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Impact of ride-hailing apps on traditional LAMAT services in Asian developing cities: The Phnom Penh Case☆

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ABSTRACT

This study examines the impact of ride-hailing apps (RHAs) on traditional services of LAMAT drivers, who have not adopted RHAs, and investigates whether such impact would encourage the drivers' intention towards adoption of RHAs. We analyzed the survey data collected from 177 drivers of traditional auto-rickshaws in Phnom Penh, December 11–14, 2018, as a case study. Comparison results showed that, after the advent of RHAs, the drivers experienced substantial reduction in number of daily trips by 47.7%, number of daily passengers by 47.6%, and monthly revenue by 43.2% ($p < 0.01$). Results from a structural equation modeling further showed that, despite the reduction, the drivers had no intention to adopt RHAs. Majority (62.0%) did not use RHAs because they had no interest in RHAs and expected a lower revenue via their services with RHAs. This study discovered interesting facts, behind the blooming business of RHA companies, for relevant policy discussion.

1. Introduction

Rapid development of smartphones with Global Positioning System, internet, and the available digital road maps has enabled technologies for ride-hailing services via ride-hailing apps (RHAs). RHAs have been developed as an online-platform to connect customers and transport operators, facilitate their matching, and allow them to communicate more efficiently. In Asia, after the introduction of Uber in 2009, more RHAs (e.g., Didi, GoJek, Grab) have been developed for LAMAT services and quickly expanded (Phun et al., 2018b). LAMAT refers to the indigenous public transport modes that are locally, adapted, modified, and advanced for a certain transport service in a particular city or region (Phun and Yai, 2016). LAMAT (Locally Adapted, Modified, and Advanced Transport) is used to refer to paratransit modes in Asia. The concept of "LAMAT" has been motivated by at least two major reasons: (i) The concepts of paratransit are quite different between developed and developing countries; and (ii) Numerous descriptions (e.g., informal transport, indigenous transport, or third-world transport) have been given to paratransit in Asian developing countries. To this end, the advanced utilization of the old-fashioned paratransit modes with innovative technologies (e.g., RHAs, electric vehicle, autonomous) is equally conceptualized as "LAMAT". LAMAT modes include Taxis, auto-rickshaws, and Motorcycle Taxis. Traditionally, citizens hail an empty-cruising LAMAT on-streets. Instead of doing so, citizens can now easily hail a LAMAT with the press of a button on RHAs in their smartphones, and GPS takes care of the locations. RHAs reduce previous information barriers caused by spatial deviation between LAMAT users and drivers–and are thus believed to be a powerful instrument for improving efficiency of LAMAT market (Wang et al., 2016).

LAMAT plays active role as urban mobility in Asian cities, with insufficient mass transit system (Phun and Yai, 2016). It provides flexible, convenient, and personalized transport services to general citizens in needs with a certain level of service quality and reasonable fare. It also boosts socio-economic activities via its service availability and job opportunities to many poor or low-skilled people. However, LAMAT receives little policy/infrastructure support from the government, as its

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services are often considered as informal.

The advent of RHAs has been well accepted by general citizens, but mixed reactions have been expressed by traditional LAMAT operators. At one hand, RHAs have been viewed as opportunities by LAMAT drivers, who operated with RHAs, due to the fact that RHAs help improve operational services and livelihood (Phun et al., 2018b). At the other hand, RHAs have been viewed as a disruptive technology by traditional LAMAT drivers, who have not operated with RHAs, due to the fact that new transport services via RHAs do not comply with the existing regulations—and consequently, traditional LAMAT drivers protested against legalization of RHAs in many cities, due to an unfair competition and reduction in the demand share (Sun et al., 2017). The advent of RHAs have created significant debates worldwide on various issues, including how RHAs should be regulated, their safety implications, and how they influence travel behavior.

Numerous studies examined the impact of RHAs on existing transport services (e.g., Tan et al., 2017; Sadowsky and Nelson, 2017). These studies discussed "rule change" from the viewpoint of market regulation, "competitive effects" from an industry standpoint, and "labor changes" from the stakeholder perspective (Sun et al., 2017). While several studies concern Taxis (e.g., He and Shen, 2015; Lim et al., 2018), only a few concern other LAMAT services such as auto-rickshaws and Motorcycle Taxis (e.g., Wollenberg and Waty, 2017). For example, Phun et al. (2018a) discussed the influence of RHAs on traditional motorcycle Taxi services, which have been long established as connective means for mass transit passengers in Bangkok. Further, Phun et al. (2018b) explored the changes in operational services among Bajaj drivers who have adopted RHAs in Phnom Penh. The impact assessment of RHAs is quite important for successfully designing appropriate regulations for RHAs particularly in Asian developing cities in the long run. Such impact assessment also allows one to know better how RHAs might support or impede goals for mobility, safety, and environmental sustainability.

This study has two main objectives: (1) to examine the impact of the advent of RHAs on operational services of traditional LAMAT drivers, who did not operate with RHAs; and (2) to investigate whether such impact would encourage the drivers' intention towards adaptation of RHAs. We examine the impact by using mean comparison tests, and investigate the drivers' intention by using a structural equation modeling. We collected operational services and subjective responses from Remork drivers, aged between 24 and 67, who operated without RHAs, in Phnom Penh as a case study. Remork is a type of auto-rickshaw, which is locally assembled (see Fig. 1a). Remork drivers were selected in this study because they appeared to be the most affected group of transport operators—the popularity of their services has been observed to gradually decline following the advent of RHAs. The results of this study provide insights into policy discussion regarding how to control/manage LAMAT operations with/without RHAs in the city. Such policy discussion would help to reduce current traffic issues (i.e., congestion, accident, emission), while stabilizing the socio-economic activities.

2. LAMAT services in phnom penh

2.1. LAMAT modes

The current public transport modes in Phnom Penh include public bus and LAMAT (e.g., auto-rickshaws, Motodop, Taxi, and Cyclo). Since the public bus services remain limited, LAMAT services by auto-rickshaws and Motodop remain indispensable. Auto-rickshaws and Motodop provide flexible and door-to-door transport services to general citizens with affordable and un-regulated fare. Auto-rickshaws include Remork and other motorized three-wheelers. Auto-rickshaws are more attractive than Motodop in terms of safety, comfort, and transport capacity (up to six passengers).

Remork is a two-wheeled carriage pulled by a motorcycle (Fig. 1a). It is believed to be originally transformed from Kang-Remork—a two-wheeled carriage pulled by a bicycle—in Cambodia during the 1960s. Citizens also refer Remork as a TukTuk or three-wheeler, despite it is actually a four-wheeled vehicle. Since Remorks have been locally assembled with respect to no specific safety and standard vehicles, the government has defined the maximum dimension (length $\leq$ 3.5 m, width $\leq$ 1.4 m, and height $\leq$ 2 m) and required a minimal safety system (rearview mirrors, effective breaking system, light system, horn $\leq$ 99 dBA) for Remork vehicles. Recently, more motorized three-wheelers have been observed on the city streets. These three-wheelers have been imported from different companies in other countries (e.g., China and India). In this study, we use the term "Bajaj" (Fig. 1b) to refer to those motorized three-wheelers imported from India (e.g., BAJAJ, TVS, PAGGIO), and "Chinese auto-rickshaws" to refer to those motorized three-wheelers imported from China. Comparing to other types of auto-rickshaws, Bajajs are more compact and standardized vehicles with an acceptable speed of 60–80 km/h at maximum. While Remorks and Chinese auto-rickshaws consume gasoline, Bajajs consume either gasoline or Liquefied Petroleum Gas (LPG). The LPG installation complies with the safety requirements of AIS 027, the Code of Practice for Use of LPG Fuel in Internal Combustion Engine to Power 2-&3-Wheeled Vehicles. Since the price of LPG is relatively cheaper than that of gasoline, most Bajaj drivers prefer using LPG, thus allowing them operate at a lower cost. LPG is also good for the environment in the city.

Currently, there is no specific regulation to control and manage LAMAT operations—there is only registration for LAMAT vehicles, but not for the drivers. The government have registered auto-rickshaws since 2009. According to the Department of Public Works and Transport (DPWT), the number of registered auto-rickshaws increased from 18,030 in February 2018 to 29,288 in November 2018—among which, the number of Bajajs quickly increased from 3232 to 14,338; The number of Chinese auto-rickshaws slightly increased from 4659 to 4859; and the

Fig. 1. Popular auto-rickshaws in Phnom Penh.

number of Remorks remained 10,091 unchanged. This trend clearly shows the growing popularity of Bajajs over other auto-rickshaw services.

Motodop, the so-called Motorcycle Taxi, is the fast and flexible mode, typically carrying two adults and one child at maximum. Since there is no official control over Motodop operations (e.g., license, registration), anyone who owns a motorcycle could become a Motodop driver. Consequently, the number of Motodops remain unknown.

2.2. Ride-hailing services

In Phnom Penh, the advent of RHAs in 2016 has been welcomed by many citizens (Phun et al., 2018b). More LAMAT drivers have also adopted RHAs following changes in transport demand.

There were at least 20 RHAs available in the city in 2017. Among them, PassApp has become the most popular RHA. The number of its installs by users and drivers via Google Play (excluding the installs via App Store) increased more than 50 times—from 10,000+ and 1000+ in 2017 to 500,000+ and 50,000+ in 2019, respectively (https://play.google.com, last accessed February 2019).

Based on our observation—a large number of LAMAT drivers who have adopted RHAs operate with Bajajs, a small number operate with other auto-rickshaws and cars, and a very few operate with Motorcycles. The vehicle design standards and alternative fuels, which allow a lower operating cost with safer and more comfort transport service, could possibly be the reasons why numerous drivers operate Bajajs with RHAs. Comparing to other modes, the lower operating cost enables the drivers to correspond to a lower fare rate defined by RHA companies, and thus attracting more customers. For instance, the fare rate of PassApp for Modern Car SUV, Car Classic, Remork, and Bajajs began at 1.50 USD, 1.25 USD, 1.00 USD, and 0.75 USD (1 USD $\approx$ 4000 KHR) for the first 1 km, with the rate of 0.58 USD, 0.50 USD, 0.33 USD, and 0.30 USD for the subsequent kilometer, respectively. The fare rate for auto-rickshaws is defined based on the travel distance alone, not including travel time. With a similar service quality, customers would prefer the cheaper transport fare of Bajaj services via RHAs to other modes. The higher demand for Bajaj services with RHAs indeed inspires the drivers to operate Bajajs with RHAs. Majority of Bajaj drivers (52.3%) were found to operate with PassApp (Phun et al., 2018b).

Before the advent of RHAs in Phnom Penh, citizens prefer to use Remork because of comfort and availability of its services (Eung and Choocharukul, 2018). In the current situation, following the market change in demand for RHA services, some Remork drivers registered themselves to operate with RHAs. However, due to the vehicle configuration (non-standardized) and higher operating cost (i.e., cost efficiency), the fare of Remork services via RHA needs to be high enough for sufficient revenue. As results, the RHA services by Remorks could not be as so attractive as that of Bajajs. To this end, it is unclear whether Remork drivers actually have intention towards RHA adaptation, following the impact of RHAs on their operational services. What will happen to the Remork services remains questionable.

3. Data

3.1. Interview survey

A questionnaire-based interview survey was conducted with Remork and Motodop drivers, who operated without RHAs, in Phnom Penh, December 11–14, 2018. The questionnaire was written in Khmer and contains four parts. Part 1 asked the drivers about their general transport services. Part 2 first asked them about the advent year of RHAs in Phnom Penh, and then asked them to report their operational services both before and after the advent of RHAs. Part 3 asked them about their perception toward RHAs. The perception questionnaire items were based on a 5-point scale (1: very unlikely, 2: unlikely, 3: neither, 4: likely, and 5: very likely). And Part 4 asked about personal information.

Three surveyors, who were trained to fully understand and administer the questionnaire, visited several locations around Phnom Penh such as markets, major intersections, terminals, bus stops, hotels, and general public places along the city streets. A simple random sampling technique was adopted—the surveyors did not request every driver they saw to join the survey. Instead, for example, they requested only two or three drivers at a pick-up station. This thus allows a wider geographical sampling distribution across the city—i.e., a variety of information would be collected from drivers at several different locations in the city. With budget and time constraints, we tried to maximize our sample size during the survey period. A potential sampling bias could be that our survey locations mainly concentrated around the downtown areas, where more drivers could be spotted, while only a few drivers were recruited at suburban areas. At suburban areas, the demand for transport services via RHAs may not change much.

The surveyors requested approximately 280 drivers, but only 217 respondents voluntarily participated in the survey. The drivers rejected our requests because they were busy, tired, waiting for customer, and afraid that the surveyors were possibly advertisers for a company or for a politician. Respondents were recruited with an incentive gift (i.e., a pen). On average, each respondent took 10−12 min to answer the questionnaire. After screening the information, only 204 sample (i.e., 177 Remork and 27 Motodop drivers) were useable for further analyses. Because we primarily focused on changes in operational characteristics of Remorks, the surveyors interviewed with only a few Motodop drivers. With this regard, since the sample of Motodop drivers is insufficient for a group mean comparison tests ($N < 30$), this study excludes detailed analyses for Motodop drivers.

3.2. Driver characteristics

The characteristics of the interviewed Remork drivers, who operated without RHAs, are reported in Table 1. The interviewed drivers were all male and with the average of 42.0 years old. The duration of working as a Remork driver ranged from one week up to 25 years, with the average of 6.9 years. The majority were married (98.3%). The minority has a driving license (26.6%), an additional job (8.5%), and an insurance (4.0%). About 12.0% joint a labor union.

Moreover, the drivers were requested to report which time of the day they experienced more customers. Their responses were summarized in Fig. 2. Majority of the drivers reported that they could get more customers between 7:00 and 10:00 (42.9%–53.1%) and between 16:00 and 18:00 (56.5%–71.8%). We also asked the drivers to describe three major

Table 1
Characteristics of the interviewed Remork drivers without RHAs ($N = 177$).

Variable	Percentage	Variable	Percentage
Age		*Years of Working as a Remork Driver*	
20-30	8.8	0-1	9.3
30-40	36.8	1-2	5.9
40-50	41.7	2-4	20.6
50-60	11.2	4-8	31.9
60-67	1.5	8-25	32.3
Marital Status		*With Dual Jobs*	
Single	1.1	Yes	8.5
Married	98.3	No	91.5
Others	0.6	*With an Insurance*	
Education Levels		Yes	3.9
Never study	1.1	No	96.1
Grade1-6	37.3	*Member of a Labor Union*	
Grade7-9	36.7	Yes	11.9
Grade10-12	23.2	No	88.1
University	1.7	*With a Smartphone*	
With a Driving License		Android	62.1
Yes	26.6	iOS	11.9
No	73.4	No	26.0

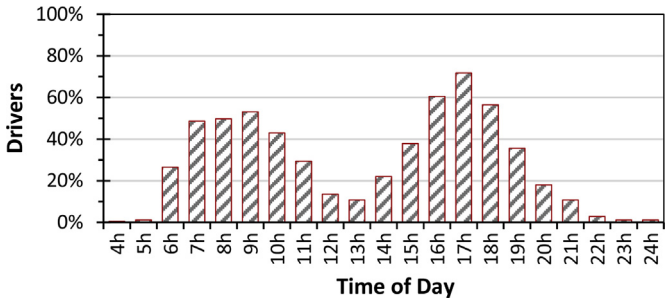

Fig. 2. High demand hours experienced by Remork drivers without RHAs.

activities they usually do during the low demand hours at their pick-up stations. About 91.0% described 371 mixed responses, which were later categorized into using a smartphone (37.5%), taking a rest (31.3%), chitchatting with friends (14.3%), waiting for customers (12.4%), and others (4.6%). Since majority of them had a smartphone (74.1%, Table 1), their major activities appeared to involve with smartphone-related social media apps such as Facebook (16.2%), music & video (12.7%), and others (8.6%).

4. Analyses and results

4.1. Before vs. after the advent of RHAs

In part 2 of the questionnaire, the interviewed Remork drivers were first requested to report the advent year of RHAs in Phnom Penh. The drivers reported different timings: 1.7%, 16.4%, 71.8%, and 10.2% reported that RHAs have become available in the city since 2015, 2016, 2017, and 2018, respectively. In particular, the majority (71.8%) realized the advent of RHAs in 2017. This is plausible because the number of RHAs increased from eight in 2016 to 20 in 2017. An RHA would take some time, after its introduction, to become well-known among general citizens (e.g., PassApp). Similarly, it would take some time for the drivers to realize the availability of an RHA by themselves—and thus, they would perceive different timings for the advent of RHAs in Phnom Penh. The drivers were then asked to report their operational services before and after the advent of RHAs in Phnom Penh. They were instructed to use their perceived advent time of RHAs as a reference time—so that they could recall their operational services in two different timings (i.e., before vs. after) relative to this reference time. Table 2 reports the summary of their responses.

Before the advent of RHAs, the drivers worked 10.7 h with 30.9 min for lunch break per day in average. They made up to 15 (average of 7.7) trips and transported up to 55 (average of 15.3) passengers per day. The drivers earned from 50 USD to 900 USD, with the average of 406.6 USD per month. Their monthly expenses (i.e., operational costs) ranged from 20 USD to 300 USD, with the average of 125.4 USD. Their monthly income and expenses vary, depending on the number of trips and the trip characteristics (e.g., number of passengers/cargos of each trip, travel distance). The drivers who made more trips each month would have longer travel distance, which in turn increasing their monthly income and expenses (gasoline and vehicle maintenance). The drivers were also asked about their cruising behaviors. About 24.7% of the drivers tried to cruise for passengers—in average, they cruised 2.3 times and spent 14.1 min per day.

We now examine the impact of RHAs on operational services of the Remork drivers, who have not adopted RHAs, by examining the proportional difference in their operational services before and after the advent of RHAs. The proportional difference was computed using (Mean2 – Mean1)/Mean1, and its negative value indicates a proportional reduction in Mean2 (e.g., After the advent of RHAs) relative to Mean1 (e.g., before the advent of RHAs). Table 2 reports the summary statistics of operational services for the interviewed Remork drivers before and after the advent of RHAs. Results from paired *t*-tests show significant differences for all variables in Table 2 ($p < 0.05$). The drivers' average working hours decreased from 10.7 h to 9.8 h per day, equivalent to a reduction (or proportional difference) in their daily working hours by 8.4% [= (9.8–10.7)/10.7]. The average time for lunch break increased by 38.4%. These findings suggest that, under the current working conditions (i.e., after the advent of RHAs), Remork drivers appeared to work shorter hours per day, while taking longer time for lunch break. In addition, there was a reduction in the average number of daily trips and passengers by 47.7% and 47.6%, respectively. The average monthly revenue was also found to decrease from 406.6 USD to 231.0 USD, equivalent to a reduction of 43.2%. Shorter working hours and fewer daily trips seemed to reduce the operational costs—the drivers' monthly expenses reduced by 25.5%. Further, the proportion of Remork drivers who cruised for passengers increased from 24.7% to 29.9%. The drivers also increased their cruising frequency by almost double (97.1%) and their cruising time by 84.7%. Noted that the number of respondents remains $N = 174$ because three of them did not report their operational services before the advent of RHAs—they claimed that they came to provide Remork services only after the advent of RHAs.

4.2. With vs. without a pick-up station

Approximately 64.4% of the interviewed Remork drivers reported that they had a proper pick-up station near hotels, markets, terminals, intersections, etc. A pick-up station often ensures that the drivers could secure potential customers whose trips originate from that station. In order to secure a pick-up station, the drivers may pay a fee to landlords for a rental parking space or to local authorities for a protection. The fee varies depending on station-specific characteristics (e.g., demand level). The fee ranges from 2.5 USD to 25.0 USD, with the average of 11.3 USD per month (Phun et al., 2015). Some pick-up stations require no fee.

We verified whether there were differences in the operational services between the drivers with and without a pick-up station. Table 3

Table 2
Operational services of Remork drivers without RHAs before vs. after the advent of RHAs in Phnom Penh.

Variables	Before the advent of RHAs[a]					After the advent of RHAs[a]					Mean comparison		
	N	Mean	SD	Min	Max	*N*	Mean	SD	Min	Max	Difference	|*t*-test|	
Daily working duration, in hours	174	10.65	3.06	3	24	174	9.76	3.68	2	24	−8.4%	5.61	***
Daily lunch break, in minutes	174	30.88	16.64	0	120	174	42.74	36.65	0	300	38.4%	4.75	***
Number of daily trips	174	7.75	2.89	2.5	15	174	4.05	2.04	0.5	10	−47.7%	20.02	***
Number of daily passengers	174	15.28	7.93	3	55	174	8.01	4.81	1	25	−47.6%	19.24	***
Monthly revenue, in USD	174	406.64	146.09	50	900	174	231.01	108.24	25	500	−43.2%	21.86	***
Monthly expenses, in USD	174	125.41	67.11	20	300	174	93.41	62.76	10	300	−25.5%	10.17	***
Whether to cruise for passengers	174	0.25	0.43	0	1	174	0.30	0.46	0	1	20.9%	2.08	**
Freq. of cruising for passengers	52	2.34	2.38	0	12.5	52	4.61	6.81	1	50	97.1%	2.32	**
Duration of cruising, in minutes	52	14.13	17.09	0	90	52	26.11	13.41	0	60	84.7%	4.88	***

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.
[a] Before and After were defined based on the perceived advent time of RHAs reported by each respondent, see explanation in section 4.1.

Table 3
Operational services after the advent of RHAs for Remork drivers with vs. without a pick-up station.

Variables	Without a pick-up station					With a pick-up station					Mean comparison			
	N	Mean	SD	Min	Max	*N*	Mean	SD	Min	Max	Difference	DF	|*t*-test|	
Daily working duration, in hours	63	9.13	3.79	3	20	114	10.16	3.56	2	24	10.1%	123.3	1.76	*
Daily lunch break, in minutes	63	45.40	36.41	10	210	114	41.56	37.24	0	300	−9.2%	132.4	0.67	
Number of daily trips	63	3.64	2.03	0.5	10	114	4.25	2.00	1	10	14.4%	128.2	1.92	*
Number of daily passengers	63	7.25	4.78	1	25	114	8.37	4.76	1.5	20	13.4%	129.4	1.50	
Monthly revenue, in USD	63	202.70	91.84	30	450	114	246.27	114.02	25	500	17.7%	154.3	2.77	**
Monthly expenses, in USD	63	81.16	55.88	10	225	114	99.91	64.98	15	300	18.8%	147.1	2.02	**
Whether to cruise for passengers	63	0.49	0.50	0	1	114	0.18	0.39	0	1	−167.1%	104.7	4.20	***
Daily cruising frequency	31	3.68	1.68	0	7.5	21	5.98	10.53	0	50	38.5%	20.8	0.99	
Daily cruising time, in minutes	31	28.39	12.67	0	60	21	22.74	14.05	0	60	−24.8%	41.8	1.48	

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

reports the comparison results using Welch's *t*-tests. Welch's *t*-test is an adaptation of Student's *t*-test, which is intended for use with two samples having possibly unequal variances. Results suggest that, although not so significant ($p < 0.1$), the drivers with a pick-up station worked longer hours per day (10.1%) and made more daily trips (14.4%) than those without a pick-up station. The driver with a pick-up station also made a higher monthly revenue (17.7%) and expenses (18.8%) ($p < 0.05$). Besides, the proportion of drivers who cruised for passengers was 49.2% among those without a pick-up station—this proportion was significantly higher than that (18.4%) among drivers with a pick-up station ($p < 0.01$). This is reasonable because the drivers without a pick-up station, as they had no specific location to wait for potential customers, would depend on cruising activities to look for more customers. Even so, there were nonsignificant differences in terms of cruising frequency and time ($p > 0.05$). In sum, the results suggest that the advent of RHAs had less impact on the drivers with a pick-up station, who earned higher revenue (by 17.7% more), than the drivers without a pick-up station.

4.3. Remorks without RHAs vs. Bajajs with RHAs

The available data in Phun et al. (2018b) enabled us to further compare the operational services between two groups of auto-rickshaw drivers: Remork drivers without RHAs and Bajaj drivers with RHAs. The comparison results are reported in Table 4. Results from Welch's *t*-tests show that the two driver groups had similar daily working hours and lunch break time ($p > 0.05$), but significant differences in terms of the number of daily trips & passengers and monthly revenue & expenses ($p < 0.01$). In average, Bajaj drivers with RHAs could make up to 14.47 trips and 20.76 passengers, while Remork drivers without RHAs could make only 4.04 trips and 7.97 passengers per day. Bajaj drivers earned 430.78 USD per month, but Remork drivers earned 230.76 USD per month. Bajaj drivers also experienced higher monthly expenses (128.55 USD) for their operational services than Remorks drivers (93.24 USD). Further, the proportion of drivers and frequency of cruising for customers were not significantly different ($p > 0.05$). Among those who cruised, the average cruising time of Bajaj drivers was significantly higher than that of Remork drivers ($p < 0.01$). This is because Bajaj drivers with RHAs usually operate without a specific pick-up station. After dropping off a customer, they continue to cruise on the city streets in order to increase their chance of intercepting orders by customers via RHAs. Remork drivers might not want to spend longer time cruising for customers, as doing so would result in them paying higher gasoline cost. These results are reasonable, given the fact that RHAs are gaining popularity over the traditional Remork services with negotiated fare in Phnom Penh.

We also compare the personal characteristics of the two driver groups. Results from Welch's *t*-tests show significant differences in terms of age, years of working as a driver, and educational levels. Remork drivers without RHAs (average age of 42.0 years old) were older than Bajaj drivers without RHAs (average age of 36.3 years old) [$t(359.0) = 6.88$, $p < 0.01$]. In average, Remork drivers had longer working experience (7.0 years) than Bajaj drivers (2.9 years) [$t(284.3) = 6.81$, $p < 0.01$]. While 74.0% of Remork drivers finished 74.0% finished grade1-9, 80.3% of Bajaj drivers could finish grade 7–12 [$t(357.5) = -4.82$, $p < 0.01$]. These results suggest that Bajaj drivers, with younger age and higher education levels, have recently register to provide Bajaj services via RHAs. This is plausible because younger and higher educated people tend to have higher adoption rate of RHAs (Clewlow and Mishra, 2017). In contrast, Remork drivers, who appeared to be in older age, longer working years, and lower education levels, may have experienced some difficulties in adopting new smartphone technologies (e.g., foreign languages, digital maps)—hence, resulting in them less likely to adopt RHAs. It should be noted that group mean comparison for the education levels was based on the categorical scale shown in Table 1. We also adjusted the time by adding 12 months to the age and years of working as a driver for Bajaj drivers with RHAs, because the survey in Phun et al. (2018b) was done one year earlier.

4.4. Intention to adopt RHAs

4.4.1. Structural equation modeling

The above results showed substantial impact of the advent of RHAs on operational services of Remork drivers, who operated without RHAs. In

Table 4
Operational services after the advent of RHAs for Remorks without RHAs vs. Bajajs with RHAs.

Variables	Remorks without RHAs					Bajajs with RHAs					Mean comparison			
	N	Mean	SD	Min	Max	*N*	Mean	SD	Min	Max	Difference	DF	|*t*-test|	
Daily working duration, in hours	177	9.80	3.67	2	24	182	10.26	2.41	2.5	17	4.7%	304.2	1.40	
Daily lunch break, in minutes	177	42.92	36.89	0	300	182	42.63	33.37	0	240	−0.7%	353.2	0.08	
Number of daily trips	177	4.04	2.03	0.5	10	182	14.47	6.38	3	40	258.5%	218.6	20.99	***
Number of daily passengers	177	7.97	4.78	1	25	182	20.76	10.75	4	100	160.5%	252.2	14.63	***
Monthly revenue, in USD	177	230.76	108.43	25	500	182	430.78	158.25	75	1000	86.7%	322.6	14.00	***
Monthly expenses, in USD	177	93.24	62.38	10	300	182	128.55	69.55	10	450	37.9%	356.7	5.07	***
Whether to cruise for passengers	177	0.29	0.46	0	1	182	0.35	0.48	0	1	19.7%	358.9	1.25	
Daily cruising frequency	52	4.61	6.81	1	50	64	6.54	7.60	1	45	42.0%	114.9	1.44	
Daily cruising time, in minutes	52	26.11	13.41	0	60	64	42.79	34.01	3.5	150	63.9%	86.3	3.59	***

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

this section, we further investigate whether such impact would encourage the Remork drivers' intention towards RHA adoption, using a structural equation model (SEM) shown in Fig. 3. SEM is a multivariate regression technique that allows us to examine theoretical model by testing hypotheses, in order to better understand the causal relationship among interested variables (Phun et al., 2018a). SEM includes both unobserved (i.e., latent) and observed (i.e., indicator) variables. A latent variable is often measured by several indicators (Schreiber et al., 2006). In this study, we formulate five hypotheses (H1-H5), corresponding to the causal relationships among four latent variables—i.e., Intention to Use RHAs, Government Support RHAs, Appreciation of RHAs, and Impacts of RHAs. Each latent variable is operationalized by three indicators. The summary statistics of these indicators are provided in Table 5. Indicators of the first three latent variables represent the subjective questionnaire items that were answered by Remork drivers on a 5-point scale (1: very unlikely, 2: unlikely, 3: neither, 4: likely, and 5: very likely).

Intention to Use RHAs refers to the behavioral intention of Remork drivers towards the usage of RHAs. According to the Theory of Planned Behavior, behavioral intention is an important indicator of drivers' future behaviors (Ajzen, 1991). In this study, Intention to Use RHAs is measured by three indicators (i.e., Intent1, Intent2, and Intent3); representing the drivers' behavioral intention and their peer recommendation towards RHA usage. The peer recommendation is used to measure subjective norm, which is constantly found to have positive effect on behavioral intention (Ru et al., 2018). Appreciation of RHAs refers to the gratefulness of RHAs that help LAMAT drivers to improve their general transport services (Apprec1) and livelihood (Apprec2), and that attract many of their peers (Malhotra and Galletta, 1999). Govt Support RHAs refers to government policy that supports the operational services of LAMAT with RHAs in general. It includes the regulations that control the number of drivers with RHAs (Govt1), facilitate Remork drivers to adopt RHAs (Govt2), and require all LAMAT drivers to operate with RHAs (Govt3).

Rather than using the subjective questionnaire items, we measure Impacts of RHAs by using the actual proportional differences in number of daily trips, number of daily passengers, and monthly revenue before and after the advent of RHAs [i.e., (Mean2 – Mean1)/Mean1] as indicators. For example, Impact1 was computed by [(Trips_after – Trips_before)/Trips_before]. Impact1 ranged from −0.87 to 0, indicating the decline in number of the daily trips from 87% to 0.0% (i.e., no impact), after the advent of RHAs. Similar procedure was done for Impact2 and Impact3. These indicators are believed to increase the predictive power of the SEM.

Table 5
Summary statistics of SEM variables ($N = 177$).

Questionnaire items (Abbreviation)	Mean	SD	Min	Max
Latent variables:				
Intention to Use RHAs				
I want to register my Remork with RHAs (Intent1)	2.64	1.17	1	5
Friends recommend me to use RHAs (Intent2)	2.90	1.19	1	5
I want to upgrade my Remork to Bajaj with RHAs (Intent3)	3.13	1.42	1	5
Appreciation of RHAs				
RHAs improve general LAMAT services (Apprec1)	3.29	1.44	1	5
RHAs improve livelihood of LAMAT drivers (Apprec2)	3.70	1.28	1	5
Many friends registered with RHAs (Apprec3)	3.18	1.19	1	5
Govt Support RHAs				
To control number of drivers with RHAs (Govt1)	3.86	1.01	1	5
To facilitate Remorks to use RHAs (Govt2)	3.34	1.10	1	5
All LAMAT drivers to use RHAs (Govt3)	3.58	1.09	1	5
Impacts of RHAs				
Decline in number of daily trips since RHAs (Impact1)	−0.45	0.22	−0.87	0
Decline in number of daily passengers since RHAs (Impact2)	−0.45	0.21	−0.89	0
Decline in monthly revenue since RHAs (Impact3)	−0.42	0.19	−0.95	0
Contextual variables:				
1 if having a pick-up station; 0 otherwise (D_pick-up station)	0.64	0.48	0	1
1 if using a smartphone; 0 otherwise (D_smartphone)	0.74	0.44	0	1

The five hypotheses (H1-H5) to be tested in the SEM are stated as follows:

H1. Impacts of RHAs has a positive effect on Intention to Use RHAs. This is because those drivers who experience substantial impacts of the

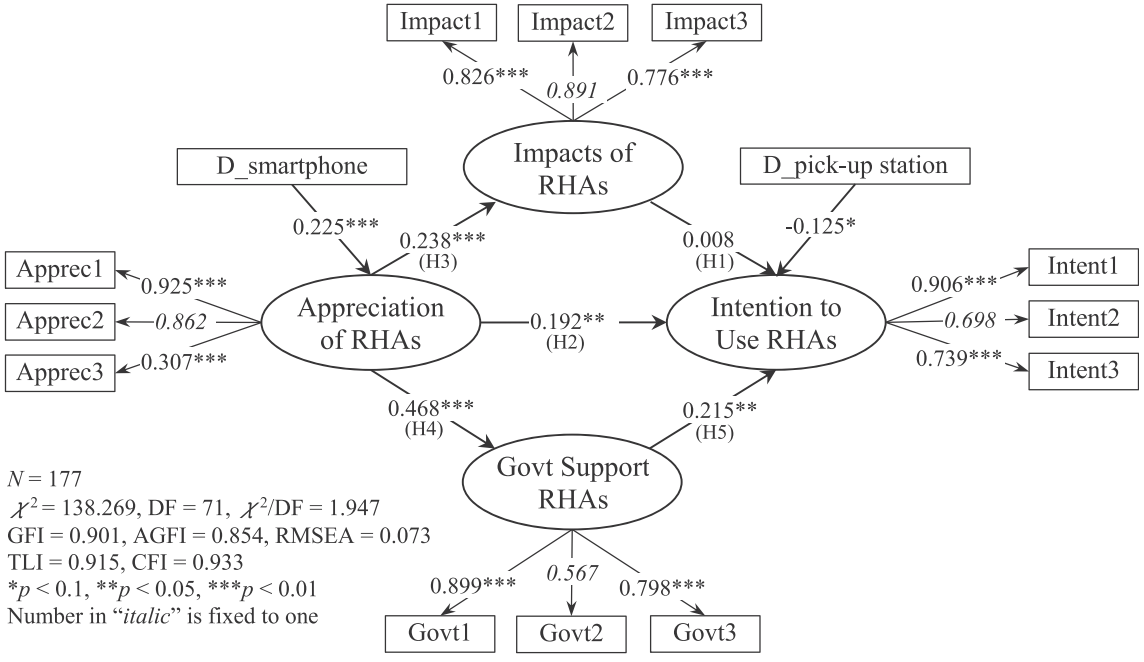

Fig. 3. Proposed SEM and its estimate results with standardized effects for Remork drivers without RHAs.

advent of RHAs on their operational services are likely to adopt RHAs in order to minimize or avoid such impacts. Otherwise, the impacts escalate following the increasing popularity of RHAs among general citizens.

H2. Appreciation of RHAs has a positive effect on Intention to Use RHAs. This is because those drivers who appreciate the usefulness of RHA features for LAMAT services are likely to have intention to use RHAs.

H3. Appreciation of RHAs has a positive effect on Impacts of RHAs. This is because those drivers who appreciate the usefulness of RHA features for LAMAT services are likely to expect more impacts of RHAs on their traditional LAMAT services.

H4. Appreciation of RHAs has a positive effect on Govt Support RHAs. This is because those drivers who appreciate the usefulness of RHA features for LAMAT services are likely to wish for the government to support LAMAT services via RHAs (e.g., regulating or managing RHAs). Noted that both Appreciation of RHAs and Govt Support RHAs variables were based on the drivers' viewpoints. Govt Support RHAs may also have effect on Appreciation of RHAs (i.e., reverse arrow of H4), but we excluded this reverse effect because the transport services via RHAs are quite new in Cambodia and the government has no specific regulation for these RHAs yet.

H5. Govt Support RHAs has a positive effect on Intention to Use RHAs. This is because those drivers who support the government in regulating/managing LAMAT services via RHAs are likely to have intention towards the usage of RHAs.

We also included two contextual variables: one (D_pick-up station) that has effect on Intention to Use RHAs, and another (D_smartphone) that has effect on Appreciation of RHAs.

4.4.2. Estimate results

Fig. 3 shows the estimate results of the proposed SEM with standardized effects for Remork drivers, who have operated without RHAs. The SEM's goodness of fit is assessed by multiple indices: $\chi 2$, Root Mean Square Error of Approximation (RMSEA), Goodness-of-Fit Index (GFI), Adjusted GFI (AGFI), TuckerLewis Index (TLI), and Comparative Fit Index (CFI) (Hair et al., 1998). In the initial model estimation, the modification indices suggest that the model could be improved by specification of an additional correlation between the error variance of Apprec3 and that of Intention to Use RHAs ($r = 0.505$). Theoretical justification of this correlation is that Remork drivers who had many of their peers operating with RHAs are likely to have higher intention to use RHAs, and vice versa. This causes additional covariance between the two error variances [Estimate covariance = 0.436, critical ratio = 5.017, $p < 0.01$]. After correcting for this correlation and re-estimating, the model fit notably improved. The $\chi 2$ of this model is 138.269, with 71 degree of freedom (DF), and $p < 0.01$. The $\chi 2$ measures the overall model fit and assesses the magnitude of discrepancy between the fitted covariance matrices and sample. The $\chi 2$/DF is 1.947, making it lower than 2, the cutoff for a good fit. RMSEA is an absolute fit index—it is one of the most informative indices that tells us how well the model would fit the population covariance matrix (Byrne, 1998). RMSEA equals to 0.073, lower than 0.08 cutoff. AGFI is 0.854, which is slightly lower than the 0.9 cutoff. The values of other fit indices (GFI, TLI, and CFI) are higher than 0.9, indicating good model fit (Hair et al., 1998). All fit indices for this model are notably high, suggesting that the overall fit of the model is acceptably good for investigating the impact of RHAs on behavioral intention of Remork drivers towards adoption of RHAs.

The number attached to each path arrow represents the standardized effect. All indicators are highly significant ($p < 0.01$) with most values higher than 0.5, suggesting that the latent variables are well measured by their corresponding indicators. The testing hypotheses H2-H5 are well supported with significantly positive values ($p < 0.01$). However, the testing hypothesis H1 is non-significant ($p > 0.05$), indicating that Remork drivers had no intention to adopt RHAs regardless the impact of RHAs on their operational services. In search for supporting reasons, we requested the interviewed Remork drivers to describe three major reasons why they did not register to operate with RHAs. We obtained 371 mixed responses from 175 drivers, and we classified these responses into the categories shown in Fig. 4. Majority (37.7%) claimed that registering themselves with RHAs would not make any revenue. This might be due to the higher operating cost (gasoline price) compared with the lower rate of distance-based fare set by RHA companies. In addition, drivers who operate with an RHA required to pay a commission fee to that RHA company in order to receive customers booking via that RHA. With this regard, some 5.4% clearly reported that they did not want to pay the commission fee to or work for RHA companies. Further, 24.3% had no interest in RHAs, as they had limited knowledge about technologies, they did not like RHAs, and they simply did not want to use RHAs. Other 13.7% argued that they had insufficient financial ability to upgrade their services, by first purchasing a new vehicle (e.g., Bajaj) and then operating with RHAs. Some 5.9% said they wanted to support Remork services, which have represented as a traditional iconic symbol for Cambodia. And 5.1% have already secured a pick-up location and had potential customers. In sum, the Remork drivers had no intention to operate with RHAs because of several reasons including expecting lower revenue, having no interest in RHAs, having no financial ability to upgrade their vehicles, and having already potential customers.

Regarding the contextual effects, results show that the driver who owned a smartphone appeared to have higher appreciation of RHAs ($p < 0.01$), and those who had secured a pick-up station seemed to have less intention to adopt RHAs ($p < 0.1$).

5. Discussion

The results showed that the advent of RHAs reduced the operational services (i.e., daily trips & customers, and monthly revenue) of traditional Remork drivers, who did not operate with RHAs. Results from SEM further confirmed that, despite reduction in their operational services, they had no intention to adopt RHAs ($p > 0.05$). In the current situation, after the advent of RHAs, their operational services were found to be far lower than those of Bajaj drivers, who operated with RHAs ($p < 0.01$). This clearly suggests that the traditional Remork services without RHAs were less attractive than Bajaj services with RHAs.

As the traditional Remork drivers had no intention to register themselves with RHAs, they might still have their potential customers and may expect to earn a certain level of revenue sufficient for their livings. After the advent of RHAs, results of this study showed that majority of Remork drivers had secured a pick-up station (64.4%), and these drivers could make a higher monthly revenue (by 17.7%) than other Remork drivers without a pick-up station ($p < 0.05$). Currently, fewer Remorks have been seen on the city streets, while many have been seen waiting for their potential customers near hotels, schools, markets, terminals, and major intersections. Other potential customers include friends/neighbors and citizens who do not use a smartphone.

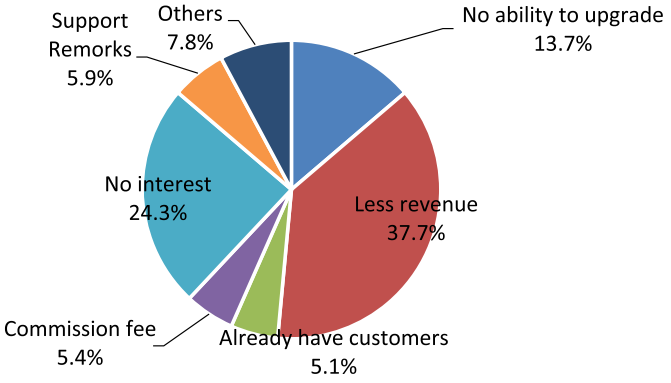

Fig. 4. The reasons why Remork drivers did not register to operate with RHAs.

As found by Phun et al. (2018b), approximately 40.0% of Bajaj drivers with RHAs were actually the former drivers of traditional LAMAT modes (e.g., Motodop, Remork). These former drivers might have responded the change in demand for LAMAT services via RHAs—therefore, they first upgraded their traditional LAMAT vehicles to Bajajs and then operated with RHAs, in order to maintain their revenue. Even some drivers have directly registered their Remorks with RHAs, their services remain not so attractive, due to the cost efficiency of Remork vehicle itself. Although there was news reported that the demand for Remork services has been squeezed by RHAs, no protest has been seen so far.

Currently, the operational services of both Remorks and Bajajs with or without RHAs are considered as informal, and are not subjected to any specific regulation, except vehicle registration. According DPWT, many Bajaj drivers did not register their vehicles. In early 2018, for example, DPWT in cooperation with traffic police enforced and banned unregistered Bajaj drivers from operations—about 200-300 unregistered Bajajs were found per week. Further, majority of Bajaj drivers with RHAs were found to be new (60.0%), young (80.2% were <40 years old), and less working experience (78.0% worked as drivers less than one year) drivers (Phun et al., 2018b). These characteristics may explain that Bajaj drivers with RHAs were less professional, and hence raising questions on their operational safety. It has been observed that Bajaj drivers with RHAs often exhibit bad driving behaviors—they operate with risky manners including speeding, reckless driving, frequent lane-changing, and penetrating among vehicles. Following this situation, on March 1st, 2019, Phnom Penh Capital Administration invited drivers of Remorks and Bajajs to a two-month training session to better understand about general traffic rules, and to get a driving license type A (≥125 cc). This effort was expected to help improve operational safety and driving behaviors.

The growing popularity of RHAs as mobility services has been seen as disruptive transportation (Clewlow and Mishra, 2017; Tan et al., 2017). Because transport services via RHAs do not comply with the traditional rules, RHAs are also seen as a threat to existing transport operators—while policymakers have considered new regulations for RHAs in several cities including cities in China, Philippines, and Thailand (Phun et al., 2018b). For example, the new Chinese RHA-related regulations provide basic principles for local government to create innovative and flexible (de-)regulation on supply quantity, fare, labor protection, and market entry (Sun et al., 2017). In Shanghai, RHA drivers are not allowed to accept orders from railway stations and airport.

In Phnom Penh, while it may not be a good strategy to protect the traditional Remork services, regulations on LAMAT services with/without RHAs should be discussed in common for the society: (i) Social welfare: RHAs should provide a better transport service to general citizens (e.g., convenience, safety, standardized fare). For this reason, transport services via RHAs should be welcomed rather than restricted. (ii) Equity among transport operators: Although the advent of RHAs might cause inequity issues in terms of jobs and revenues among LAMAT operators, in particular, Remork drivers should have the same opportunity to improve their operational services by shifting to Bajajs with RHAs. If there are necessary reasons that require Remork drivers to upgrade their vehicles to Bajajs (e.g., air quality, safety), regulations supporting this upgrading may be considered (e.g., subsidy). (iii) Equity among servicing regions: RHAs may provide geographically biased supply because most drivers with RHAs appeared to serve at more densely areas rather than poorly demanded areas for maximizing their profit (Phun et al., 2018b). This means that those citizens who reside at lower population-density areas may lose their access to LAMAT services via RHAs. In line with this situation, regulations for spatial distribution of LAMAT services via RHAs across regions should be considered for a better accessibility. (iv) Stability of transport services: The stability of transport services via RHA-based system is still unclear. The service robustness may be better in the traditional Remork services. However, a web-based system is highly expected to work more efficiently, and to optimize the services better than a manual-based system. (v) Safety & security: Safety & security are one of the main issues to be considered in transport services via RHAs. As Bajaj drivers with RHAs may not be so qualified, they may provide less safe services to customers than a more professional driver (i.e., authorized driver). This requires the introduction of safety & security regulations for transport services via RHAs (e.g., professional driving license). And (vi) Environment: Although Bajajs with RHAs consume LPG, which is better for the environment than Remorks without RHAs consume gasoline, RHA-oriented system may lead to a car-oriented society rather than a public-public-transport-oriented society, which in turn producing more CO_2. However, it remains difficult to explain the rationale of introducing regulations for the environment.

6. Conclusion

This study examined the impact of RHAs on traditional LAMAT services among drivers who did not operate with RHAs and investigated whether such impact would encourage the drivers' intention towards adoption of RHAs in Asian developing cities. Results from Phnom Penh case showed that RHAs had substantial impact on operational services of Remork drivers, who did not operate with RHAs—i.e., the drivers reported that the advent of RHAs has substantially reduced their number of daily trips by 47.7%, number of daily customers by 47.6%, and monthly revenue by 43.2% ($p < 0.01$). Their operational services were also found to be significantly lower than that of Bajaj drivers, who have operated with RHAs. It was further found that, despite the fact that the advent of RHAs affected their operational services, the traditional Remork drivers had no intention to adopt RHAs. They had no intention to operate with RHAs because they expected a lower revenue, they had no interest in RHAs, they had no financial ability to upgrade their vehicles, and they already had potential customers, etc.

This study revealed fascinating truths behind the blooming business of RHAs regarding the impact of RHAs on traditional LAMAT drivers, who have not registered to operate with RHAs, in Asian developing cities. Results from Phnom Penh case provided fundamental insights into relevant policy discussions for regulating LAMAT services with and without RHAs, from the supply side. The change of behavior for drivers with/without RHAs should be further investigated to distinguish the impacts of RHAs from economic trend. However, to formulate a proper policy, future studies should examine the impact of users' RHA adoption on travel behavior and mass transit ridership (i.e., demand side). Whether to use RHAs or not is surely the choice of users. Users' satisfaction and/or negative experiences might affect the demand for RHAs. If more citizens use RHAs for door-to-door trips, the traffic congestion may become worse. Studies with similar purposes should also be conducted in several cities in order to identify differences in travel behaviors and preferences, as well as to enhance our knowledge for RHA impacts. Finally, a review and summary of existing regulations for RHAs worldwide would be useful for transport policy makers in the era of ride-hailing services.

Declaration of competing interest

We, the author and co-authors of this manuscript, entitled "Impact of Ride-Hailing Apps on Traditional LAMAT Services in Asian Developing Cities: The Phnom Penh Case", declare no conflict of interest.

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