all stakeholders' profits. From the perspective of total system gain, evaluated as the summation of all stakeholders' profits, the most favorable FCC situation is PPP at an outskirt location with a large carrier size. Such findings are consistent with most existing studies.

Of course, along with the innovations of this study, some limitations exist. To utilize the findings of previous studies, profit functions are simplified. Estimated parameter values also rely heavily on the LPR case study. As a result, some subtle interactions between players could not be captured fully. For example, there is no direct link between local residents (who reside closely to the FCC) and government (which represents the interest of the entire involved region). In other words, local residents' opinions are not communicated directly to or considered influential by the government. Future work on this type of study will include the identification and development of more theoretically grounded cost functions and more robust parameter values from empirical studies. Moreover, future work could benefit from the incorporation of more factors and more players because FCC development decisions are affected by many other factors, such as local economic and transportation conditions. There could also be multiple carriers with heterogeneous features and different groups of residents.

The analysis prototype developed here allows for a preliminary investigation of the FCC development decision process. Findings in this paper will help practitioners gain a better understanding of the interactions between stakeholders in the decision-making process. With some refinement, this insightful framework can be expected to effectively improve FCC planning and decision making and contribute to the development of more sustainable freight transportation systems.

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