Distribution of small packages in metropolitan area by motorcycle courier services

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Abstract: Small packages such as important documents, receipts and gifts are usually distributed in a short time window in a metropolitan area of congested traffic and limited parking spaces. While conventional four-wheel vehicles are not suitable for intra-city deliveries, motorcycles are perfect since they are more mobile. This paper tries to investigate business models suitable for distributing small packages in metropolitan area by analysing two courier networks: a point-to-point and a hub-and-spoke courier network. Pros and cons, as well as the simplified mathematical models for these two networks will be proposed and analysed to give more insights for this business.

Keywords: motorcycle courier; metropolitan area; hub-and-spoke; point-to-point; PP; urban logistics; network design; small package.

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Biographical notes: I-Lin Wang is an Assistant Professor in the Department of Industrial and Information Management, National Cheng Kung University in Taiwan since 2003. His research areas include the design and analysis of optimisation algorithms, with applications in the supply chain management, network flow optimisation, telecommunications, and bioinformatics. He received his PhD in 2003 from the School of Industrial and Systems Engineering at Georgia Institute of Technology, and his MS in 1996 from the Operations Research Center at Massachusetts Institute of Technology. He has published papers in various referred journals including *Transportation Science* and *IEEE Transactions on Electronics Packaging Manufacturing.*

1 Introduction

Communications among enterprises have become closer and more frequent because of the growing economy and competition. How to distribute the products, funds, and information as quickly as possible between the stages of a supply chain usually serves as the key to its success. Although the internet has successfully saved some physical logistic costs in information and cash flows, it also urges more demands for faster physical product distribution. In particular, small packages, like important documents, receipts, and gifts, usually require to be distributed in a short time window in a metropolitan area where the traffic is easily congested and parking spaces are limited. Such a task is not suitable for conventional four-wheel vehicles owing to the limited parking space. On the other hand, a courier service using motorcycles is perfect for this task. In particular, although a motorcycle has smaller capacity (up to 10 kg and 2.5 m^3), lower speed, and shorter range than a four-wheel vehicle, it is more mobile, convenient to park, and a sales rider can easily distribute small packages to customers located in high buildings in a metropolitan area. This paper studies the business models of motorcycle courier services for delivering small packages in a metropolitan area. The consignments are assumed to be of small size and urgent (e.g., has to be finished within 2 or 3 h) with locations unpredictable in advance, scattered around the entire metropolitan area.

Conventional motorcycle courier services usually use a PP courier network where the sales riders pick up and distribute packages on the way following the orders of the central office (call centre). A customer requests a delivery order by a call to the central office, and then an experienced dispatcher assigns the order to a sales rider according to the rider's position and capacity status. A sales rider may hold several orders on hand and decide by his experience on the priority and routings of orders. Thus it is quite likely for an earlier order to be accomplished later and affect the deadline guarantees. Even worse, a sales rider may intentionally report incorrect position or capacity information to grab more orders for his own advantages. All of these non-standard operating procedures may result in worse and more uncontrollable quality of service.

On the other hand, a hub-and-spoke courier network, which has been successfully exploited in the airline industry (see Bryan and O'Kelly, 1999), seems to have more advantages for a motorcycle courier service in a metropolitan area. In particular, a metropolitan area can be divided into several service zones according to the amounts and locations of demands. Each zone is assigned to one representative sales rider who is responsible for any order (package) originated from or terminated at the zone. Leaving from the central office (call centre, or, hub) in the beginning of a business day (e.g., 9 am), each sales rider starts to collect and distribute packages in his spoke zone, then returns to the hub every turnaround time (e.g., 80 min) for package exchanges, and then repeat these procedures several times until the end of a business day (e.g., 6 pm). Since the location for each spoke zone is determined and its range is not so large, compared with the PP system, a sales rider in a hub-and-spoke system usually has better distribution efficiency. Furthermore, the relationship between customers and the sales rider can be built up and become closer since each sales rider usually serves his zone instead of travelling around the whole metropolitan area. However, all of these advantages come with the price of higher facility and personnel cost.

To our knowledge, the motorcycle courier service has not yet been investigated or discussed in the literature. This paper thus tries to make the first step by investigating suitable business models for distributing small packages in metropolitan area. In particular, two courier networks, a PP system and a hub-and-spoke system, will be analysed and compared based on both the managerial and theoretical insights. The rest of this paper is organised as follows: Section 2 reviews business models. In Section 3, we suggest successful strategies for different courier networks in metropolitan area, from the experience in the airline business. Simplified mathematical models for both courier networks will be discussed and analysed in Section 4. A successful motorcycle courier firm in the Taipei metropolitan area will be investigated and discussed in Section 5. Finally, Section 6 concludes the paper and suggests future research directions.

2 Business models

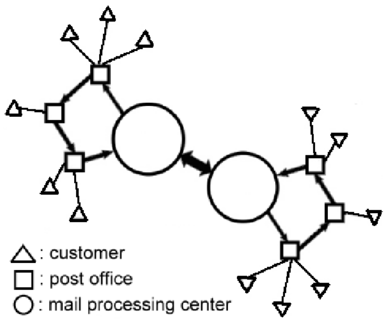
Since there is no literature about motorcycle courier service, this section focuses on the business models for motorcycle courier firms in metropolitan area. We first review how the state-owned postal service works, and then illustrate the PP courier network and the hub-and-spoke system used by private motorcycle courier firms.

2.1 State-owned postal service

The package distribution service in many countries is a monopoly and has to be done by the national or state-owned postal services. Recently, more and more countries (e.g., Japan) start to privatise parts of the postal services in response to the people for better postal services and for more efficient government management.

Most state-owned postal services require customers to carry their packages to a post office. Customers have to specify the delivery options and pay the post fees accordingly. A package will be sorted and shipped from the local post office, if the destination is located in the same area of the origin. Otherwise, a package will be shipped to the area mail processing centre, which processes and dispatches part or all of both incoming mail and outgoing mail for a designated service area. Grouped packages of the same destination area will be delivered between area mail processing centres. Each package will be sorted and dispatched to a local post office, and then be delivered to its destination by a postman. The distribution network of the postal service is illustrated in Figure 1.

Figure 1 Distribution network of the postal service



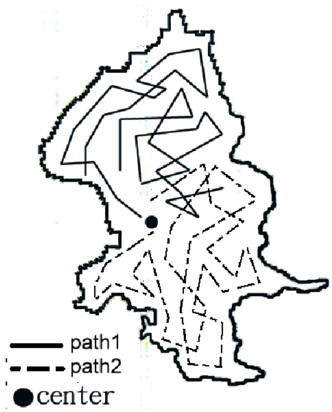
Since the postal service in many countries is a monopoly, the employees usually are less efficient. Most postmen do nothing more than delivery. The salary of an employee in the state-owned postal service is stable and does not depend so much on the amount, efficiency, or quality of his performance. The customer service is not as good as private courier firms, either. For example, a customer usually has to absorb the cost of mishandled, delayed, or even missed deliveries himself/herself without any compensation when using a postal service.

In a metropolitan area, the quickest postal service is the same-day delivery, which requires a package to be received in a post office in the morning and then delivered in the afternoon. Since the postal services focus more on the general mailing services that are cheaper and not urgent for most people, the industries and business firms that seek faster service would like to be served by some private courier firms capable of services such as 2 h (or even faster) delivery guarantees. The demands for faster, cheaper, and safer delivery services for small packages in a metropolitan area create a niche market for private motorcycle courier firms. On the other hand, a private motorcycle courier firm cannot compete with the state-owned postal service for long-distance deliveries.

2.2 Point-to-Point (PP) courier network

A PP courier network has a simple management structure and lower fixed cost. In particular, a central office receives orders via phones or internet and then some experienced dispatchers assign a received order to a sales rider depending on the location and capacity status of the rider. Each sales rider has to report his location and capacity status to the central office upon enquiry. The dispatchers play a very important role in the PP courier network since any inappropriate assignment of orders may result in longer delivery time. Advanced electronic equipments such as GIS, GPS, or mobile phones may make the dispatching more effective. In particular, with GIS and GPS, a dispatcher can easily locate a nearby sales rider to pick up consignments. Instant messages can also be transmitted between a sales rider and the central office whenever an order is assigned or finished. An example of the distribution network for a PP courier network is illustrated in Figure 2, in which two sales riders are travelling around the metropolitan area for delivering random received consignments.

Figure 2 Distribution network of a Point-to-Point (PP) courier network



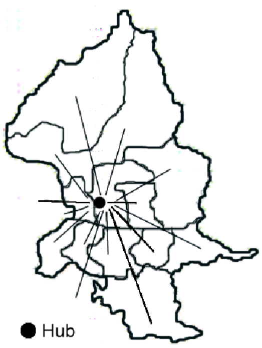
If the dispatchers are the brain of a PP courier network, the sales riders would be the hands that follow the commands of the brain. Mathematically speaking, each sales rider encounters a Vehicle Routing Problem (VRP: see Toth and Vigo, 2002, for details) in which several demand points assigned by the dispatcher will have to be visited in an efficient way while new demands may appear in the mean time. A skilled sales rider may manage a better routing to delivery packages than a novice, which makes the quality of the service become more rider-dependent and unstable. Since a sales rider will get more payment for more consignments, some sales riders may try to manipulate relationships with an unfair dispatcher for more profits. On the other hand, the maximum number of consignments that a PP sales rider can conduct is limited because of the scattered demands around the entire metropolitan area. In our survey, a PP sales rider in the Taipei metropolitan area may conduct 15–25 deliveries on average in a business day. This upper bound is difficult to break through.

2.3 Hub-and-spoke courier network

A hub-and-spoke courier network consists of a number of spokes extending outward from a central hub, similar to a bicycle wheel as illustrated in Figure 3, where a hub is located in the centre of the metropolitan area and the connection from the hub to each service zone can be considered as a spoke. Each consignment must be routed through a central hub before reaching its destination. The hub is a sorting facility and requires more capital investment than the central office of a PP courier network. A larger network may require more than one hub. Many researchers have investigated the problem of hub locations (see Campbell, 1994; O'Kelly and Miller, 1994). Since every consignment has to pass through a hub, a consignment may require more time to reach its destination than a direct PP shipping. In particular, the time required for each shipment in a hub-and-spoke network is dominated by the travel time from its origin zone to the hub and then from the hub to its destination zone. Although the direct PP shipping consumes less travel time, it incurs more labour costs. With the same number of sales riders to accomplish many scattering consignments around the metropolitan area, a hub-and-spoke network, on average, requires less travel time than a PP network.

To effectively collect and distribute consignments in a hub-and-spoke network, a metropolitan area can be divided into several service zones to average the workload for each sales rider using the data on the amounts and locations of historical demands. Each service zone is assigned with a sales rider who is responsible for picking up and distributing any package in his zone. Most hub-and-spoke courier services require the sales riders to return to the hub every period of time (i.e., the turnaround time, or cycle time) so that the collected packages can be exchanged and distributed to their destination zones in a guaranteed period. Although a sales rider in his zone also encounters a VRP for visiting his customers, this VRP is easier to solve than the one in a PP network since the range of travelling is more limited (i.e., in his service zone rather than the entire metropolitan area). Therefore, a sales rider in a hub-and-spoke courier network usually finishes more consignments than that in a PP courier network. In our survey, a PP sales rider in the Taipei metropolitan area may conduct 50–70 deliveries on average in a business day. This upper bound is also difficult to break through, but is already several times more than the capability of a sales rider in a PP courier network.

Figure 3 Distribution network of a hub-and-spoke courier network



The salary for a sales rider is calculated according to the number of accomplished consignments that he has conducted. If a sales rider explores more markets in his service zone, the zone may be further divided to average his workload. However, such a zone reassignment may discourage the original sales rider to explore new market unless he receives some extra rewards. Since the operating procedures are more standardised in a hub-and-spoke courier network, it can give better guarantees in the efficiency and quality of service, which incur higher consignment fee for their service.

3 Strategies for motorcycle courier services

This section will give detailed analysis on the pros and cons of different motorcycle courier networks. Factors that affect the efficiency of a motorcycle courier network as well as strategies to achieve its success will be discussed.

3.1 Experiences from the airline flight networks

Competition in courier services has increased since more and more countries have started to privatise parts of the postal services, which is similar to the aviation deregulation of airline business in the USA in the late 1970s. In the airline business, it evolves into two extremes: the Low-Cost Carriers (LCCs) and the Network Carriers (NCs), where the former airlines usually exploit PP flight networks and the latter ones use hub-and-spoke flight networks.

In particular, an LCC is an airline that offers generally low fares in exchange for eliminating many traditional passenger services. Typical LCC practices include a single passenger class, a standardised airplane type, a simple fare scheme, short flights, and simplified routes. Gillen and Lall (2004) analyse the competitive advantage of LCC and point out that the strategic success by Southwest, the largest LCC in the USA, is not generic. The simplicity of the organisation and information flows of Southwest result in greater relational coordination, which serves as the key to high productivity and lower costs. Such a success in system coordination makes the duplication of its business model more difficult. On the other hand, other LCCs like Ryanair and easyJet, two of Europe's largest LCCs, achieve their success by relentlessly driving down costs. These two airlines imitate the operational efficiency, instead of the strategy, of Southwest. Moreover, both airlines outsource everything other than cabin crew, pilots, reservation agents, head office functions, and some maintenance (Gillen and Lall, 2004) to decrease the total cost and make aggressive expansion of their business possible. Outsourcing also makes it difficult to manage organisational relationships and to create good corporate culture. In particular, with more subcontractors, the customer service and other service attributes may require more efforts to maintain. The business model of Ryanair and easyJet is thus easily copied, compared with the Southwest model. As a result, there exist the first mover advantages for carriers like Ryanair and easyJet.

On the other hand, most NCs such as Delta Air Lines, Northwest Airlines, and FedEx develop hub-and-spoke flight networks to increase the load factor, which is the ratio of paid passenger seats to the total seating capacity of a particular flight. Higher load factors bring more profits. Previous researches (Bryan and O'Kelly, 1999; Kuby and Gray, 1993) indicate that a PP flight network is not as efficient as a hub-and-spoke flight network. The business model of a hub-and-spoke network has achieved its success not only in air passenger and cargo transportation, but also in ground transportation, communication networks, and other logistics systems (Aykin, 1995). In particular, it creates economies of densities (Caves et al., 1984), results in higher flight frequency, and broader geographic coverage. Furthermore, any force that increases traffic volume on the spokes will reduce fares in the markets it serves owing to economies of density on the spokes (Brueckner et al., 1992). Therefore, fares in the individual markets should be lower in a large network, which may attract more demands. However, with the needs for larger capital investments and fixed costs, major airlines using hub-and-spoke networks have been struggling in financial difficulties recently after September 11 terrorist attacks as well as its subsequent downturn. Even worse, several largest US carriers were operating under bankruptcy protection.

Hu (2005) has investigated the decision for an airline to use either a PP or a hub-and-spoke flight network by a three-stage duopoly game where two airlines serve a three-city network with uncertain demands. Intuitively, a hub-and-spoke network gives more flexibility of allocating capacities after the uncertainty is resolved, which gives it more advantages than a PP network, if the excess investment costs in the hubs are ignored. However, this intuition does not necessarily hold. In particular, a hub-and-spoke network does not always dominate a PP network. Hu (2005) has showed that a monopolist may favour a PP network, if the demand variation is small. Hu (2005) also concludes that a larger demand variation or an extreme high or low unit capacity cost generally favours hub-and-spoke networks whether there is competition or not.

The research and experience learned from the airline business may help the analysis for motorcycle courier services since both business models involve similar network structures. Further modifications on these research results are required for the motorcycle courier services.

3.2 Niche markets for motorcycle courier services

There are several fundamental differences between the airline business and the motorcycle courier services. First, the passenger transportation requires more considerations such as security, services, and safety, which are usually not required, or at least only to a very limited level, in the package courier services. In particular, motorcycle courier services deliver letters, documents (e.g., contracts to be signed, printing films, blueprints, etc.), promotional materials, product samples, etc. The most important concern would be to deliver the consignment safely before its guaranteed accomplished time, which corresponds to the issue of operational efficiency.

Second, the capital investment in the airline business (e.g., aircrafts, crews and airports) is far more than that (e.g., motorcycles, sales riders, and call centres) in the motorcycle courier services. This favours the use of the hub-and-spoke networks for motorcycle courier services. However, besides the extra investment in the hubs, the hub-and-spoke system comes with a more complex management scheme, which may also require extra efforts for smooth integration.

Third, the origin and destination locations (i.e., airports) of passengers and cargos, as well as the flight routes in airline business are fixed and deterministic, whereas the locations of packages to be picked up or delivered may appear anywhere in the metropolitan area and the routes are far more dynamic and flexible in motorcycle courier services. In other words, the motorcycle courier networks are far more complex and dynamic than the airline flight networks in terms of the problem nature, although the scale of the airline business is larger in terms of the capital investment.

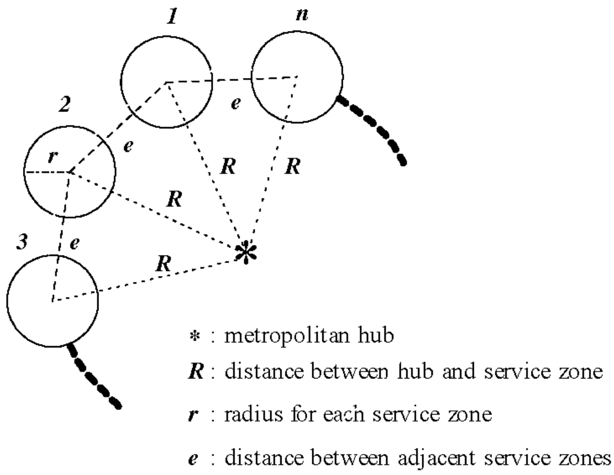
Despite these fundamental differences, there are still some similarities between the airline business and motorcycle courier services. In particular, when the scale of demands becomes large or the locations of demands are randomly scattered in the metropolitan area (e.g., Taipei, Tokyo or New York), a hub-and-spoke courier network will take more advantages than a PP courier network. Furthermore, the simplicity of operations and organisation makes duplication of the PP motorcycle courier network easier, which in turn induces more cutthroat competitions, similar to what happens in the LCC markets.

These points also suggest suitable strategies to the niche markets for different motorcycle courier networks. In particular, since the hub-and-spoke courier network achieves much better quality of services to deliver a large number of consignments in short time, the PP courier network should not directly compete with the hub-and-spoke courier network for the same market of similar guarantees, unless the amount of demands is not as large, the consignments require extra care (so that direct shipping is preferred), or the demands are distributed in locations of some specific pattern (e.g., corridor type), which makes the use of the hub-and-spoke network in vain. For example, the PP courier network may target at the markets of faster delivery requirements (e.g., 1 h delivery), the markets requiring extra services but not so time-sensitive (e.g., some human resource outsourcing services), or the markets of shipping special consignments that require extra care which prefer direct shipping instead of some transhipment in the hub. On the other hand, for the hub-and-spoke courier network to be more successful, the rule of thumb is to explore more markets all over the metropolitan area and design a good organisational structure.

4 Mathematical models

Here we propose two simplified mathematical models, denoted by HS and PP, to have a big picture on both courier networks, where HS and PP stand for hub-and-spoke and point-to-point, respectively. Suppose the metropolitan area is a large circle and divided into $n \geq 2$ service zones, where each zone is approximated by a smaller circle with radius equal to r. Let the distance between centres of each service zone and the metropolitan area equal to R. Let v_r and v_R denote the average velocity for each sales rider to travel inside his service zone and from the hub to the centre of his service zone, respectively. Let θ represent the total number of consignments a sales rider has processed (including both picking up and delivering) in the period when he stays inside his service zone. Assume $\theta \leq \theta_u$ where θ_u represents the upper bound of the consignments that one can process in each cycle. Suppose the courier network operates for a total of T units of time per workday. Suppose the demands arise equally likely at anywhere in each service zone with rate equal to ρ consignments per unit of time. Furthermore, we assume that all the demands arisen inside a service zone have to be delivered equally likely to any of the other $n - 1$ service zones. Then, there are no local deliveries within any service zone. See Figure 4 for more details.

Figure 4 Illustration for the simplified courier network



To model the hub-and-spoke courier network (HS), we have to define more parameters and variables. In particular, let T_R, T_r, T_h and T_c be the time to travel between the hub and each service zone centre, the time spent inside each service zone to collect and deliver consignments, the time in the hub to exchange consignments, and the turnaround time (i.e., cycle time), respectively. Within a cycle, each sales rider travels from the hub to his service zone, collects and delivers inside his service zone, travels back to the hub, and then exchanges consignments inside a hub. Thus $T_c = 2T_R + T_r + T_h$ and $v_R = (R/T_R)$. To estimate the lower bound on the capacity of an HS sales rider in his service zone, we assume that an HS sales rider has to travel a distance of $2r$ to collect or deliver two consignments. In other words, on average every consignment requires r/v_r time to be processed, and thus $T_r = \theta(r/v_r)$, or $\theta = (T_r v_r/r)$.

The number of cycles within a workday, denoted by K, can be calculated by $\lfloor (T/T_c) \rfloor$. Let $D_{HS}^{j,k}$ and $D_{HS}^{j,\mathrm{ALL}}$ denote the number of delivered consignments for each sales rider $j = 1, \ldots, n$, in a hub-and-spoke courier network within the kth cycle and during the entire workday, respectively. Similarly, define $C_{HS}^{j,k}$ and $C_{HS}^{j,\mathrm{ALL}}$ to be the number of collected consignments for each sales rider $j = 1, \ldots, n$, in a hub-and-spoke courier network within the kth cycle and during the entire workday, respectively. We assume $K \geq 2$ so that each service zone will receive consignments. Based on these parameters and assumptions, we can observe the following properties.

Theorem 1:

(*a*) *For each sales rider* $j = 1, \ldots, n$, $C_{HS}^{j,k} = \theta$ *and* $D_{HS}^{j,k} = 0$ *when k is odd;* $C_{HS}^{j,k} = 0$ *and* $D_{HS}^{j,k} = \theta$ *when k is even.*

(*b*) *Suppose K is even, then* $D_{HS}^{j,\mathrm{ALL}} = C_{HS}^{j,\mathrm{ALL}} = (1/2)K\theta = (T\theta / 2T_c)$.

(*c*) *Suppose* V_R, V_r, *and* T_h *are constants, then* $T_r^* = (r/V_r)\theta_u$, *if* $\rho Tc \geq \theta_u$*; or* $T_r^* = (r\rho(2T_R + T_h)/(V_r - r\rho))$, *if* $\rho Tc \geq \theta_u$.

Proof: (a) In cycle 1, each sales rider j only collects θ consignments without any delivery in his service zone. Thus a total of θ consignments will be carried to the hub for exchange, where $1/(n-1)$ of these θ consignments will be exchanged to each of the other $n-1$ service zones for delivery. In the hub, each sales rider j will collect $\theta/(n-1)$ consignments exchanged from each of the other $n-1$ service zones, and then carry these θ consignments to deliver in his service zone. The process will then be repeated every two cycles. In particular, each sales rider collects θ consignments in his service zone in one cycle, and then delivers θ consignments in his service zone in the next cycle.

(b) There are totally $K\theta$ consignments to be processed within one workday, and half of them are to be delivered. Thus, the total amount of delivered and collected consignments both equal $(1/2)K\theta = (T\theta/2T_c)$.

(c) When a zone has more cycle demands (i.e., ρT_c) to be processed than the operational capacity θ_u for a sales rider, it is a waste to spend a period longer than $(r/V_r)\theta_u$ in a service zone per cycle, since the sales rider cannot handle over capacity at all. On the other hand, when there are fewer cycle demands than the operational capacity, we may set $\theta = \rho T_c$ to estimate the optimal T_r^*, since longer period in the service zone will not help one to collect more demands after all. Therefore, $(T_r V_r/r) = \rho(2T_R + T_r + T_h)$ and thus $T_r^* = (r\rho(2T_R + T_h))/(V_r - r\rho)$ can be calculated.

Using the T_r^*, one may derive $D_{HS}^{*,\mathrm{ALL}} = \sum_{j=1}^{n} D_{HS}^{j,\mathrm{ALL}} = (T\theta/2T_c) = T\theta\big/(2(2T_R + T_r^* + T_h))$, the maximum amount of the consignments delivered by n sales riders for a hub-and-spoke courier network within one workday, and compare it with $D_{PP}^{*,\mathrm{ALL}}$, the maximum amount of the consignments delivered by n sales riders for a PP courier network within one workday, to evaluate the performance for different courier systems.

To model the Point-to-Point courier network (PP) and compare it with the hub-and-spoke model based on the same environment, we use the same demand distribution and service zones as assumed in the HS model. In particular, there are totally n sales riders for n service zones, and the demands also arise equally likely anywhere anytime in a workday. Theoretically, a PP sales rider may visit service zones in a random order. However, such a travelling pattern is difficult to analyse. To estimate the upper bound on the capacity of a PP sales rider in his service zone, we assume an ideal situation in which each PP sales rider spends $\hat{T}_r$ time in a service zone to process $\hat{\theta} \le \theta_u$ consignments (including collecting and delivering), and then travels a distance of e units in $\hat{T}_e$ time to his counterclockwise adjacent service zone. In particular, during each cycle of $\hat{T}_c$ time, each sales rider will collect and deliver consignments in his own service zone for $\hat{T}_r$ time, spend $\hat{T}_e$ time in travelling to his counterclockwise adjacent service zone counterclockwise, and then repeat these cycle operations until the end of a workday. Thus $\hat{T}_c = \hat{T}_r + \hat{T}_e$. Without loss of generality, we assume each sales rider to operate for $\hat{K} = \lfloor (T/\hat{T}_c) \rfloor \ge 2$ cycles during a workday. It is also easy to derive $\hat{T}_e = (2R/V_R)\sin(\pi/n)$ from the topology of the courier network in Figure 4. Moreover, suppose the jth sales rider serves the $z(j,\hat{k})$th service zone in the $\hat{k}$th cycle for each $\hat{k} = 1,\ldots,\hat{K}$ and each $j = 1, 2, \ldots, n$, where $z(j,\hat{k}) = (j + \hat{k} - 1)(\mathrm{mod}\cdot n)$.

Let $D_{PP}^{j,\hat{k}}$ and $D_{PP}^{j,\mathrm{ALL}}$ denote the number of delivered consignments for each sales rider $j = 1, \ldots, n$, in a PP courier network within the $\hat{k}$th cycle and during the entire workday, respectively. Similarly, define $C_{PP}^{j,\hat{k}}$ and $C_{PP}^{j,\mathrm{ALL}}$ to be the number of collected consignments for each sales rider $j = 1, \ldots, n$, in a PP courier network within the $\hat{k}$th cycle and during the entire workday, respectively. Suppose $C_{PP}^{j,\alpha} = 0$ for any $\alpha \le 0$. Let $\widehat{D}_{PP}^{i,\hat{k}}$ and $\widehat{D}_{PP}^{i,\mathrm{ALL}}$ denote the number of delivered consignments for each service zone $i = 1, \ldots, n$, in a PP courier network within the $\hat{k}$th cycle and during the entire workday, respectively. Similarly, define $\widehat{C}_{PP}^{i,\hat{k}}$ and $\widehat{C}_{PP}^{i,\mathrm{ALL}}$ to be the number of collected consignments for each service zone $i = 1, \ldots, n$, in a PP courier network within the $\hat{k}$th cycle and during the entire workday, respectively. Based on these parameters and assumptions, we can observe the following properties.

Theorem 2:

(*a*) $\widehat{D}_{PP}^{i,\hat{k}} = D_{PP}^{j,\hat{k}} = (1/(n-1))\sum_{\alpha=\hat{k}-n+1}^{\hat{k}-1} C_{PP}^{j,\alpha}$ *and* $\widehat{C}_{PP}^{i,\hat{k}} = C_{PP}^{j,\hat{k}} = \hat{\theta} - D_{PP}^{j,\hat{k}} = (1/(n-1))\sum_{\alpha=\hat{k}-n+1}^{\hat{k}-1} D_{PP}^{j,\alpha}$, *for each* $j = 1, \ldots, n$, $\hat{k} = 1, \ldots, \widehat{K}$, *and* $i = z(j, \hat{k})$.

(*b*) $\lim_{\hat{k}\to\infty} D_{PP}^{j,\hat{k}} = \lim_{\hat{k}\to\infty} C_{PP}^{j,\hat{k}} = (1/2)\hat{\theta}$.

(*c*) *Let* $\beta = (n-2)/(n-1)$. *If* $\rho T_c \ge \theta_u \ge \hat{\theta}$ *and* $\widehat{K} \le n$, *then* $C_{PP}^{j,\hat{k}} = \hat{\theta}\beta^{\hat{k}-1}$ *and* $D_{PP}^{j,\hat{k}} = \hat{\theta}(1-\beta^{\hat{k}-1})$ *in the* $\hat{k}$*th cycle, for each* $j = 1, \ldots, n$, *and* $\hat{k} = 1, \ldots, \widehat{K}$. *Also,* $\widehat{D}_{PP}^{i,\mathrm{ALL}} = D_{PP}^{j,\mathrm{ALL}} = \hat{\theta}(\widehat{K} - (n-1)(1-\beta^{\widehat{K}}))$, *for each* $j = 1, \ldots, n$, *and* $i = 1, \ldots, n$.

(*d*) *Suppose* $\theta = \hat{\theta}$ *and* $K = \widehat{K} \le n$, *then* $D_{PP}^{j,\mathrm{ALL}} \le D_{HS}^{j,\mathrm{ALL}}$ *for each* $j = 1, \ldots, n$.

Proof: (a) Since the jth sales rider will serve the $i = z(j, \hat{k})$th service zone in the $\hat{k}$th cycle, we know $\widehat{D}_{PP}^{i,\hat{k}} = D_{PP}^{j,\hat{k}}$ and $\widehat{C}_{PP}^{i,\hat{k}} = C_{PP}^{j,\hat{k}}$, for each $j = 1, \ldots, n$ and $\hat{k} = 1, \ldots, \widehat{K}$. By the assumption of our simplified HS model, the consignments to be delivered for the jth sales rider in the $\hat{k}$th cycle are equal to the consignments collected by the same sales rider in the previous $n-1$ cycles for that specific service zone. Since we assume that the consignments are equally likely distributed, only $1/(n-1)$ of the total consignments collected will be delivered. Thus $D_{PP}^{j,\hat{k}} = (1/(n-1))\sum_{\alpha=\hat{k}-n+1}^{\hat{k}-1} C_{PP}^{j,\alpha}$. Finally, $C_{PP}^{j,\hat{k}} = \hat{\theta} - D_{PP}^{j,\hat{k}}$ by assumption, which equals to $\hat{\theta} - (1/(n-1))\sum_{\alpha=\hat{k}-n+1}^{\hat{k}-1}(\hat{\theta} - D_{PP}^{j,\alpha}) = (1/(n-1))\sum_{\alpha=\hat{k}-n+1}^{\hat{k}-1} D_{PP}^{j,\alpha}$.

(b) $\lim_{\hat{k}\to\infty} D_{PP}^{j,\hat{k}} = (1/(n-1))\lim_{\hat{k}\to\infty}\sum_{\alpha=\hat{k}-n+1}^{\hat{k}-1} C_{PP}^{j,\alpha} = (1/(n-1))(n-1)\lim_{\hat{k}\to\infty} C_{PP}^{j,\hat{k}} = \lim_{\hat{k}\to\infty} C_{PP}^{j,\hat{k}}$, since $\lim_{\hat{k}\to\infty} C_{PP}^{j,\hat{k}} = \lim_{\hat{k}\to\infty} C_{PP}^{j,\hat{k}-\alpha}$ for $\alpha = 1, \ldots, n-1$. Furthermore, since $D_{PP}^{j,\hat{k}} + C_{PP}^{j,\hat{k}} = \hat{\theta}$ for any $\hat{k}$, we know $\lim_{\hat{k}\to\infty} D_{PP}^{j,\hat{k}} + \lim_{\hat{k}\to\infty} C_{PP}^{j,\hat{k}} = 2\lim_{\hat{k}\to\infty} C_{PP}^{j,\hat{k}} = \hat{\theta}$, and thus $\lim_{\hat{k}\to\infty} D_{PP}^{j,\hat{k}} = \lim_{\hat{k}\to\infty} C_{PP}^{j,\hat{k}} = (1/2)\hat{\theta}$.

(c) By assumption, $C_{PP}^{j,1} = \hat{\theta}$ and $D_{PP}^{j,1} = 0$. Thus $D_{PP}^{j,2} = (1/(n-1))\hat{\theta}$, and $C_{PP}^{j,2} = ((n-2)/(n-1))\hat{\theta} = \beta\hat{\theta}$. Now we show $C_{PP}^{j,\hat{k}} = \hat{\theta}\beta^{\hat{k}-1}$ by mathematical induction. Suppose the statement is true for $\hat{k} = k'$. For the case of $\hat{k} = k'+1$, $D_{PP}^{j,k'+1} = (1/(n-1))\sum_{\alpha=k'-n+2}^{k'} C_{PP}^{j,\alpha} = (1/(n-1))\sum_{\alpha=1}^{k'} C_{PP}^{j,\alpha}$ since $C_{PP}^{j,\alpha} = 0$ for any $\alpha \le 0$.

Thus $D_{PP}^{j,k'+1} = (1/(n-1))\sum_{\alpha=1}^{k'} C_{PP}^{j,\alpha} = (1/(n-1))\widehat{\theta}(1+\beta+\cdots+\beta^{k'-1}) = (1/(n-1))\widehat{\theta}\cdot((1-\beta^{k'})/(1-\beta))$ $= \widehat{\theta}(1-\beta^{k'}) = \widehat{\theta} - \widehat{\theta}\beta^{k'}$, which implies $C_{PP}^{j,k'+1} = \widehat{\theta}\beta^{k'}$. By mathematical induction, we have shown that $C_{PP}^{j,\hat{k}} = \widehat{\theta}\beta^{\hat{k}-1}$ and thus $D_{PP}^{j,\hat{k}} = \widehat{\theta}(1-\beta^{\hat{k}-1})$. Since each sales rider has conducted the same amount of operations in each zone, we know $\widehat{D}_{PP}^{i,\text{ALL}} = D_{PP}^{j,\text{ALL}}$ for each i and j. Furthermore, $D_{PP}^{j,\text{ALL}} = \sum_{\alpha=1}^{\widehat{K}} D_{PP}^{j,\alpha} = \sum_{\alpha=1}^{\widehat{K}} \widehat{\theta}(1-\beta^{\alpha-1}) = \widehat{\theta}(\widehat{K} - ((1-\beta^{\widehat{K}})/(1-\beta))) = \widehat{\theta}(\widehat{K} - (n-1)(1-\beta^{\widehat{K}}))$ since $(1/(1-\beta)) = n-1$.

(d) By Theorems 2(c) and 1(b), we are to show that $\theta(K-(n-1)(1-\beta^K)) \le (1/2)K\theta$. In other words, we are to show $(1/2)K \le n-1+(n-1)\beta^K$. This is true since $(1/2)K \le (1/2)n \le n-1$ for $n \ge 2$, and $(n-1)\beta^K$. Thus $D_{PP}^{j,\text{ALL}} \le D_{HS}^{j,\text{ALL}}$ for each $j = 1, \ldots, n$, when $\theta = \widehat{\theta}$ and $K = \widehat{K} \le n$.

Although our mathematical models are rather simplified, our analyses are first-hand, to our knowledge, in deriving the amounts of consignments collected and delivered by each sales rider in each service zone during each cycle for both the hub-and-spoke and PP courier networks. A few insights can be concluded from our analyses. For example, Theorem 2(b) implies that a PP sales rider will finally collect and deliver the same amount of consignments in the long run. However, in practice there are usually no more than ten cycles within one workday, thus a PP sales rider will collect more but deliver fewer consignments, compared with an HS sales rider. Theorem 2(d) also shows that the HS model will deliver more consignments than the PP model within one workday, under the same circumstance when there are more consignments. This again certifies our intuition that an HS sales rider has better distribution efficiency, as discussed in Sections 1–3.

Other than the amounts of collected and delivered consignments, our mathematical models also provide a means to estimate the optimal duration for the time spent in each service zone and hub, or to estimate the best number of cycles, to maximise the amount of delivered consignments. Using different objectives or more complicated constraints and assumptions, our models can be further extended to give better understanding on the theoretical behaviours for these two courier networks.

5 A successful example

Here, we give a case study on the business model of Global Business Express Co. (GBE), the largest and most successful motorcycle courier service in the Taipei metropolitan area. GBE started its own business in 1998. During these seven years, it evolved from a small company of ten employees with daily volume of 50 consignments and annual revenue 500,000NTD, to a large express cooperation of 195 employees with daily volume of 5000 consignments and annual revenue of more than one billion NTD. It is the only motorcycle courier service in Taiwan that exploits the hub-and-spoke network.

GBE divides the Taipei metropolitan area into more than 110 service zones. Its current practice is as described in Section 2.3. Presently, GBE uses a single hub, which gives a 90-min guarantee for consignments to be delivered inside Taipei city, whereas a conventional PP courier service may take 150 min on average. A GBE sales rider accomplishes 50–70 consignments per business day on average, whereas a conventional PP sales rider usually finishes 15–25 daily consignments.

What makes the GBE model so special is not only its hub-and-spoke network, but also the hierarchical management structure of the sales riders. In particular, each sales rider not only conducts the routine deliveries, but is also encouraged to seek new customers (i.e., explore new markets). When the amount of consignments achieves a predefined threshold due to the large number of customers, an old sales rider may seek new sales rider (who may be assigned by the company) to share his workload, and the old sales rider takes commission on the consignments accomplished by the new sales rider. In the mean time, the old sales rider can spend more time seeking new customers. This hierarchical management structure of the sales riders successfully increases the market shares and the revenue of GBE. It not only encourages the sales riders to explore new markets, but also resolves the problem of sharing the extra workload caused by more consignments.

6 Conclusions and suggestions

With the growing economy and the convenient communication channels, demands for more personalised and faster delivery services are increasing, especially in the metropolitan area where more enterprises are located in high buildings. In this paper, we study the metropolitan courier service using motorcycles, which are mobile and convenient even in the limited parking space.

The PP courier network incurs less capital investment owing to its simplicity in operations and organisation structure, while the quality of its service is more erratic and becomes worse when the scale of demands increases and locations of demands are more scattered around. The business model of a PP courier service is easily duplicated. To prevent the cutthroat competition, a PP courier service should better seek new markets such as faster delivery or outsourced human resource service. Special training to the sales riders of a PP courier service may be helpful for conducting outsourced human resource service.

The hub-and-spoke courier network requires more capital investment. Although it has better quality of service and faster turnaround time, there are still several aspects requiring more consideration for further success. The successful example of the Global Business Express suggests an intriguing hierarchical management structure of the sales riders, which can not only increase the market share but also encourage the loyalty and hardworking attitude of employees. The idea of serving each zone by the same sales rider will also help possible future business opportunities, which is definitely more advantageous than a PP courier service whose customer may be served by different faces all the time.

Since there is no literature in the motorcycle courier service, to our knowledge, this paper tries to take the first step. Our proposed simplified mathematical models provide useful information and means for further analysis. Our first-hand analysis in the total amounts of collected and delivered consignments also certifies our intuition to select a hub-and-spoke courier network rather than a PP courier network for the cases of more demands. There are still many potential research topics worth investigating, for example, a simulation model for testing the optimal strategies for the number and location of hubs, or the applicability of the game theory for airline business models to the motorcycle courier services.

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