A Pilot Study for Measuring Roadway Exposure Through GPS Watches Worn by Bicycle Messengers and Food Delivery Workers During Work Shifts

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Abstract

We conduct a pilot study on the delivery trips of bike messengers and food delivery workers using GPS-derived data to understand these gig economy jobs. Between July and September 2018, 19 workers were equipped with GPS watches for two consecutive days (n=38 participant-days). One-second signal data was classified using an algorithm to identify idle time periods between trips. This enabled us to extract times, speeds and distances on the road, as well as idle time blocks and as a share of total work shift. Extrapolated data on number of deliveries is compared with exit interview recalls as benchmark. Workers travel on average 31km (SD=13.3km) in shifts of over 5 hours (316 min., SD=84.4 min.) and conduct on average 20 deliveries (SD=5.8). They spend on average 10 min. bouts waiting for food or packages (SD=2.8) and spend on average 36% (SD=11%) of their work shifts on the road. The pilot provides important information on shift characteristics and deliveries and indicates the importance of time idling waiting for packages. This suggests greater per time and per kilometer injury risks than could be estimated when assuming workers are always on the streets. In a context of commission-based work, idling also reduces potential wage.

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Keywords: Bike; Deliveries; Distance; Idle time; gig economy

1. Introduction

Bike messengers and food delivery workers spend considerably more time on central city streets than most utilitarian cyclists and are therefore exposed to considerable amounts of injury risks (Denerlein and Meeker, 2002; Heyer et al. 2015; Lachapelle et al., 2020). Because of the organization of labor in this field, little data is available to assess characteristics of this work and how it translates to exposure to risk.

This paper aims to explore the use of Global Positioning System (GPS) tracking devices—a tool that has become increasingly popular in analyzing physical activity (Heesch et al., 2016), bicycle trips (Lißner et al. 2020) and travel behavior (Elis et al. 2014) but which has yet to be applied specifically to bicycle workers (also referred to as commercial cyclists). Our objective is to explore the feasibility of collecting, transforming, and using the resulting exposure measurements.

Although methods for recording the training data of cyclists is well developed, bicycle messengers and food delivery workers make trips that can be rather problematic because these individuals enter and exit buildings (restaurants and domiciles) regularly. This can cause GPS signals to be lost and can potentially compromise the quality of the gathered data. It also makes overall averages of speed and time on the road less meaningful.

In this study, GPS watches were provided to a restricted sample of bicycle workers in order to: 1) evaluate the feasibility of using these watches to accumulate data on trips made by bicycle workers; and 2) test the production of travel measurements (average speed, distance duration of single trips and work days, portion of time spent on the road) that could be used to define working conditions and evaluate workers' exposure to risk and 3) test an approach to identify territories of activity. The data could also serve in future studies as denominators when calculating time and distance-based incidence rate of collisions and injuries for these workers.

After presenting key elements of literature on bicycle messengers and food delivery workers, we present our pilot study protocol and data processing procedures. The presentation of results is followed by a discussion on the value of the data, its potential uses and contribution to documenting the experience of this group of workers.

2. Literature review

2.1. From niche messengers to mainstream gig economy: the collective benefits and individual drawbacks

While bicycle messengers have long been seen as fixtures of the urban landscape and useful assets in logistics chains involving moving small goods over modest distances in the fastest possible ways, they remained a niche market for years in western cities (Wehr, 2009). This changed considerably with the growth of food delivery apps using workers on bicycles to complete deliveries. Companies such as *Uber Eats, Foodora, Just Eat* and *Deliveroo* have grown at a rapid pace and food delivery workers can be seen travelling the streets of many cities, especially at lunch and dinner time. Considering the growth of different forms of employment involving the use of bicycles in recent years, very little research has been produced to objectively characterize their work.

Three intersecting research fields can be defined with respect to bicycle deliveries. First, sociological studies are interested in the nature of the work and the struggles for workers' rights, pointing to the difficult work conditions, time pressures, and high level of risks (Fincham, 2006; Wehr, 2009; Pupo & Noack, 2014). Second, sustainability and logistics research seek to explore this new last mile logistics model, define best use cases, and measure related emission reductions associated with avoided motorized trips (Maes & Vanelslander, 2012; Koning & Conway, 2016; Conway et al., 2017; Rudolph & Gruber, 2017; Christie and Ward, 2018). This research typically focuses on larger cargo bicycle deliveries although some interest in smaller package delivery exists (Aguilera et al., 2022; Dablanc et al., 2017). Finally, health and safety studies try to understand the risks involved in such forms of work: injuries, etiology of injuries and the possible implications for policies and health coverage (Dennerlein & Meeker, 2002; Van Belleghem & Bourgeois, 2004; Baverstock et al., 2007; Kudask et al., 2010; Lachapelle et al., 2021).

Exposure to injury risks potentially occurs throughout a work shift but it can be argued that the risks for most important injuries may occur on the streets while conducting deliveries due to expected speed of deliveries, roadway conditions unfavorable to cyclists and interactions with other road users in various traffic conditions and road environments (Lachapelle et al., 2021). Roadway environment know to increase risk in leisure and commuting cyclists include namely intersections, multi-lane roundabouts, major roads with higher speeds and higher volumes and roads with on street parking and without any cycling lanes (Reynolds et al., 2009; Vanparijs et al., 2015; Pucher and Buehler, 2016; DiGioia et al. 2017).

In most cases, workers receive orders over phones or apps, move to pick up package, may be required to wait if the food is being cooked and package finalized, and ride to the delivery location. Workers are expected to go beyond the curbside and make door-to-door deliveries which may involve going up and down stairs and through buildings. Studying bike messengers in Chicago, Dennerlein and Meeker (2002) anecdotally pointed to the important share of work time spend off a bike. In the words of one of their participants: “I feel I ride elevators more than my bike” (p.522). This makes per hour basis incidence rates difficult to compare with other similar jobs or activities. Time spent in on-road delivery and distance travelled can thus be used to define exposure (Lachapelle et al., 2021) and as denominators in incidence rate measures. But this type of data is seldom available outside the platforms that connect delivery workers to delivery tasks.

2.2. Using Global Positioning System (GPS) to study active travel, environments, and workers

Increasingly, studies on active travel have deployed GPS systems on the field to track routes, make spatial based environmental measurements or derive measures related to travel. Apparicio et al. (2016; 2017) have, for example, used them together with noise and air quality monitors on a group of trained assistants to capture environmental data at the level of micro-environments in Montréal, Canada. Such studies avoid the issue of training participants to use the devices.

A systematic review (Krenn et al., 2011) of 24 studies using GPS data to study physical activity and active travel of different types of population has identified a number of issues that are frequently identified in studies that rely on participants with limited training in using GPS devices. This includes battery failures that lead to incomplete data and loss of information as well as incomplete application of use protocols, which can be too complicated to follow by participants. Furthermore, loss of information due to loss of signal occurs with many of these studies. Hutt and colleagues (2021) as well as Merry & Bettinger (2019) point to the greater risk and higher frequency of signal loss in central city areas. In addition, not all studies are conducted within a detailed spatial framework. Webber & Porter (2009) focused on the timing over the day, distances, and travel times of older pedestrians without focusing on the details of travel locations. Their analyses suggest that moving from outdoor to indoor environments complicates data collection.

There are few available studies using GPS on workers and they usually involve workers in very formal contexts such as policing. Beyond measuring distances, speeds, times and locations, Hickman et al. (2011) harnessed the power of GPS watches equipped with heart rate monitors to assess the stress levels of police officers in space-time contexts. Hutt et al. (2021) have used GPS traces to study where police officers have patrolled and suggest that slow refresh rates lead to unclear and incomplete location data and obscure the use of informal pathways such as going through parks or using an alleyway. Signal refresh rates at every second should likely be warranted when studying workers expected to swiftly move across space.

The current study harnesses some of these learnings to inform the data collection protocol. It focuses on simplifying the participants’ experience and deriving simple and useful data to assess factors influencing safety and to better describe the work experience of delivery workers.

3. Methods

3.1. GPS data collection protocol

As part of this pilot study, we sought to evaluate the feasibility of using geolocation data to assess the activities of bicycle delivery workers. The process should enable the production and analysis of actual activities during a work shift. These include exposure and risk-related variables among bicycle workers (number of trips routes, travel time, kilometers covered, average speed, time spent on the road vs. time spent making deliveries/waiting for orders), as well as work related indicators: number of deliveries, wages and hourly wages. A literature review suggests that distance, time and trips have been used as measures of exposure (Vanparijs et al., 2015). We sought to develop a protocol that generates all three measures and others more specific to delivery workers.

To collect this data, we used Garmin FENIX 3 watches, which we programmed to collect positioning data every second. The watches were also programmed to calibrate themselves based on GPS (Global Positioning System) networks and the GLONASS (Global Navigation Satellite System)—the Russian equivalent of the GPS satellite. The combined use of these two systems allows for more precise measurement points from the ground.

3.2. Recruitment of participants

Between July and September 2018, we recruited 19 bicycle workers that were asked to wear a GPS watch over two workdays. Bicycle messengers and food delivery persons were selected to conduct this pilot since they represent the largest group of bicycle workers in Montreal. The initial objective was to meet with 10 messengers and 10 food delivery persons. We also sought to put together a sample that included an equal number of male and female participants. Due to the temporary nature of the work and the lack of official data on workers, it is impossible to ensure that the sample is representative.

Three recruitment strategies were used: 1) As part of a larger study (Lachapelle et al., 2020; 2021) interviews were conducted. Some participants to the interview process expressed an interest in this pilot study and were re-contacted when this phase began. 2) These participants helped us contact other potential candidates through snowball recruitment. Finally, 3) bicycle workers frequently gather at specific locations after their workday or during shifts. The project research assistant met with them at these specific locations, presented the project and exchanged contact information with interested individuals.

Once participants agreed to be included in the study, research assistants and the participants set a time and place to meet to sign the consent form, explain the protocol, collect basic information, and provide them with the GPS watch, information on use and one-page user documentation to ensure seamless data collection. Two days later, our research assistant met participants again to collect the watch and carry out a debriefing interview. Text messages were sent to the participants to confirm the two meetings and to ensure that the GPS watch was being turned on and off at the beginning and end of the day (Figure 1). The debriefing interview asked to comment on the routes that were used, whether this seemed representative of a usual workday, how much money was earned, how many deliveries were carried out and if participants had additional comments they wanted to share with the research team.

Based on the consent form, participation would be suspended if a participant became involved in a road accident or if the participant requested to be excluded from the study. No requests were made to this effect. The research protocol was approved by the University's ethics board (project No. 2016_e1039).

3.3. Processing of data and analyses

The data generated using the watches is compiled in a database with an observation for every second and includes a timestamp, geographic coordinates (lat./long.) and speed recorded based on location of previous point. This data must be processed and aggregated to trips (deliveries) and to individuals. Information of interest includes total work time, time spent biking on the road and delivery periods (where the worker leaves his bike to enter buildings, whether to collect food from restaurants or to deliver food to individuals who have placed an order online or using a mobile app).

An ideal approach would have been to ask participants to stop their watches when arriving at a collection or delivery destination and start it up again before getting back on the road so as to readily collect specific trip level data. Considering that users were not necessarily accustomed to using this type of watch, and that this involves more manipulation, recall risk would have been quite high. We thus asked participants to start their watches up in the morning when leaving the house and stop them in the evening when getting back home. We chose this option to ensure that participants more naturally remembered to start and stop their watches, and because we could send SMS messages to verify that this was done. This ensured that information on some deliveries was not missed because a participant forgot to launch the GPS watch. Although this procedure is easier for the participant, it nonetheless requires additional classification of a continuous stream of raw data.

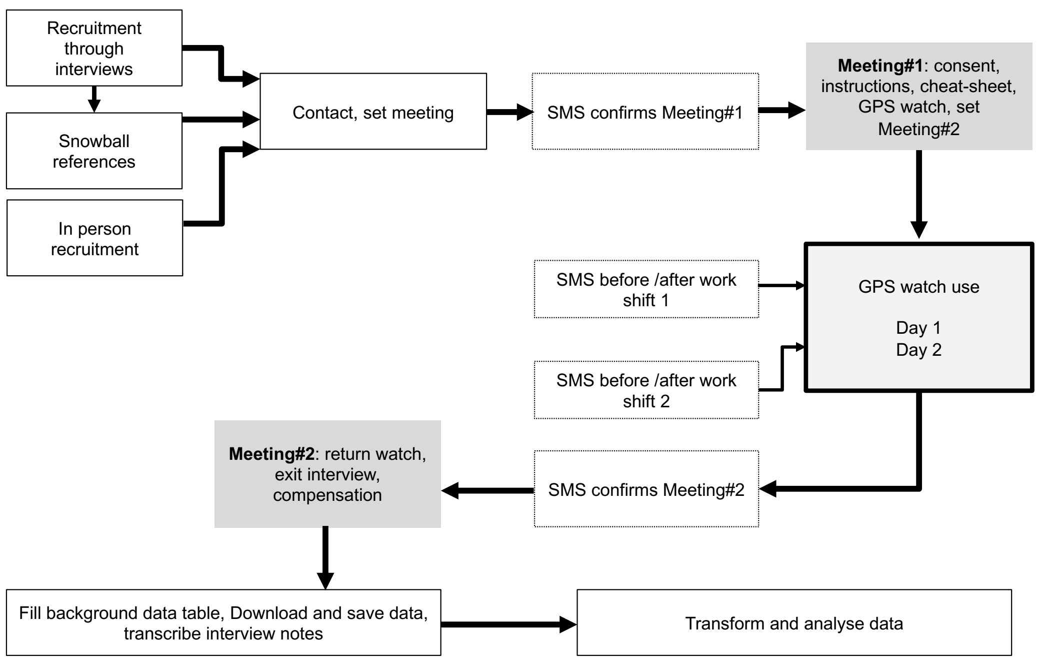


Fig. 1. Data collection protocol

A first procedure is therefore to identify the sections where participants are travelling on the streets and those where they are off their bicycles and making a pick-up or delivery. In order to identify which particular category a point of information refers to, an algorithm was produced to identify these periods. To identify periods of a delivery, three criteria were used to distinguish them from stops. A stop must have been done during a minimum period of 2 minutes and 30 seconds, record speeds of 5 km/h or less between data points (this corresponds to an unhurried walking pace) and the recorded points must be clustered near one another (less than 50 meters). The minimum time was established to be 2 minutes and 30 seconds to avoid pauses at traffic lights or times when participants stop to look at incoming orders or directions on their phone to be recorded as a delivery stop. These thresholds were established after examining the raw data and after a few coding iterations with shorter and longer time periods, shorter and longer recorded speed, and shorter and longer distance between points. The procedure involves first establishing where the stops were made and second, tracing the different trips and calculating the variables of interest. Data points were inspected manually and a Kernel Density Estimation (KDE) map was produced to assess areas of operation of sampled riders. Using QGIS 3.22, the heatmap is computed with quartic kernel shape, 500-meter Kernel radius and 50-meter cell sizes.

The watches generate periods of missing data (for example, when the GPS signal is obstructed by downtown buildings or when study participants enter a larger building), which further complicated the procedure. Some of these missing data had to be completely excluded since they create breaks in trips. In other instances, the missing data occurs during delivery times and must therefore be considered. When recording disruptions occur and the participant is forced to start the watch up again, a second file is generated and added to the first file.

The final files allow us to determine routes, distance covered, average speed and travel time for each delivery. They also allow us to calculate the number of trips, number of stops and total idle time (deliveries) spent during a workday. Delivery data were also compiled to provide total travel time, stopped time and distance covered during a given workday, as well as the share of a work shift spent off a bicycle or waiting for orders/meals to be prepared.

We descriptively present these results and compare them to key interview items, the reported commissions and tips (summed into salary) and the self-reported number of deliveries to assess the strength of correlation with our derived measures of number of deliveries.

4. Results

4.1. Travelers' GPS data, presentation of data

In total, we obtained data from 19 participants, each completing two work shifts over two consecutive days. We therefore received data representing 38 completed workdays. Table 1 shows that almost half of the participants-days are from women and most participants combine bicycle messengers and food delivery shifts (Combined). Exclusive food delivery workers were the least represented group. Although most of the work shifts involved food delivery, we nonetheless distinguished those exclusively doing food delivery because evidence suggest that those with background as a messenger continue this task for a longer period, have more experience as riders (Wehr, 2009; Fincham, 2007) and may ride faster (Lachapelle et al., 2020). Many participants explained that messenger delivery requirements reduced during lunch and dinner times and taking food delivery orders could help fill these downtimes in messenger service. All riders in this study used two-wheeled, non-cargo, non-electric bikes.

Table 1. Description of participants-days

	Messengers	Food delivery	Combined	Total
Male	10	2	6	18
Female	2	2	12	16
Prefer not to say	0	0	4	4
Total	12	4	22	38

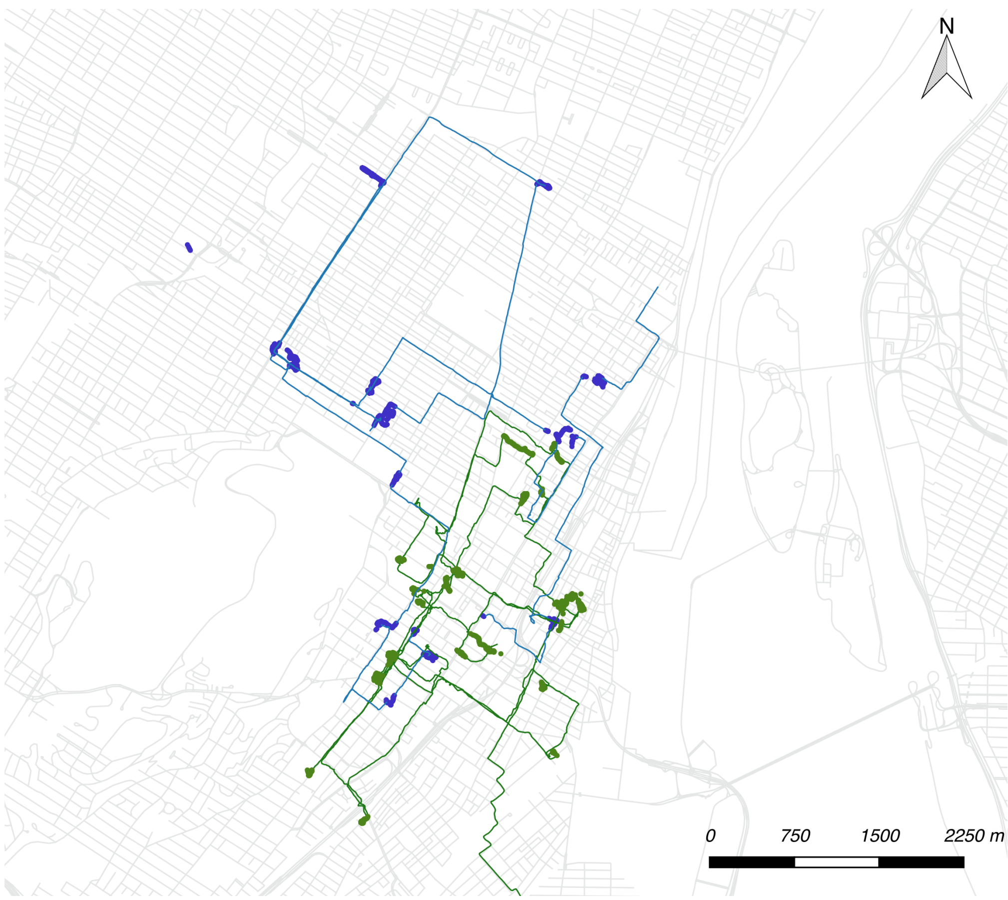
Figure 2 provides the GPS trace signals projected on the Montreal street network map for the workdays of two individuals (Worker 1: Messenger in green and worker 2: Food delivery in blue). It also shows in darker tones the cluster of points that we classified as being stops/deliveries.

The participants often find themselves on the same streets (where the businesses and offices are located) to pick up documents and packages or meals. Although we were not able to determine which stops were made for pick-ups (since items may have been delivered to a business) and which were made for deliveries (from business to customer), in general, the deliveries involved a relatively short distance. Food delivery does take participants into residential areas outside of the downtown core, as was the case for the Blue participant. The Green participant, for his part, conducted all his activities within or close to the downtown core, which suggests a business-to-business messenger sequence of deliveries. Visual exploration of the traces of all participants suggests similar patterns with messenger activities occurring mostly in the central business district and food delivery spilling over into residential neighborhoods.

By observing the paths of all participant-days using a Kernel Density heatmap (Figure 3), it seems that the territory covered is generally very similar, tends to be concentrated in the downtown core and can extend to approximately 10 km from the core. The linear shapes of the zones of higher density reflect repeated returns to commercial streets with multiple restaurants and businesses.

4.2. Overview of typical workdays: Total work time, both on the road and while stopped and/or waiting

Data classification and compilation of interview data allowed for the extraction of information based on the observed workdays (Table 2). Because of the modest size of groups, we calculated overall values. Participants declared that they earned an average of $87 during their shifts (between $60 and $125). It is estimated that the average value of a trip is $7.50 (We divided the salary by the declared number of deliveries). Work shifts lasted on average 5 hours and 15 minutes (315 minutes) and could last up to 9 hours. According to the GPS data, participants covered an average of 31 (SD=13.3) kilometers during a single day, with one particular participant covering over 74 km. Based on the classification described in the methodology, participants spent, on average, slightly over 36% of the time on the road, and always less than 60%. An average of 20 (SD=5.8) deliveries were carried out during a typical work shift (and up to 41). The average number of daily deliveries reported by the participants after their two workdays—13 deliveries—was considerably lower. Our classification algorithm of number of deliveries roughly matches stated deliveries (Spearman's rank-order correlation 0.563; sig. p <0.001) although both measures cannot be seen as fully accurate. Many of the participants admitted during the debriefing interview that this was only a rough estimate and that they rarely calculated the number of deliveries they made. Apps for food delivery workers did provide this information specifically but only two of our participants (four workdays) could report using this system. While self-reported



number of deliveries is therefore not the most accurate benchmark, it does provide some confidence that the delivery-identifying algorithm is reasonable.

Fig. 2. Example of two GPS traces (green messenger and blue food delivery) during one delivery workday, with clusters of stopped point (pickup/deliveries) indicated in darker tones

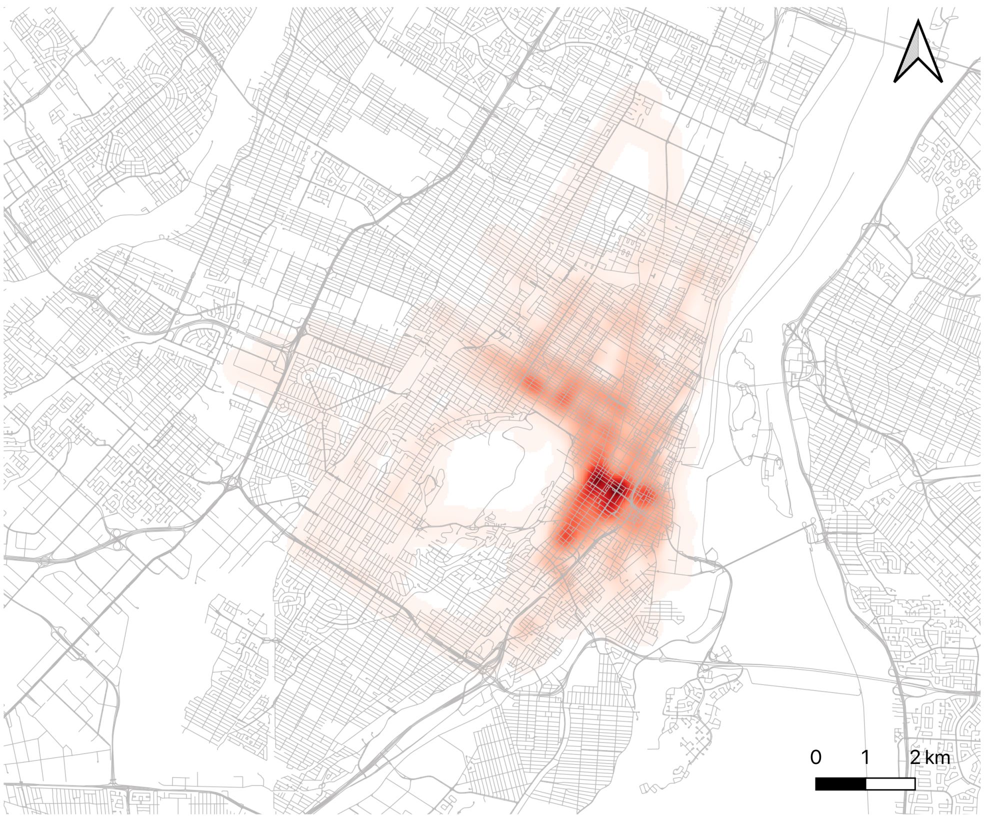


Fig. 3. Kernel Density Estimation of deliveries showing concentration in the Central Business District (Darker red for higher densities)

4.3. Overview of separate deliveries: Speed, time spent on the road and time spent stopped and/or waiting

The average speed during all delivery trips was 16.6 km/h, but could reach an average of 20 km/h overall for one single trip. Trips covered an average distance of 1.8 km and the average travel time for a single trip was 7 minutes. Stops lasted an average of 10 minutes (SD=2.8). Some of the participants claimed during interviews they sometimes had to wait for delivery orders for quite a while before they could leave again. For messengers, the time required to make their way up and down office buildings to deliver documents and packages could potentially also be considerable.

5. Discussion: Data limitations and issues stemming from the use of GPS data for a delivery worker population

The work done to collect GPS data provided a variety of informative data on the workdays of participants. There were however inherent issues related to the recruitment of participants, data collection as well as concerning the technology used and work circumstances. Because of the absence of a structure or network of workers, recruitment was dependent on participants' willingness to refer other potential participants and was more difficult than expected. Our sample should not be considered as fully representative of cyclist workers in Montreal where we would expect food delivery workers to account for more than half of workers.

During the data processing stage, we identified invalid data episodes (lat/long coordinate errors and/or speed recording errors), with a mean of 4.8 lost min. over a day (SD=13.6, just over 1% of total time). Such issues are quite standard in research based on GPS data (Krenn et al., 2011) and are, in this case, modest.

Table 2. Information produced on the workdays of participants

	Observations	38			
		Mean	Standard deviation	Minimum	Maximum
Declared revenue					
	Total salary ($)	87.0	21.1	60.0	125.0
	Salary/delivery ($)	7.5	3.2	3.1	20.8
Work time					
	Total time (minutes)	315.7	84.4	116.2	537.4
	Travel time (minutes)	114.6	48.4	41.4	266.4
	Stopped timed (minutes)	201.1	66.7	57.2	416.2
	Proportion spent on the road	0.36	0.11	0.16	0.56
	Missing data (minutes)	4.8	13.6	0.47	71.5*
	Proportion of missing data	0.01	0.03	0.00	0.15
Information on the day					
	Number of trips	16.9	5.0	8	39
	Number of deliveries (stops/2)	20.4	5.8	8	41
	Distance covered (meters)	30,961	13,353	11,099	7,4398
Data on trips					
	Average trip time (minutes)	6.8	1.9	3.2	12.2
	Average stopped/delivery time (minutes)	10.1	2.8	6.6	18.0
	Average speed	16.6	1.8	12.2	19.9
	Average trip distance (meters)	1,834	561	854	3916

Note: One participant inadvertently shut down his watch during. A procedure to lock the watch was instilled afterwards.

Two participants stated that they accidentally hit their watch, stopping the recording process as a result. After this occurred, a procedure for locking the watches (where stopping recording required pressing a button during a longer period) was suggested and proved to be an effective solution. Since we asked participants to record two back-to-back days of data, two bicycle messengers who worked longer hours were subject to battery failure on the second day of recording. This likely impacted the correlation between estimated and recalled number of deliveries.

Although we attempted to validate the data obtained using the GPS with information reported by the participants when the watch was returned, we noticed that participants frequently had difficulty reporting data related to the number of deliveries and their salaries. The initial data can often disappear from the phone apps they use at the end of the day or, depending on how certain companies operate, it is not directly recorded. Few of the participants in our sample were naturally concerned with keeping track of the details of their daily activities. In hindsight, prompting participants to collect this information in the entry interview so as to have more accurate data in the exit interview would be warranted.

With respect to salary, depending on the organizational methods of different companies, the total salary amount (including tips) is not always clearly available to workers at the end of their work shifts. Moreover, tips are sometimes shared among workers. In other instances, workers are simply unclear as to the value of the tip. Many stated that the declared salary for the day was only a rough estimation.

Many of the participants enjoyed being able to visualize the data related to their trips, the kilometers covered and the calories burned over the course of the day on a tablet (or phone) connected to the watch during the exit interview. While some of them use fitness apps such as Strava, many do not have means to obtain summaries of their activities.

6. Conclusions

This article focused specifically on objectively exploring the delivery trips of food delivery workers and bicycle messengers. We were able to observe the multiple trips that form a work shift and thereby obtain a relatively accurate portrait of work time, travel distances, travel speeds, delivery number and distances and time spent idling and waiting for a package. The data also provides information on the work zones covered by workers.

The study's participants recorded work shifts between 2 and 9 hours, covered an average of 30 kilometers (minimum 13.3; maximum 74.4) and made between 8 and 41 stops (average of 20 stops). The average speed during their trips was 16.6 km/h, average delivery distances were of 1.8 km (average travel time of 7 minutes) and stops lasted an average of 10 minutes. We calculated that, on average, 36% (maximum 53%) of the work shift was spent on the road, where the workers were exposed to road injury risks. Off road time are not necessarily entirely safe as other types of injuries can occur. Our study is the first to record idle time of workers and the share of time spend waiting for deliveries.

While there are few sources for comparable data, Boston messengers studied by Dennerlein and Meeker (2002) self-reported a mean of 28.5 deliveries per day over 8.5 hours days on average. In Aguilera et al. (2022)'s study, 48% of Parisian food delivery workers made between 10 and 20 deliveries per day and another third reported more than 20. The same study identified that 84% of deliveries were less than 5 kilometers. In London, Allen et al. (2021) found that food delivery workers made on average 9.6 deliveries of 2.2 kilometers and travelled a mean of 41.3 kilometers over a day. While there is no record of speeds of bicycle messengers and food delivery workers, Bernardi and Rupi (2015) found that utilitarian and leisure cyclists in Bologna traveled at between 15 and 22 km/h, with cyclist moving faster while riding in mixed traffic. Given differences in the studied populations and locations, these results make our observations plausible and support the use of multiple exposure metrics to calculate incidence rates (Vanparijs et al., 2015). Somewhat surprisingly given the importance of speedy deliveries, our sample of bicycle worker does not seem to travel much faster than the utilitarian and leisure cyclists observed by Bernardi and Rupi (2015).

Our approach demonstrates the value of producing data on characteristics of the job and basic risk exposure (i.e. time on the road) as well as potential injury rate denominators. More in-depth data and data analysis would be required to identify the actual use of bike paths or high-traffic or higher speed streets, for example, through map matching to data-rich GIS roadway layers. Such information could help better understand the preventive measures used by bicycle workers and the detours the latter are willing to make in order to avoid more dangerous streets. Given the fast growth in this group of bicycle worker and the paucity of data on their activities, there is an important need to improve our knowledge and ability to capture information on their behavior, working conditions and risk exposure. Future work should strive to recruit a representative sample of the messenger and delivery worker population.

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