MAPPING ACCRA'S JITNEY NETWORK WITH SMARTPHONES: THE ACCRAMOBILE EXPERIMENT

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ABSTRACT

This paper presents a data collection exercise conducted by the Department of Transport of the Metropolitan Assembly of Accra, Ghana, to further its knowledge of transportation services placed under its jurisdiction. In order to map the city's transportation network, a partnership was developed between local authorities and a Canadian university with the support of the French bilateral development agency. The implementation of an innovative methodology based on the use of smartphones and digital technologies allowed the project team to collect and map 315 jitney routes in less than two months. Collectors equipped with GPS-enabled smartphones surveyed Accra's formal jitney network in its entirety and daily transmitted data to a team overseas in charge of mapping and analysis. The first map of the city's transportation network is presented here and preliminary observations are drawn from it. An original insight into the spatial distribution of the demand for transportation in Accra is also presented through the mapping of passengers' boarding and alighting. This research opens both methodological and operational perspectives. In the wake of previous works, it contributes to a growing body of literature on jitneys and transportation planning in developing countries. It also demonstrates that transportation data can be collected with limited time and resources through the use of mobile technologies. From a practical point of view, this data will assist the authorities in regulating, planning and developing Accra's transportation network.

Keywords: Ghana; smartphones; data collection; jitneys; network mapping

DISCLAIMER

The views expressed in this article are those of their authors only and do no not necessarily represent the position of their respective institutions.

INTRODUCTION

Cities in the developing world face a common challenge when trying to better organize their transportation systems: they lack accurate and spatialized information on the existing transportation network. Without a clear picture of what is already in place, it is difficult for them to know how to improve it. This is partly because a large share of transportation services is provided by semi-formal operators who cannot be precisely monitored, and partly because transportation data collection is a complicated and costly exercise. The Department of Transport (DoT) of the metropolitan assembly of Accra (AMA), Ghana, encountered this issue shortly after its creation in 2015. Although responsible for the regulation of a vast network of minibus and taxi operations, it lacked essential information on the geographic distribution of the hundreds of routes falling under its authority.

This was an impediment to the fulfillment of its mandate to register, plan and regulate the provision of small-scale transportation services. In this context, the DoT approached a partner development agency (Agence française de développement) with a specific project: mapping the city's jitney network with a very limited budget and within a short time frame. This objective was achieved through a partnership with an academic institution (Concordia University, Canada), which allowed for the development of an efficient and innovative methodology, based on the exclusive use of mobile phones for data collection. This paper presents the results and lessons learnt from this experiment.

BACKGROUND

Mobile technologies in data collection

A vast body of literature exists documenting the use of mobile phones for data-collection purposes. The GPS capabilities of recent handsets, in particular, have been successfully leveraged to record and analyze spatialized data. Examples of this include the use of cell phones to monitor traffic conditions (*1*), infer transportation modes (*2; 3*), model route-choice behaviors (*4*), and study transportation routines (*5*). Another stream of research uses data collected by telecommunication operators to study users' behaviors through the location of their phones. These large amounts of data, though generally coarse-grained, have been exploited to generate origin-destination matrices (*6*), study traffic conditions (*7*) and analyze the spatial distribution of telecommunication activity (*8*).

Building on the concept of "technological leapfrogging" (*9*), scholars and experts from the development community consider that information and communication technologies (ICTs) open new opportunities for developing countries (*10-12*). By directly adopting the most advanced ICTs, these countries could leap over less efficient, more cumbersome technologies – and even gain a head start on developed countries. At the forefront of promising ICTs are mobile technologies. In Kenya, for instance, the innovative use of cell phones has allowed health professionals to better keep track of patients' information (*13*). Our research seeks to contribute to this global dynamic by adopting progressive tools and methods for data collection in Ghana.

Network mapping in developing countries

Germane to our project are previous endeavors to use mobile phones to survey the transportation systems of large cities in developing countries. In Bangladesh, smartphones were used to map the bus network of Dhaka, in an attempt to strengthen the users' understanding of the transportation system (*14*). In the same vein, Eros et al. (*15*) use an Android application tracking the user's location to develop a map of Mexico City, in a project supported by the World Bank. Finally, a collaborative mapping experiment was recently conducted in Nairobi, Kenya (*16; 17*). This project, called Digital Matatus, uses cell phones to collect data on minibus routes and stops in order to create a map of Nairobi's transportation network. The data is compiled in Google's General Transit Feed Specification (GTFS) standard and made publicly available, thus allowing others to use it to develop transport-related applications for smartphones.

Although close to our research, these experiments differ from our work in their scope and approaches. While the Dhaka and Digital Matatus projects both focus on passenger information, the goal of our research is to assist local authorities in their transportation planning mandate. Our data is therefore primarily aimed at informing public policy decision-making. Another specificity of the AccraMobile project results from the constraints to which we were submitted. Having to work with limited financial and time resources, we designed a methodology that allowed us to simultaneously carry out the data collection and mapping tasks, thus allowing the mapping to be done in a short period of time.

Jitneys in Ghana

Ghana joined the club of middle income countries in 2011, at a time of fast economic growth following the discovery of offshore oil resources. Although its economy has since been in turmoil, the country still registers fast population growth and rapid urbanization, resulting in increased congestion and demand for transportation (*18*). One of the characteristics of the public transport

sector in Accra, as in many cities of the developing world, is the prevalence of jitney services. Operations by medium-capacity vehicles, ranging from large jeeps to minibuses, have been documented in different parts of the world, from Latin America to Asia, and most notably, Sub-Saharan Africa (*19-21*). The emergence of these private transport services is often linked to the demise of state-owned transportation companies due to their inability to sustain profitable business models (*20; 22*).

In Ghana, the collective minibuses commonly called "trotros" are usually second-hand passenger vans or retrofitted utility vehicles. A typical trotro seats approximately twenty passengers, in addition to a driver and a conductor. The conductor is responsible for collecting fares, announcing stops and helping passengers to get on and off the vehicle. Issues associated with this transportation mode have been documented at length in Ghana and elsewhere. They include poor vehicle maintenance, aggressive driving and erratic stopping – which, in turn, result in pollution, accidents and congestion of the road network (*23; 24*). Nevertheless, jitneys remain vital to mobility because of their affordability and of the flexibility of the service they offer (*25*).

The legal status of these services ranges from fully licensed operations – registered with local authorities, affiliated with a union and operating out of dedicated terminals – to completely informal ones – picking up passengers on the side of the road and often competing with official trotros for customers. Despite this semi-formal nature, the trotro industry is both internally and externally regulated. Firstly, operators' unions exert a strong control on the sector. These associations manage transportation terminals, allocate routes to their members, and regularly sit with the Ministry of Transport to negotiate harmonized fares. Secondly, municipal assemblies have gradually increased their regulatory role as part of a donor-funded project started in 2008. They now register the routes, drivers and vehicles operating within their boundaries. It is in this context that AMA's DoT sought to acquire a better knowledge of the services placed under its jurisdiction.

Paper's contribution

An abundance of works have explored the use of mobile technologies in transportation studies. However, few of these works apply their innovative methods to the particular context of developing countries. Our research contributes to filling this gap by making use of smartphones to map Accra's transportation network, in a spirit of technology leapgfrogging. Unlike previous endeavors, it does so to provide local authorities with operational data for transportation planning. Additionally, this paper will add to an emerging body of literature on jitneys in developing countries.

METHODOLOGY

Scope of the study

This research focuses on jitney services operating within the boundaries of AMA. This municipality is host to both the civic center of the nation (where most ministries are located) and the biggest marketplace of the country (a neighborhood known as Makola). For these reasons, along with its central location and historical significance, AMA is at the core of Accra's urban transport network.

The scope of this study is limited to operations having their origin or destination within the boundaries of AMA. As mentioned above, trotros operating from designated terminals have to

register their activity with municipal authorities. Our initial survey plan was therefore established based on this registry. A preliminary desk study was conducted to eliminate irrelevant records and produce a list of 580 unique routes to survey. Long-distance services (reaching outside of the metropolitan area) and duplicate routes were excluded from this list. Each route was subsequently divided into two trips (outwards and return), thus constituting a list of approximately 1,160 trips to record. This list was distributed between eleven collectors, having three routes each (that is, six trips) to record every day.

Although this survey was designed to be as comprehensive as possible, it should be remembered that not all trotros in circulation belong to sanctioned operations. The DoT estimates that as many as half of the trotros on the streets could be unregistered services – therefore not captured in this study.

A single data-collection tool: the smartphone

After setting the scope of this survey, we developed a data collection protocol defining guidelines for the recording, treatment and transmission of data. This was achieved through an iterative process between the academic and operational teams. The university provided a methodological basis, which was adjusted by stages following test phases on the field. Figure 1 illustrates the roles and interactions of the two teams throughout the project.

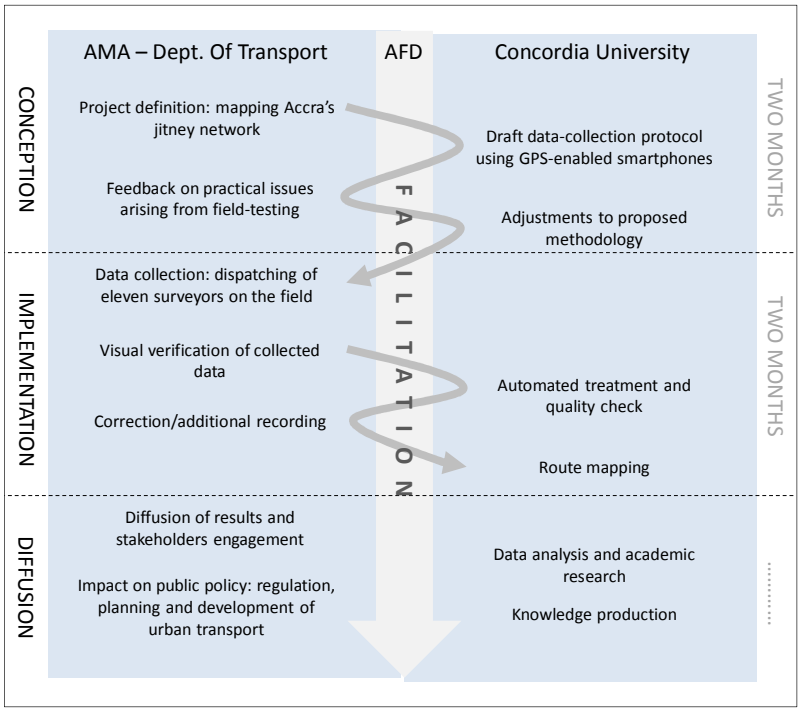

FIGURE 1 Project flowchart illustrating task distribution and interactions.

The singularity of the approach used for this data-collection exercise lies in the exclusive use of cell phones to record spatial information. Surveyors were equipped with mid-range Android cellular phones (Samsung Galaxy Discover SGH-S730M 3G models, purchased at a unit cost of

CAD 85$). Each phone came installed with two applications. The first application, called DataMobile (www.datamobileapp.ca), was originally developed by the TRIP Lab at Concordia University as a travel survey application. It runs in the background of the phone and records GPS points every thirty seconds. These points are automatically uploaded to a dedicated server at regular intervals and can be manually transferred as well. The second application is called Tap Log and was used to actively record stops along the trotro routes. It offers an intuitive interface to log different types of information: numbers, text, and GPS coordinates. In case the intensive use of GPS capabilities by the two applications reduced batteries too quickly, each phone was paired with a power bank providing the necessary autonomy to go through a full day of data collection. The smartphone thus constitutes an all-in-one data collection tool and there is no need for any form of paper record. This makes data transmission easier, saves transcription work and eliminates a major source of errors.

The typical day of a collector was organized as follows. In the morning, the collector comes to the DoT to pick up his charged phone and daily assignment. This assignment contains the origin and destination of the routes he needs to record, the name of the operator and a link to a map showing the exact location of the departure terminal. The collector keeps his phone turned off until he reaches the first terminal, so as not to record irrelevant GPS coordinates. Before boarding a trotro, he makes sure that his phone has a good GPS lock. Once onboard, the surveyor sits by a window and close to the conductor – this is to maximize GPS signal reception and be able to ask information on stops when needed. The surveyor uses Tap Log to record the number of people onboard at the time of departure, the fare paid for the trip, the time elapsed between boarding and departure, and data on each stop made along the way. Every time a passenger boards or alights the vehicle, a new record is created containing the name of the stop, its GPS coordinates and the number of passengers in and out. This routine is repeated for the six daily trips, and at the end of the day the surveyor goes back to the DoT to upload his data and put his phone to charge.

Two teams working in parallel in an iterative process

Upon reception of the data, the DoT performs a preliminary quality control by visually checking the coherence of manual inputs and spatial distribution of collected points. If no error is identified, records are transmitted to the team in charge of mapping and analysis in Canada. In order to map a trotro route, two different sets of data are combined: 1) the DataMobile data, which defines the itinerary of the vehicle and 2) the Tap Log data, containing information on the stops and identifying each record with a unique number. The two datasets are subject initially to automated processing that organizes the data collected and produces .shp files to be used in the stages requiring manual treatment. These two sets of data are visualized against the background of the road network of Accra. Each route is drawn in ArcGIS by connecting the points together using the "Trace" tool and following the most likely pathway. Figure 2 illustrates how spatial data collected using DataMobile is mapped in ArcGIS.

FIGURE 2 From data collection using DataMobile to mapping in ArcGIS.

Since DataMobile records GPS coordinates every thirty seconds, the path taken by the trotro is usually easy to infer. Besides, trotros tend not to travel at a very high speed because of congestion and of the frequent stops they make. The distance between two recorded points is thus generally limited.

In this project, the responsibility for data collection and data processing was split between two different teams. This division of labor allowed for the quick production of outputs through increased specialization and permanent feedback between the two teams. Using cloud storage services (Dropbox and Google Drive) also made it possible to seamlessly share data and have multiple users work on the same documents simultaneously. Inconsistencies and gaps in the collected data were readily identified and immediately corrected by sending collectors back to the field when needed. In this way, data quality issues were diagnosed and resolved "on the fly", instead of having to wait for the end of the survey period.

RESULTS

Learning from the data collection campaign

The first results of this experiment came from the process of data collection itself. Although the original scope of the survey comprised 580 routes, 315 were actually recorded. This is explained by the high number of registered routes that turned out to be inexistent or inactive. Inexistent routes resulted mostly from erroneous information given by the operators at the time of registration. Inactive routes, on the other hand, are said to be in use by an operator but are actually not being exploited. Our inquiries revealed that many operators preventively register routes that they think will be profitable one day in order to have a monopoly on them. Indeed, registering a route gives an operator an exclusive to operate it. While operators estimate that the current level of demand on some routes is too low to be profitable, they want to make sure that no competitor can thrive on them in the future. Becoming aware of the wide extent of this phenomenon was an important discovery for the DoT. It resulted in the exclusion of over 150 "ghost routes" from our survey sample, and helped the DoT get a clearer sense of the actual extent of active trotro services.

During the data collection phase, it also became apparent that the definition of what constitutes a route was not the same for all operators. In the hypothetical case of a service going from Terminal A to Terminal C via Terminal B, some operators register two different routes (A-B and B-C) while others count this trip as a single route (A-C). For the purpose of this study, routes were defined by the longest trip that can be made between two terminals without changing vehicles. Therefore, we decided to exclude registered routes that were actually consecutive segments of a longer route. This resulted in the further exclusion of dozens of ill-defined routes from our sample.

The survey also revealed that some services are only offered occasionally. Not surprisingly, there is little demand for transportation from the city center towards the periphery in the morning (and reciprocally in the evening), since most commuters reside in the outskirts of town. Operators thus tend to adjust the number of vehicles they provide in each direction to the movements of commuters. This causes certain routes to be only active in one direction during morning and evening peaks. Another example of occasional service was given by an operator catering to the specific needs of market women. These traders regularly privatized a vehicle to carry their wares to their place of business on market days. While interesting to observe, such services do not constitute regular operations and were therefore excluded from the scope of our study. In this respect, this data collection campaign was an opportunity for the DoT to update its records.

Route characteristics and variations

Throughout the data collection phase, a table listing all travelled routes and their characteristics was constructed. As the mapping exercise progressed, additional information on route length,

travel time and fare were added. Table 1 shows an extract of this database together with descriptive statistics on route characteristics. Each route is numbered with a three-digit identifier and split in two different records for outward and return journeys. The main variables associated with each record are the name of the operator group, the origin and destination terminals, the length and duration of the trip, the average speed of the vehicle, and the fare paid for the journey. Since each route generated a round trip (with the exception of nine "one-way" routes), it was also possible to measure the variation of these characteristics between outward and return journeys. Although changes in traffic conditions between the recording of the two directions might introduce a bias, this gives an idea of the effect of directionality on public transport. These results are presented below.

Route n°	Dir.	Operator	From	To	Km	Minutes	Km/h	GHS
...	...	...	...	...	...	...	...	...
238	A	Dansoman Branch of GPRTU	Dansoman	Circle	10.20	37	16.59	1.5
238	B	Dansoman Branch of GPRTU	Circle	Dansoman	10.90	81	8.05	1.5
239	A	Dansoman Branch of GPRTU	Dansoman	Mallam	7.72	21	21.59	1.5
239	B	Dansoman Branch of GPRTU	Mallam	Dansoman	7.64	39	11.85	1.5
240	A	Dansoman Branch of GPRTU	Dansoman	Nyamekye	9.80	38	15.40	1.7
240	B	Dansoman Branch of GPRTU	Nyamekye	Dansoman	9.53	32	17.64	1.7
241	A	Circle Overhead Branch of G.P.R.T.U	Circle Overhead	Bawaleshie	11.89	38	19.01	1.8
241	B	Circle Overhead Branch of G.P.R.T.U	Bawaleshie	Circle Overhead	11.83	46	15.39	1.8
242	A	Dansoman Branch of GPRTU	Dansoman	Odorkor	7.05	20	21.25	1.4
242	B	Dansoman Branch of GPRTU	Odorkor	Dansoman	7.02	21	20.40	1.4
243	A	Dansoman Branch of GPRTU	Dansoman	Santa Maria	11.15	32	20.77	1.8
243	B	Dansoman Branch of GPRTU	Santa Maria	Dansoman	13.05	54	14.40	1.8
244	A	Dansoman Branch of GPRTU	Dansoman	Accra New Tema	8.76	23	22.96	1.4
244	B	Dansoman Branch of GPRTU	Accra New Tema	Dansoman	8.08	31	15.87	1.4
246	A	Dansoman Transport Society	Dansoman	Mallam Junction	6.97	24	17.47	1.2
246	B	Dansoman Transport Society	Mallam Junction	Dansoman	7.15	27	16.15	1.5
247	A	Darkuman Branch of G.P.R.T.U	Darkuman	Agbogbloshie	7.97	37	12.95	1.4
247	B	Darkuman Branch of G.P.R.T.U	Agbogbloshie	Darkuman	7.43	47	9.50	1.4
...	...	...	...	...	...	...	...	...

N=629	Length			Time			Speed			Fare		
	km	var. in km	var. in %	min.	var. in min.	var. in %	kmh	var. in kmh	var. in %	ghs	var. in ghs	var. in %
Minimum	1.06	0.00	0%	3	0	0%	4.17	0.01	0%	0.50	0.00	0%
Maximum	38.71	11.22	331%	128	59	352%	59.24	41.74	295%	8.00	4.50	150%
Mean	10.03	1.21	17%	38	12	43%	16.07	4.72	42%	1.67	0.14	9%
Median	7.56	0.64	9%	34	7	30%	14.59	3.62	28%	1.50	0.00	0%

TABLE 1 Route Database Extract and Characteristics

We can see that jitney services in Accra span over a wide range of distances, from local hops to remote commutes. Longer routes are characterized by higher travel speeds (as fast as 59 km/h) resulting from fewer stops and the use of highway links. The median fare paid for a trip is 1.5 Ghana cedi (0.4 US dollar) and the average price per kilometer is 0.23 Ghana cedi (0.6 US dollar). This likely indicates a good level of affordability of public transport in Accra, although there is indication that commuters typically combine several trips to reach their destination (see below).

Although outward and return trips were recorded consecutively, they tend to display important variations in journey length, time and speed. The average variation in journey time by 43% might

be inflated by a few extreme values, but the median variation of 30% confirms a significant discrepancy between the two directions of a route. This figure illustrates the importance of directional peak hour traffic, as can be observed every day in Accra. While passengers converge towards the city center to tend to their daily activities in the morning, they migrate back to residential areas at the end of the day. As a result, one direction is generally more fluid than the other on any arterial road in Accra.

Equally interesting is the average variation in trip length by 17%. This difference suggests significant changes in itinerary between outward and return journeys. As with trip duration, these changes likely result from the effects of traffic on jitney operations. In an attempt to avoid heavily congested links, trotro drivers often resort to alternative itineraries, driving through back streets, construction sites and empty lots in order to save time on their trips.

Finally, it is worth noting that direction only marginally affects the fare paid for the trip. This suggests a strong adherence of the operators to the prices negotiated between the unions and the authorities. While this might be interpreted as a sign of effective regulation, the system of fixed fares also is a source of economic inefficiencies. Although operators spend on average 43% longer driving in one direction than the other, they charge passengers the same amount for both trips. This results in a disincentive to operate certain directions in case of heavy traffic, thus creating insufficient supply of public transport for passengers travelling on these routes. Long queues forming at terminals during peak hours attest to this phenomenon.

Mapping the network

Records in the database are associated with spatial data describing each route in both directions. For each direction, a .shp file representing the itinerary taken by the trotro is available. Using ArcGIS, these .shp files are combined to produce the first complete map of Accra's trotro network, presented in Figure 3. Looking at this map, it is important to recall that it gives a snapshot of jitney operations at a specific time rather than a definite picture of the network. As noted above, this transportation mode is characterized by a high level of variability: drivers on a given route might choose different itineraries between the same two points depending on the time of the day and traffic conditions. Nevertheless, the map clearly shows that trotro routes form a dense network providing transportation services to the whole AMA area. This map emphasizes the radial organization of Accra's road network. Circular movement is supported by the city's beltway (Ring road), while North-South flows are distributed by arterial roads. East-West traffic, on the other hand, is almost entirely constricted on a single link: the G. W. Bush motorway. Consequently, passengers traveling to or from these directions are likely to have to change vehicle to reach their final destination, resulting in longer travel times and distances.

Not surprisingly, the network is denser in central locations and thins out at the fringes. Some areas appear to be underserved in the eastern part of the city. The few trotro lines going through the neighborhoods known as Labone and Cantonments (center-right of the map) are concentrated along major axes and do not cover secondary roads. This can be explained by the fact that these neighborhoods are home to Accra's most affluent residents. This wealthy population overwhelmingly travels by individual car and makes little to no use of trotro services. West of the city, the trotro network also seems to present wider links in the area known as Tunga (center-left of the map), although for different reasons. In this poorer neighborhood, trotro routes all follow the same main street because it is the only asphalted road. People living further away on backstreets therefore have to take a taxi, moto-taxi or walk to reach their homes.

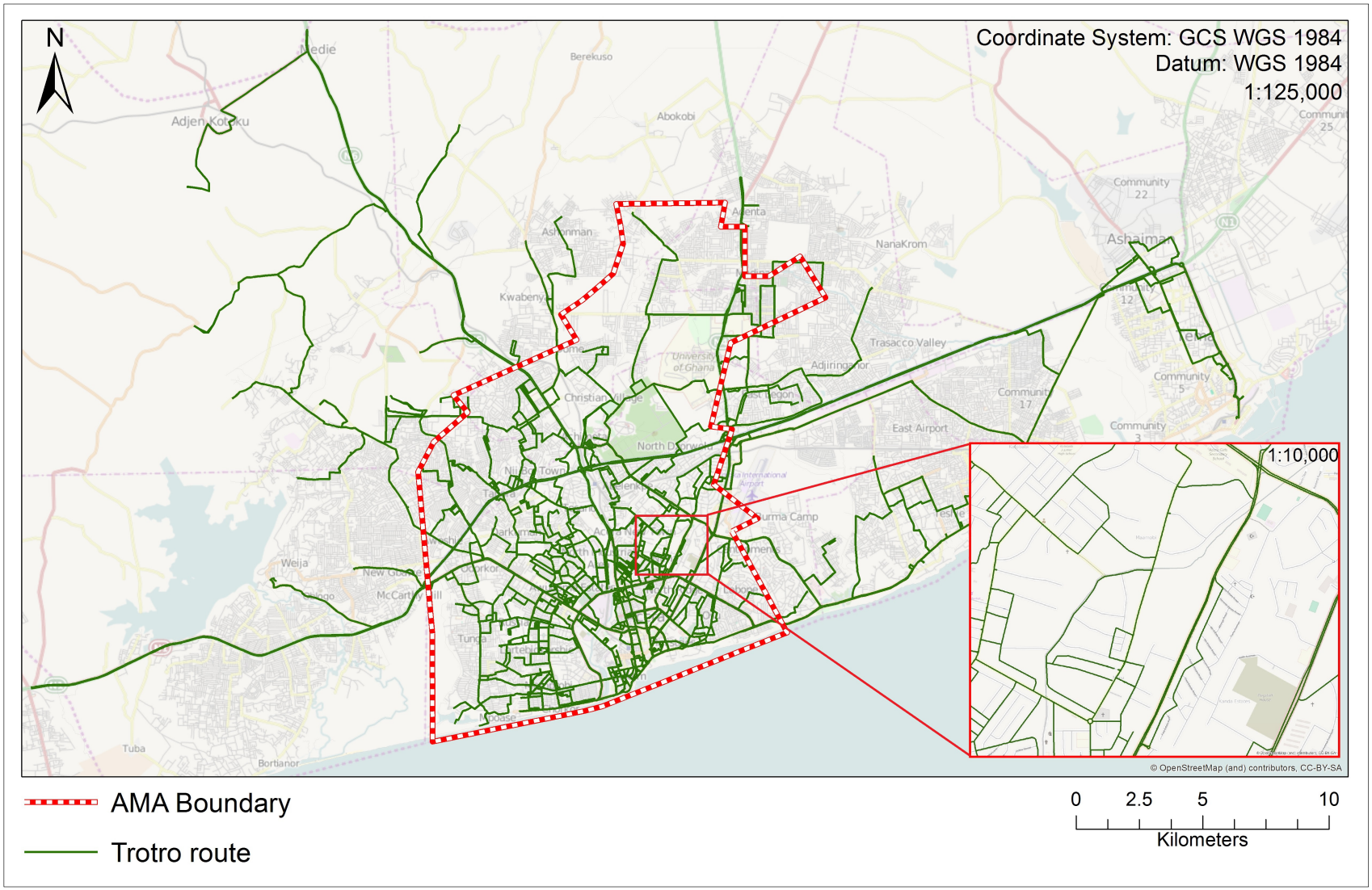

FIGURE 3 Accra's jitney network

Spatial distribution of transportation demand

This research also allowed us to get unprecedented insight on the spatial distribution of passengers' boarding and alighting across the city. This was an important objective for the DoT as virtually no information was available on the demand side of the transportation system. While coarse data on the supply of transport services is collected through route registrations exercises, little is known about passengers' mobility needs. By recording data on stops and passengers boarding and alighting, we were able to obtain a schematic picture of transportation demand, presented in Figure 4. This map reveals grouping of stops following two patterns.

The first one consists of stops gathered around a strategic point, usually close to a trotro terminal. These "hotspots" are either transportation hubs, situated at important crossroads, or market areas, concentrating a high density of commercial activities. Some of these locations combine these two functions. Kaneshie, for instance (center-left of the map), is both a hub distributing traffic throughout the city and a large market attracting customers and traders from the whole metropolitan area. Similarly, Nkrumah Circle (center of the map) combines these two functions. It is both a transportation hub commanding Accra's beltway and one of its major North-South trunk roads, and an area of intense trade activity. On the other hand, Makola (bottom of the map) is first and foremost a marketplace. Conversely, Abeka-Lapaz (left upper part of the map) can be considered as being primarily a transportation hub, drawing its importance from its strategic position on Accra's biggest motorway.

A second pattern of points-grouping can be observed along highly-travelled corridors. Examples of this include Abeka road, Oxford street and Dansoman High street. Some of the corridors generating the highest demand logically follow trunk roads such as the G. W. Bush Motorway or Winneba road. However, other corridors correspond to secondary roads with much more limited capacities for vehicular throughput. In the cases of Nima road and New Town road, for instance, a dense continuum of stops can be observed over stretches of 1.5 to 2 kilometers. Yet, the road infrastructure there is not particularly well suited to accommodate the frequent stopping, boarding and alighting of jitney services on these links. Such observations would need to be reinforced and systematized, but could inform future developments in road infrastructure to better match the demand for transportation.

Figure 4 also introduces a heat-map of passenger transit in Accra. Areas presenting high concentrations of passengers boarding and alighting are shown in warm colors, while less active zones are represented in cool tones. While confirming observations made above, this map provides additional information by highlighting the importance of Achimota transport terminal (top of the map). Contrary to other transportation hubs spread out over extensive areas, Achimota is a standalone transportation terminal, fenced off and isolated from general traffic. As a result, points recorded at this terminal are concentrated on a small area of land and displayed on top of each other. The heat-map corrects this bias by giving a more accurate representation of passenger throughput density across the city.

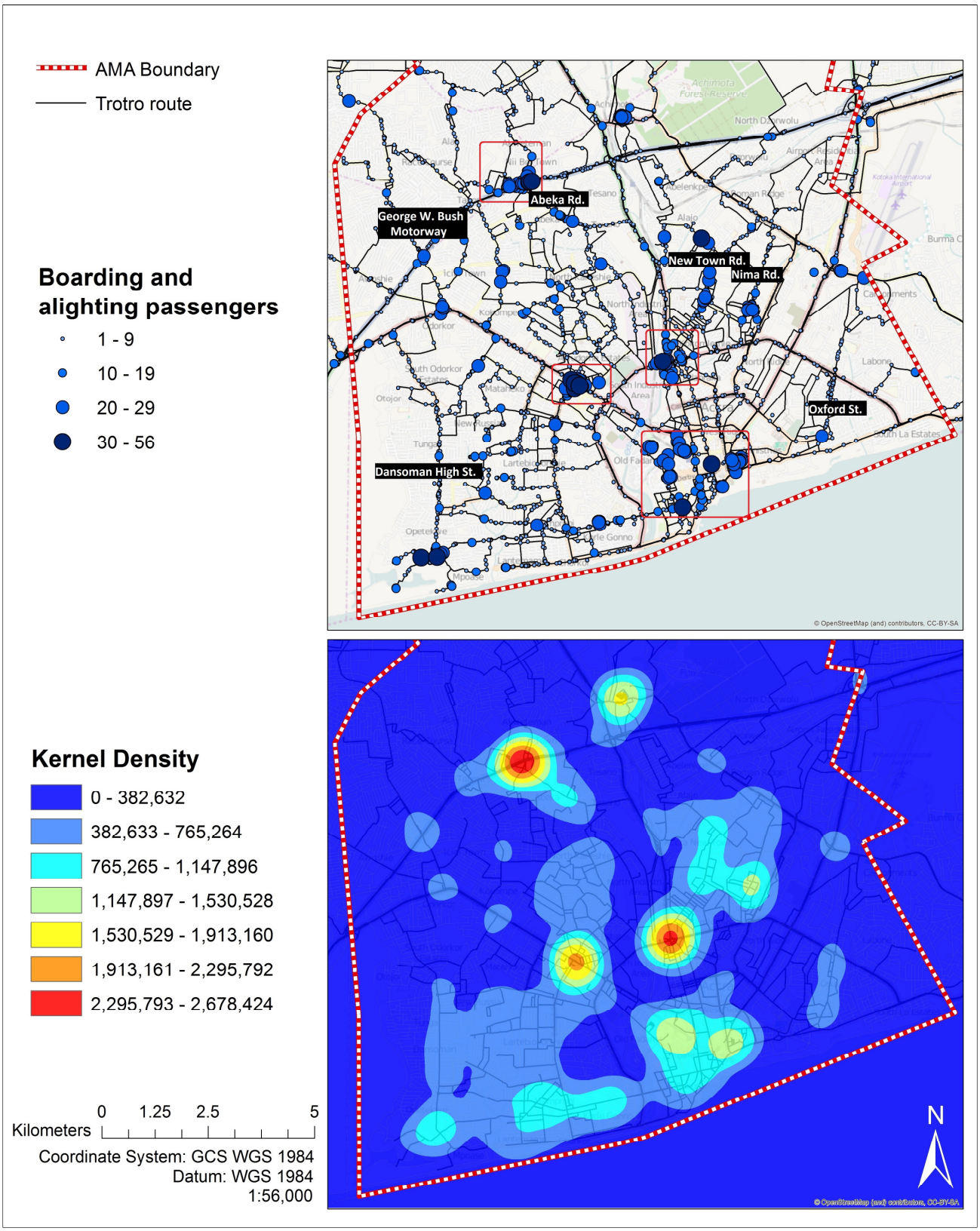

FIGURE 4 Spatial distribution of passenger throughput

DISCUSSION & PERSPECTIVES

The results described above open new avenues for both transportation research and planning. First, the results have implications for the regulation of the transport sector. As explained above, public transport in Accra is mostly internally regulated, through rules decreed by unions and the laws of supply and demand. While this has permitted the emergence of a vast network of jitneys, it has also resulted in economic inefficiencies and spatial inequities. Some areas of the city appear to be underserved, while a few corridors attract most of the competition between operators. Based on this observation, incentives could be designed to better distribute trotro routes across the metropolitan area. Most public transportation systems in the world involve some form of cross-subsidy, whereby part of the profits generated on the most traveled routes finance operations on less profitable segments of the market. A similar arrangement could be considered in Accra by tying the right to operate on profitable routes to an obligation to provide a minimum level of service on other routes. Yet, a more stringent regulation of the sector will only be possible if informal operations are progressively phased out and transformed into registered services. An end should also be put to the registration of "ghost routes" in the sole purpose of eliminating competitors. By preventing other operators to start services on these routes, this practice artificially reduces the provision of transportation services in some areas of the city. Information collected by this research will help the authorities target their efforts to increase the quality and efficiency of the jitney network.

Second, this research offers the first pictures of the distribution of transportation demand across the city of Accra. While this picture deserves to be considerably furthered, it could be interesting to compare it with the map of existing transport infrastructure. This would give an idea of the gaps in infrastructure provision that need to be addressed. It might become apparent that a new terminal is needed in a busy area or that a bus stop would gain to be moved from one intersection to the next. Our data indicates that several underprivileged neighborhoods in Accra face important volumes of passenger throughput while not having the infrastructure to adequately absorb these flows. Spatial information made available through this research could be leveraged to resorb these infrastructure gaps.

From a methodological point of view, this project has shown that the mapping of the core transport network of a large city could be done at a minimal cost and within a short time period of time through the use of mobile technologies. The bulk of our data collection campaign was done within a month, and it took another month to correct some data quality issues and complete the mapping. Using readily available resources also made it possible to carry out this project with a budget of less than 10,000 euros. Nonetheless, it has to be mentioned that this research benefitted from the convergence of favorable conditions. One important prerequisite that enabled the quick completion of the survey was the existence of a registry listing all the official jitney routes. Although the routes listed did not always match actual operations, this registry provided a useful framework to define the scope and direction of our survey. Another key factor in the success of this project was the existence of skilled and motivated partners at the DoT. While these conditions may not be replicable as such, similar projects could in all likelihood be conducted in other developing cities. Given the extensive use that could be made of collected data, such mapping exercises no doubt constitute worthy investments for municipal as well national authorities.

CONCLUSION

As a pilot project, the interest of this research lay as much in the process itself as in the results it produced. In terms of methodology, the use of a flexible work organization combined with collaborative technologies allowed for a continuous feedback between two teams working thousands of miles apart. An iterative process was followed in the definition of the project's objectives, the conception of a methodology and the verification of collected data. This experiment also confirmed the interest of using smartphones for spatial data collection campaigns. The light weight, advanced functionalities and versatile nature of mid-range handsets make them powerful tools for both data recording and transmission. Exploiting these capabilities made it possible to map Accra's jitney network using only a fraction of the resources that would have been required by traditional methods. Finally, this project illustrated the kind of mutually beneficial relationship that could be established between a research institution and a public agency in a developing country. From a scientific point of view, it offered an opportunity to work with original data on a virtually untouched territory. At the same time, this project contributed to building the capacities of Accra's Department of Transport by introducing state-of-the-art technologies and data collection methods.

Looking at results, the collected data will have an impact at different levels. First, it will contribute to a better knowledge of jitney services in Accra and provide information relevant to other jitney systems across the developing world. Through the dissemination of results, trotro passengers as well as public agencies will have access to up-to-date information on the network they use or oversee. Second, this data will assist local authorities in making public policy decisions in the urban transport sector. From a regulation standpoint, for instance, identifying ghost routes is a necessary step towards increasing the level of service on deserted links. Investment decisions regarding the construction of new infrastructure too might benefit from spatial data made available through this project. Our analyses indicate that the provision of specific infrastructure is lagging behind transportation needs along several corridors. Additional studies on transportation demand could therefore help better target public works on the most critical areas.

At the crossroad between the worlds of research and public action, this project constitutes a successful example of international cooperation in transportation planning that could be replicated in a different context.

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