International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 5
ISSN: 2088-5334

Exploring the Substitution Effect of Ride-Sourcing in Commuting and Transport Stations Trips: Learning from Evidence in Bandung City, Indonesia

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***Abstract*— Ample evidence shows that ride-sourcing can substitute the existing transport system (i.e., public transport or private transport). However, the effect of the type of trip (i.e., commuting or transport station trips) on this substitution is still not fully understood. Therefore, this study aims to investigate the substitution effect of ride-sourcing based on the type of trip, i.e., commuting trips as well as trips to transport stations (e.g., the airport, terminal, rail station), conducted by private vehicles and public transport services. The effects of socio-demographics, spatial characteristics, and attitude were integrated into the discriminant model to explore this further. For this purpose, this study collected data from a questionnaire distributed to ride-sourcing users in Bandung in 2020. Discriminant and multivariate analyses are used to investigate the substitution effect of ride-hailing. It is found that the substitution of private transportation occurs for high-income online transport users and longer trips. Moreover, people who previously used public transportation are associated with users who experience increased productivity. Ride-sourcing vehicles, such as online taxis, provide more space for activities. In addition, a lack of access to other transportation tends to be associated with public transport users rather than private vehicle owners. Public transport users can experience increased productivity because the travel time is significantly reduced when ride-sourcing is used. The improvement of public transport, specifically for people who are carrying more belongings and have more intense and widespread activity participation, is then suggested by this study.**

***Keywords*— Ride-sourcing; commuting; transport station trips; substitution; attitude.**

Manuscript received 6 Aug. 2021; revised 16 Oct. 2021; accepted 13 Dec. 2021. Date of publication 31 Oct. 2022.

I. INTRODUCTION

The rise of ride-sourcing has challenged the existing transportation system and has resulted in changes in public and private transport users [1]–[6]. This has attracted researchers from various disciplines to investigate the effect of ride-sourcing on the use of public and private transportation [7], [8] and its impact on the environment [9], [10]. Due to its attractiveness for congestion mitigation, most previous studies have investigated the substitution effect of ride-sourcing. The findings, however, varied depending on the geographical locations. One example is a study from Clewlow and Mishra [11], which found that ride-sourcing reduces the use of light trains and buses in various cities in the United States. The study of Dias et al. [12] found that ride-sourcing reduces the number of public transport users in high-density areas while at the same time reducing bicycle use and pedestrians. On the other hand, several studies in Indonesia by Irawan et al. [7] found that ride-sourcing users are also users of rail mass transit, such as the Electric Rail Train (KRL) or the Integrated Highway (MRT) in DKI Jakarta. The inconsistency of these findings indicates that studies of ride-sourcing need to be explored further and should integrate more variables that influence trip behavior.

The decrease in public and private transport use caused by ride-sourcing does not only occur for commuter trips [13]. In Indonesia, trips to transportation station nodes (e.g., the airport, terminal, rail station) have experienced a significant change. For example, Soekarno-Hatta Airport bus and taxi users have decreased due to ride-sourcing [14]. As a result, several terminals and airports have banned ride-sourcing operations [15]. These trips to transportation stations are for facilitated work and social and cultural activities at locations at higher spatial distances. This type of trip is considered important due to the need for more reliability in ensuring that individuals are present at specific times related to the schedules of the transport stations (e.g., the train, airplane, or bus schedules). However, most studies on ride-sourcing modes focus on commuter trips, while studies on trips to transportation stations are still limited. Investigating the ride-sourcing substitution effect for trips to transportation stations is very important for formulating the management of specific travel demands. This is due to the significant mobility of these trips, which contributes to congestion, especially around transport stations.

Moreover, most travel behavior studies have shifted from only integrating variables concerning trip characteristics (e.g., distance, travel time, and costs) and personal characteristics (e.g., age, income, and occupation) to also accommodating multi-dimensional variables, such as attitude and satisfaction [4], [7], [16]–[18]. This is because a user's particular attitude and satisfaction with a particular mode influence their travel behavior, such as the mode choice [19]–[21]. It appears that when the attitude towards certain modes is positive, due to the satisfaction experienced on previous trips, people tend to take the same mode of transport on their next trip [22], [23]. In Indonesia, a study by Irawan et al. [7] integrated aspects of attitude into three categories: waiting for time satisfaction, facility integration of public transportation modes, and ease of application. Several studies indicate that using public transportation correlates with more negative attitudes than using private transport [24], but there are no specific studies that elaborate on people's attitudes toward using ride-sourcing in more detail.

Based on this background information, this study investigates the substitution effect of ride-sourcing based on commuting and transport station (e.g., airport, terminal, rail station) trips. Moreover, this study will address two questions: (i) how does the substitution effect occur on commuting and transport station trips, and (ii) what factors affect these trips? The effects of socio-demographics, spatial characteristics, and attitude were integrated into the discriminant model to explore this further. For this purpose, this study collected data from a questionnaire distributed to ride-sourcing users in Bandung in 2020. This study uses factor analysis to reduce the noise and the dimension of the attitudinal questions. Moreover, the factor analysis results of attitude factors were used as the independent variables in the discriminant analysis of the substitution effect.

Following this introduction, the literature concerning ride-sourcing is described in the second section. The third section describes the methodology of the research design and data collection, which is followed by an overview of the descriptive statistics for key variables. Then, the paper presents the discriminant analysis for the substitution effect in commuting and transport station trips. A discussion of the findings is presented in the discussion section. Finally, the paper provides some concluding remarks.

II. MATERIALS AND METHOD

A. *Substitution Effect of Ride-Sourcing*

With its particular characteristics, ride-sourcing has raised the issue of competition with public transport and conventional taxis. Ride-sourcing can be either complementary or substitutionary concerning public transport and conventional taxis [25]. The complementary effect refers to the effect of ride-sourcing supporting existing public transport services. On the other hand, substitution is associated with a decrease in the use of conventional public transport [7].

Most studies on ride-sourcing behavior have focused on the substitution and complementary effects due to their attractiveness for developing policies on congestion mitigation and protecting the environment [9], [26]–[30]. A study in Shenzhen, China, found that ride-sourcing causes a profound decrease in the share of trips performed by conventional taxis and, in a certain period, imposed additional traffic congestion and lowered the travel speed by 8% [31]. Various studies in major US cities have indicated that ride-sourcing has interesting effects, and it has been shown to increase commuter rail demand by 3% and decrease light rail and bus demand by 3% and 6%, respectively [11]. Notable studies on the interaction between motorcycle-based ride-sourcing (MBRS) and other modes of transport in Indonesia have been carried out by Medeiros et al. [32] and Irawan et al. [7]. Medeiros et al.'s [32] study indicated that MBRS plays a complementary role and is an alternative to public transport, and Irawan et al. [7] also indicated that MBRS is complementary to bus rapid transit and commuter rail. Most of these studies, also supported by an extensive review by Tirachini [8], confirm that ride-sourcing has the potential to be a substitute for modes of transport other than taxis and private transport.

Generally, from a travel behavior perspective, personal characteristics (e.g., gender, income) and trip characteristics have been the factors that influence the choice of travel mode, including ride-sourcing usage [2], [16], [33], [34]. A study by Rayle et al. [25] found that ride-sourcing users tend to be younger males who are highly educated and reside in zero-car households. Younger users also tend to have previously used public transport more than older users [2]. Moreover, previous studies showed that ride-sourcing users tend to use the services for trips over short distances and with low travel times [25]. Short-distance trips also tend to show more of a substitution effect of ride-sourcing on traditional transport modes (car, bus, taxi, and paratransit) based on a study in Beirut [35]. The ride-hailing services also tend to be used for occasional trips that complement other daily trips [36], [37].

Moreover, prior studies also indicates the role of attitude towards mode choice [16], [18], [21], [38], [39]. Several studies have used attitude to evaluate whether passengers would like to use ride-sourcing [40], [41]. Fu [40] found that frequent users of information and communication technology (ICT) in China have a stronger willingness to use ride-sourcing and were motivated by their positive attitude and satisfaction with ride-sourcing services. A study in Vietnam indicates that service quality influenced personal loyalty to ride-sourcing trips [41]. Instead of influencing the attitude towards ride-sourcing, the perceived usefulness is also influenced by the relative advantage of finding ride-sourcing compared to other modes and ride-sourcing accessibility [41]. Moreover, interestingly, Rizki et al. [2] found that a more positive attitude towards ride-sourcing does not straightforwardly increase the usage of ride-sourcing services.

B. Ride-Sourcing in Indonesia

In recent decades, the mobility service market has experienced substantial growth due to the introduction of mobile application-based services (e.g., Uber, Lyft, Grab, Go-Jek, DiDi). There are various app-based ride-sharing platforms, such as 'ride-sharing', 'ride-matching', or 'peer-to-peer' services [42]. This study refers to an app-based ride-sharing platform as ride-sourcing [25]. Systematically, ride-sourcing companies connect potential passengers with informal 'community' drivers who drive private vehicles, attaching various pieces of information (e.g., information about the drivers and trips) through a mobile app platform [42], [43].

In Indonesia, the spark for online transportation services was the establishment of Go-Jek in 2010, with a call center system [44], [45]. The mobile application for Go-Jek was launched in early 2015, and it is now continuously being upgraded, with various services being added, from food and package deliveries to room-cleaning services. In 2018, Go-Jek employed more than one million drivers [2], [44]. In 2014, Uber entered the Indonesian market, followed by Grab in 2015. In 2018, Grab acquired Uber, and since then, Go-Jek and Grab have dominated the ride-sourcing service market in Indonesia. The substantial growth in ride-sourcing services is shown by the increasing number of cities in which they are available – from one city in 2013 to 50 cities in 2018.

With its advantages, ride-sourcing has disrupted established transportation business models that provide similar services [11]. Ride-sourcing can only be distinguished from traditional taxicabs [25] or traditional motorcycle taxis [1], [32] by its users' use of smartphones. Regarding management, ride-sourcing services tend to avoid safety, labor, and supply regulations due to framing themselves as ride-sharing services [46]. This has sparked opposition all over the world, especially from taxi companies. In Indonesia, the presence of online services for transportation has caused a social disparity with the conventional transportation that already exists and is regulated by law (e.g., taxis and public transport) [47]. Between 2015 and 2017, there were a series of demonstrations demanding the banning as well as the regulation of online ride-sourcing. For example, in the first quarter of 2016, opponents of ride-sourcing, led by taxi and public transport drivers, called for a ban on online-based transportation companies [47]. In their article, Nangoy and Silviana [47] cited the following statement from the director of a taxi company in Indonesia: 'online transport apps have destroyed some local taxis, mainly the small players. In the city of Bandung, paratransit operators experienced a decline in the number of passengers after ride-sourcing emerged [48].

Furthermore, after a series of regulations created by the Ministry of Transportation during the period from 2017 to 2019 (Law No. 102/2017; Law No. 118/2018; Law No. 12/2019), online taxi and *Ojek* drivers expressed their disagreement with the fare standards. According to these drivers, the fare standards were too low and could not be accepted. They held a demonstration where they demanded the abolition of low online fares and tighter regulation of ride-hailing companies [49]. The drivers typically own the assets used by ride-sourcing drivers and are obliged to pay the maintenance and operational costs, which are usually deducted from their income. Therefore, fare standards are important to ensure a sustainable cash flow for drivers.

C. Research Design

In the present study, the research design investigates the substitution effect of ride-sourcing for daily and transport station trips. To explore this substitution effect, this research will accommodate various variables, such as socio-demographic characteristics (e.g., income, gender, age, etc.), trip characteristics (e.g., distance, fare, luggage, etc.), and attitude. The proposed models are designed based on a theoretical model of the substitution effect and its determinant.

The substitution effect in this study impacts the transport modes that users chose before ride-sourcing was established. As the transport modes, which are the dependent variables, are discrete data, and because various characteristics will be integrated into the independent variables, multivariate analysis was used [50]. Discriminant analysis is used to analyze the substitution effect. Previous studies have used this analysis to investigate the substitution effect in ride-sourcing [2] or e-shopping [51]. A discriminant analysis specification is appropriate for modeling the substitution effect's determinants when the dependent variables' outcomes are categorical and non-ordered and for explaining the relationship that affects the category in which an object is located [50].

Moreover, as this study explored the effect of attitude on the substitution effect, factor analysis was used to reduce the dimension of the attitude data from the questionnaire. This new dimension (factors) represents the fundamental construct assumed to underlie the original variables [50]. Factor analysis provides the tools for analyzing the structure of the interrelationships (correlations) among a large number of variables (e.g., test scores, test items, questionnaire responses) by defining sets of variables that are highly interrelated, which are known as factors [50]. Factor analysis is appropriate when the data is on a continuous or ordinal scale; in this study, exploratory factor analysis is used rather than confirmatory factor analysis, which is generally used in structural equation modeling (SEM).

D. Data Collection

This study distributed questionnaires to users of ride-sourcing services (i.e., users of Uber, Gojek, and Grab) in Bandung, Indonesia. We chose a sample size of 400 using Yamane's equation [52], given that the population of Bandung was 2,503,710 [53] and assuming a 5% significance level. The sample size was upgraded to 500 to overcome possible errors during the survey. Moreover, there were two different questionnaires. The first was the questionnaire for respondents who used ride-sourcing for their daily trips, and the second was for users who have used ride-sourcing for trips to transportation stations. The questionnaire was constructed based on the literature regarding ride-sourcing [8] and travel behavior [12] to capture the users' travel behavior and their experiences [16], [17], [54].

The questionnaire consisted of three sections. The first sections contained questions about the respondents' socio-demographic characteristics, such as their gender, age, occupation, education level, residential location, and income. The characteristics of their ride-sourcing use, consisting of travel time, cost, length, and frequency, are collected in the second section. Moreover, in this part, there are additional questions regarding the amount of luggage carried and the type of transport station (e.g., airport, rail station, and bus station) for the transport station trip questionnaire. In the last part of section two, respondents had to rate their attitude towards ride-sourcing services on a five-point Likert scale from strongly disagree (1) to strongly agree (5). There are 24 attitudinal questions concerning the reasons to use ride-sourcing.

The data collection was conducted using an online platform; the web-based questionnaire was distributed through various online forums (i.e., WhatsApp, Facebook, Instagram, Twitter, and Line). This method was selected because face-to-face interactions were limited during the pandemic. However, like other online surveys, this survey is biased because some groups in society could not access the questionnaire due to some limitations (e.g., not having a smartphone or access to the internet, or not having a social media account). On the other hand, people who are more familiar with social media and have better access to the internet and ICT facilities tend to be more likely to access this online questionnaire. However, since most people in Indonesia owned a smartphone in 2020 [55], [56], this limitation is not regarded as serious in terms of data collection and sampling representativeness. The respondents were recruited using convenience sampling, and the authors distributed the web-based questionnaire to various connections with the help of students and other colleagues. Some survey assistants recruited through social media also helped distribute the questionnaire. Similarly, they distributed the questionnaire with their social media account and connections to increase the sample representativeness and maintain their safety during the survey.

The questionnaire distribution took place from Mar. 30 to Apr. 20, 2020. After this distribution, the data were evaluated based on completeness. The data from 500 filled-out questionnaires were then reviewed, and the filtered data from 452 respondents were used for further analysis. This data contained the data of 242 respondents for daily/commute trips and the data of 210 respondents for trips to transportation stations.

E. Respondent Characteristics

To investigate the substitution effect, the respondents had to select the transport mode they frequently used before ride-sourcing services existed. The options were private vehicles (PV; cars and motorcycles) and public transport (PT; buses, paratransit, taxis, etc.). Table 1 shows that for commuter trips, most respondents (50.4%) were PV users, while for transport station trips, most respondents were PT users. This description underlines ride-sourcing's possibility of substituting for both PV and PT.

Moreover, Table 2 describes the respondents' demographic characteristics. Most of the respondents were male, students and in the productive age range (18–40 years old). Interestingly, while commuting trips ages 18–22 dominate, the distribution for transport station trips is quite similar between the groups from 18–22 years old and 23–30. Most respondents also have an income/allowance of around 2–6 million IDR (150–500 USD). Most of the respondents were residents of the city of Bandung.

Regarding travel characteristics, most respondents use ride-sourcing for 2–6 km commuting trips. On the other hand, most respondents use ride-sourcing for trip distances of more than 10 km for transport stations. In line with the travel distance, most commuting trips last for 15–30 minutes, while to reach a transport station, the travel time is around 15–60 minutes. While the average fare for commute trips is around 10–20 thousand IDR, the average fare to reach a transport station is more than 50 thousand IDR. Moreover, for transport station trips, most respondents went to the airport (48.6%). Most respondents who made trips to transport stations carried one piece of luggage (64.3%), followed by respondents carrying one suitcase (47.6%).

TABLE I
DESCRIPTION OF SUBSTITUTION MODES BASED ON TYPE OF TRIP

Substitution Modes	**Type of Trip**	
	Commute Trips (%)	**Transport station trips (%)**
Private Vehicle (PV)	50.4	32.9
Public Transport (PT)	49.6	67.1

TABLE II
DESCRIPTION OF RESPONDENTS' DEMOGRAPHIC CHARACTERISTICS

Variable		**Commute Trips (N = 242)**	**Transport station trips (N = 210)**
		Proportion (%)	**Proportion (%)**
Gender	Male	39.7	43.3
	Female	60.3	56.7
Occupation	Student	76.0	63.8
	Entrepreneur	3.3	8.6
	Jobless	4.5	0.5
	Civil Servant/Army/Police	1.7	1.0
	Private/BUMN Workers	7.4	15.7
	Lecturer/Teacher/Doctor	2.9	5.7
	Housewife	1.2	2.9
	Other	2.9	1.9
Age	< 18 years old	2.5	21.9
	18–22 years old	76.4	34.8
	22–30 years old	18.6	29.5
	31–50 years old	2.5	11.9
	> 50 years old	0	1.9
Income/ allowance‡	< IDR 1,000,000	15.4	18.6
	IDR 1,000,001– IDR 2,000,000	7.0	10.0
	IDR 2,000,001– IDR 4,000,000	22.3	26.2
	IDR 4,000,001– IDR 6,000,000	21.9	22.9
	IDR 6,000,001– IDR 8,000,000	14.5	9.0
	IDR 8,000,001– IDR 10,000,000	10.7	3.8
	IDR 10,000,001– IDR 12,000,000	6.2	2.4
	> IDR12,000,000	2.0	7.1
Resident locations	Bandung	63.6	84.8
	Bandung District	16.9	1.9
	West Bandung District	2.9	0.5
	Cimahi	4.5	3.8
	Other Locations	12.0	9.0

*1 USD equal to 14,500 IDR in April 2020.

TABLE III
RESPONDENTS' TRIP CHARACTERISTICS

Variable		Commute Trips (N = 242)	Transport Station Trips (N = 210)
		Proportion (%)	Proportion (%)
Average Distance Using Ride-Sourcing	< 2 km	10.3	6.2
	2–4 km	31.0	11.0
	4–6 km	21.5	14.3
	6–8 km	14.9	14.3
	8–10 km	9.1	13.8
	> 10 km	13.2	40.5
Average Travel Time Using Ride-Sourcing	< 15 minutes	18.6	7.1
	15–30 minutes	57.9	34.3
	30–60 minutes	21.5	25.2
	60–90 minutes	1.2	12.4
	> 90 minutes	0.8	21.0
Average Ride-Sourcing Fare‡	< IDR 10,000	9.5	4.8
	IDR 10,000–IDR 20,000	42.6	11.0
	IDR 20,000–IDR 30,000	26.4	16.2
	IDR 30,000–IDR 40,000	12.0	14.3
	IDR 40,000–IDR 50,000	4.5	15.2
	> IDR 50,000	5.0	38.6
Type of Transport Station	Airport	-	48.6
	Bus station	-	12.9
	Rail station	-	38.6
Number of pieces of luggage carried	0	-	0.5
	1	-	64.3
	2–3	-	28.6
	> 3	-	6.6
Number of suitcases carried	0	-	30.0
	1	-	47.6
	2–3	-	18.6
	> 3	-	3.8

*1 USD equal to 14,500 IDR in April 2020

III. RESULTS AND DISCUSSION

A. *Factor Analysis of Attitude Towards Ride-Sourcing*

This section presents the estimation results from investigating the substitution effect of ride-sourcing on commuting and transport station trips. However, since this study also explores the effect of attitude on the substituted modes, we performed factor analysis on the attitudes towards ride-sourcing aspects. The section about the attitude towards the services/reason for using the service consists of 24 questions. The questions concern reliability, availability, cost-effectiveness, the app's interface, and safety and security. These questions use a Likert scale ranging from 1–5, with 1 being strongly disagree and 5 being strongly agree. Before the factor analysis, we described the attitude towards ride-sourcing in Table 4. For commuting trips, the most common reasons were not requiring parking (4.227), distribute economic benefit with the driver (4.260), and more definite costs (4.145). For the transport station trips, the most common reasons were that ride-sourcing was in service every time (3.943), easy non-cash payments (3.967), and more definite costs (3.962). On the other hand, the least common reasons for users on commuting trips included lower costs (3.054), being unable to use private vehicles (2.473), no rides (2.690), and not owning private vehicles (2.360). Meanwhile, the least common reasons for transit station trips include no rides (2.690) and not owning private vehicles (2.657).

TABLE IV
DESCRIPTION OF THE ATTITUDE TOWARDS RIDE-SOURCING

I use ride-sourcing because…	**Commute Trip (N = 242)**		**Station Node Trip (N = 210)**	
	Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
Service every time	4.066	0.666	3.943	0.710
Not having trouble getting a vehicle	3.711	0.809	3.752	0.798
Not owning private vehicles	2.360	1.077	2.657	1.114
Limited access to public transportation	3.227	1.020	3.390	0.973
Unable to use private vehicles	2.479	1.233	3.038	1.062
No rides	2.690	0.897	2.776	0.965
Vehicles never break down	3.508	0.826	3.700	0.752
Does not require parking	4.227	0.736	3.733	0.915
Expert drivers	3.744	0.664	3.790	0.644
Vehicle comfort	3.764	0.728	3.852	0.643
Useful facilities are available	3.744	0.789	3.800	0.625
Sense of security at night	3.550	0.778	3.781	0.712
Easily report incidents to operators	3.893	0.749	3.924	0.622
Safe every time	3.632	0.741	3.824	0.658
Time savings for other activities	3.835	0.661	3.852	0.686
Punctuality provides an opportunity to set time	3.785	0.690	3.810	0.686
Multitasking on trip	3.690	0.788	3.743	0.789
Lower cost	3.054	0.865	3.638	0.796
Many tariff promotions	3.921	0.848	3.833	0.646
Easy non-cash payment	4.037	0.775	3.967	0.701
Cost certainty	4.145	0.624	3.962	0.610
Many interesting promotions	3.971	0.847	3.800	0.697
Distribute economic benefit	4.260	0.702	3.652	0.800
Good design	4.058	0.697	3.614	0.738

Furthermore, factor analysis was carried out on the reasons for users to obtain attitude variables for ride-sourcing. Factor analysis [50] is conducted to identify several relatively small factors that can be used to explain many interrelated variables. Principal component analysis (PCA) was applied with varimax rotation to provide adequate information about the variables under examination and simplify the factor structure.

The suitability parameters of the presented factor analysis are also evaluated [50]. The Kaiser-Mayer-Olkin (KMO) test gives a value of more than 0.7 (0.844). The results of Bartlett's test of sphericity show a significant value (< 5%) and a correlation value of more than 0.5 [50]. Table 5 shows the results of PCA, where seven factors were constructed from 24 variables: cost savings, the convenience of the facilities, safety, accessibility of private and public transportation, productivity during the trip, design and social aspects, and service availability. The results of the factor loadings for each factor and variable are presented in the table below. Based on the statistical requirements of Hair et al. [50], only loading factors above 0.5 are stated in the table containing the factor analysis results. Furthermore, the factor analysis results are used as independent variables in the discriminant analysis in the next section.

TABLE V
FACTOR ANALYSIS OF ATTITUDE TOWARDS RIDE-SOURCING USE

Attitude Towards Ride-sourcing Use	**Factor Loadings**						
	Service availability	**Accessibility to private and public transportation**	**Convenience of the facilities and services**	**Safety**	**Cost savings**	**Productivity during trip**	**Design and social aspects**
Service every time	0.766						
Not having trouble getting a vehicle	0.736						
Does not require parking	0.526						0.517
Not owning private vehicles		0.782					
Limited access to public transportation		0.577					
Unable to use private vehicles		0.72					
No rides		0.723					
Vehicles never break down			0.709				
Expert drivers			0.776				
Vehicle comfort			0.743				
Useful facilities are available			0.559				
Sense of security at night				0.795			
Easily report incidents to operators				0.646			
Safe every time				0.818			
Lower cost					0.566		
Many tariff promotions					0.825		
Easy non-cash payment					0.62		
Cost certainty					0.518		
Many interesting promotions					0.803		
Time savings for other activities						0.629	
Punctuality provides an opportunity to set time						0.762	
Multitasking on trip						0.702	
Distribute economic benefit							0.766
Good design							0.64

B. Classification Model for Commuting and Transport Station Trips

This sub-section describes the models of the substitution effect of ride-sourcing based on commuting and transport station trips. The substitution effect in the analysis refers to the transport modes chosen by users before ride-sourcing was available. The discriminant analysis was used to model this substitution effect with various characteristics, such as user demographics, trip characteristics, and attitudes, which are added as independent variables. The analysis used a stepwise method, and we retained several insignificant variables in some models because of their interaction with other variables and their importance in explaining the characteristics of the models.

1) Classification Analysis of Commuting Trips: The discriminant analysis results for commuting trips can be seen in the left section of Table 6. Before interpreting the discriminant analysis results, the model's fitness and quality are evaluated. The statistical value used to show the quality of this discriminant analysis can be seen from the squared canonical correlation value in each function, which indicates that the model can explain 16% (0.400^2) of the variation. In addition, the classification suitability value in the model shows a value of more than 67.8%. Although the model validation requirements in the Box-M test show a significant value, this is not considered a serious issue for a large number of samples [50].

Based on Hair et al. [50], the interpretation of the discriminant model relates to the functions of group centroids (FGC). The FGC refers to the means of the discriminant function scores by the group for each function calculated. Since the discriminant function is a classification analysis based on the group of dependent variables, the number of functions that represent the separation function depends on the number of groups/categories of dependent variables. In this research, there are two groups of dependent variables (PV and PT); therefore, only one classification function is produced. The interpretation was done by evaluating the options with the most positive and most negative values with a structural matrix loading greater than 0.3, as suggested by Hair et al. [50]. The classification function is developed: it separates the respondents who previously used private vehicles (0.288) from the respondents who previously used public transportation (-0.654).

The discriminant analysis results show various variables that separate groups of ride-sourcing users who previously used private vehicles and public transportation. Based on the matrix structure, independent variables that are associated with the function are users who experience fare savings, a lack of access to other transportation, and increased productivity. In addition, from a demographic perspective, the first function is also associated with an income of more than 6 million IDR. In terms of the characteristics of the trip, the first function shows an association with a travel time of more than 30 minutes and a fare of more than 30 thousand IDR.

TABLE VI
CLASSIFICATION MODEL ESTIMATION

Variable	Commute Trips				Transport Station Trips			
	Dependent Variable Group Mean		Test of Equality of Group Means (F)	Structure Matrix	Dependent Variable Group Mean		Test of Equality of Group Means (F)	Structure Matrix
	PV	PT		DF	PV	PT		DF
Attitude Towards Ride-sourcing Use								
Cost savings	0.098	-0.215	4.415	0.311	-0.054	0.022	0.324	0.061
Convenience of the facilities and services	-0.132	0.021	1.204	-0.162	0.001	0.145	0.982	0.107
Safety	-0.086	-0.181	0.446	0.099	0.111	0.144	0.052	0.024
Accessibility to private and public transportation	-0.247	0.123	7.033	-0.393	-0.259	0.356	20.652	0.489
Productivity during trip	-0.168	0.201	7.608	-0.408	-0.01	0.099	0.514	0.077
Design and social aspects	0.477	0.432	0.152	0.058	-0.483	-0.558	0.316	-0.06
Service availability	0.063	0.121	0.201	-0.066	0.276	-0.273	12.887	-0.386
Demographic Characteristics								
Male [D]	0.435	0.311	3.303	0.269	0.435	0.433	0.001	-0.003
Student [D]	0.726	0.838	3.536	-0.278	-	-	-	-
Income < 1 million IDR [D]	0.048	0.068	0.4	-0.094	0.217	0.319	2.355	0.165
Bandung resident [D]	0.655	0.595	0.8	0.132	0.826	0.858	0.366	0.065
Income > 6 million IDR [D]	0.494	0.297	8.307	0.427	0.261	0.206	0.808	-0.097
Age < 25 years old [D]	0.923	0.932	0.071	-0.04	-	-	-	-
Age 25–40 years old [D]	0.077	0.068	0.071	0.04	-	-	-	-
Trip Characteristics								
Using Online Ojek [D]	0.857	0.851	0.014	0.017	-	-	-	-
Distance < 1 km [D]	0.071	0.108	0.908	-0.141	-	-	-	-
Distance < 4 km [D]	-	-	-	-	0.13	0.191	1.211	0.118
Travel distance > 10 km [D]	-	-	-	-	0.391	0.411	0.077	0.03
Travel time < 15 minutes [D]	0.167	0.23	1.346	-0.172	0.043	0.085	1.206	0.118
Travel time > 30 minutes [D]	0.274	0.149	4.516	0.315	-	-	-	-
Travel time > 60 minutes [D]	-	-	-	-	0.478	0.567	1.477	0.131
Fare < 10 thousand IDR [D]	0.071	0.149	3.585	-0.28	0.043	0.05	0.038	0.021
Fare > 30 thousand IDR [D]	0.482	0.311	6.262	0.371	-	-	-	-
Fare > 50 thousand IDR [D]	-	-	-	-	0.29	0.433	4.024	0.216
Distance < 4 km [D]	0.381	0.419	0.308	-0.082	-	-	-	-
Brings > 1 bag [D]	-	-	-	-	0.522	0.277	12.747	-0.384
Brings > 1 suitcase [D]	-	-	-	-	0.58	0.496	1.283	-0.122
To airport [D]	-	-	-	-	0.478	0.489	0.023	0.016
To station [D]	-	-	-	-	0.362	0.397	0.235	0.052
Car availability	-	-	-	-	0.797	0.312	17.516	-0.45
Motorcycle availability	-	-	-	-	1.348	1.028	5.801	-0.259
Drive alone [D]	-	-	-	-	0.261	0.461	7.984	0.304
Box's M [F; df1;df2;*p-value*]	265.236 [1.125; 210; 66950.270; 0.103]		Prior Transportation Mode	DF	431.317 [1.231; 300; 60029.467; 0.004]		Prior Transportation Mode	DF
Eigenvalues [Canonical Correlation]	0.190 [0.400]		PV	0.288	0.416 [0.542]		PV	-0.917
Wilks' Lambda of DF [p-value]	0.840 [0.005]		PT	-0.654	0.706 [0.000]		PT	0.449
Percent Correct of Classification (%)	67.8%				75.7%			

PV = Private Vehicle; PT = Public Transportation; [D] = Dummy variable; 1 = yes; 0 = otherwise; DF = Discriminant Function

The model shows that ride-sourcing users with an income of more than 6 million IDR tend to be PV users rather than public transportation users. This finding indicates that respondents with higher incomes have also shifted to ride-sourcing. Based on the characteristics of the trip, respondents with a travel time of more than 30 minutes or a fare above 30 thousand IDR tend to be private transport users rather than PT. This shows that longer ride-sourcing trips have more potential to be substituted for PV.

Furthermore, ride-sourcing users who use the service because of fare savings tend to have previously used private vehicles rather than PT. This is related to the lower costs associated with moving from using a private vehicle to ride-sourcing, with increasing transportation costs (parking, fuel) in urban areas, particularly for private cars when there is more traffic congestion. Meanwhile, ride-sourcing users who experience increased productivity and lack access to other transportation tend to be associated with PT users rather than private transportation. Public transport users can experience increased productivity because the travel time is reduced significantly by ride-sourcing. This is related to the fact that the PT network is limited and of inadequate quality, resulting in high travel times. This reduction in travel time allows users to be more productive in performing their daily activities.

2) Classification Analysis of Transport Station Trips: Like the previous analysis, a classification analysis is also carried out for trips to transportation stations. Transportation stations in this research encompass airports, train stations, and bus terminals. The dependent variable in the discriminant analysis is the transportation mode used before ride-sourcing existed, and the independent variables are the demographic characteristics, the respondents' trips, and their attitude towards ride-sourcing. The discriminant analysis results can be seen on the right side of Table 6.

The interpretation of discriminant analysis is determined based on the function of the center of the FCG that separates the existing groups. The function separates respondents who previously used public transportation (0.449) and respondents who previously used private vehicles (-0.917). Meanwhile, only structural matrix loadings that are more than 0.3 are interpreted.

The discriminant model for the transport station trips (right part of Table 6) shows that the function of the structure matrix is associated with various independent variables, including the number of goods carried and vehicle availability. Meanwhile, the reasons for use associated with the discriminant function (DF) include the lack of access to private and public transportation and ride-sourcing availability at various times and places.

The modeling results show that ride-sourcing users who carry various goods on the way to the station locations have previously been PV users. Similarly, it is found that ride-sourcing users who have access to private car vehicles are more associated with people who initially used PV. These two things show that ride-sourcing has a substitution effect on PV, especially for people with more economic power. In addition, people who drive alone are more associated with people who used PT in the days before ride-sourcing existed. This is related to station node trips, which are continued with other modes of transportation, like most non-commuting trips. This means that the use of PV itself is inefficient: it requires parking for a long time, so it has greater cost consequences. This makes PV users tend to drive together to transport station nodes.

Based on the reasons for use, it was found that the lack of access to public and private transportation is more associated with public transportation users. This confirms the findings from the previous model, where ride-sourcing is a substitute for PT because PT does not provide sufficient accessibility. Meanwhile, the reason related to service being available at various times and locations is more associated with private vehicle users. This finding is thought to be related to the efficiency of ride-sourcing at certain times, such as at night, when driving requires more concentration. This is an advantage of ride-sourcing over private transportation, which requires one to concentrate on driving activities.

IV. CONCLUSION

Ample evidence shows that ride-sourcing can substitute for the existing transport system. However, the effect of the type of trip on this substitution effect is still not fully understood. Therefore, this study aimed to investigate the substitution effect of ride-sourcing based on the type of trip as well as trips to transport stations. Moreover, this study provides an analysis based on data from Bandung, Indonesia, which represents developing countries.

The findings of this study are not only in line with previous research but also extend the knowledge regarding the substitution effect of ride-sourcing. Generally, the study found that ride-sourcing users previously were both public transportation users and private vehicle users. This is consistent with various prior studies [1], [2], [8]. The commuting travel model shows that the substitution of PV occurs for high-income ride-sourcing users. The reason might be related to fare savings and travel time, as well as the efficiency offered by ride-sourcing. This is supported by the reasons for using ride-sourcing, which indicated that users who previously used PV experience fare savings when using ride-sourcing services. This is related to costs decreasing when people move from private to ride-sourcing transportation, with increasing transportation costs (parking, fuel) in urban areas, particularly for private cars when there is more traffic congestion [26].

On the other hand, PT already has a low fare, so this financial advantage is less achievable than private transportation, especially for motorbikes. Meanwhile, the model also finds that longer trips using ride-sourcing have more potential to substitute for PV than PT. This is thought to be related to the effectiveness of driving. With a longer trip, ride-sourcing or PT means that a person can carry out various activities [57], [58] on a trip, whereas driving a PV requires a user to focus on driving the vehicle.

People who previously used PT are associated with users who experience increased productivity. This might be associated with the facilities of ride-sourcing offered compared to those owned by PT. PT in Bandung (i.e., paratransit and bus) is of lower quality and offers limited space to carry out activities due to limited vehicle conditions [59], [60]. Ride-sourcing vehicles, such as online taxis, provide more private space for online/offline activities [58]. Similarly, using ride-sourcing due to a lack of access to other transport modes tends to be associated with users who previously used PT. Increased productivity can be experienced by users who previously used PT because the travel time is significantly reduced when using ride-sourcing. This is related to the limited PT network of inadequate quality in Bandung [60], resulting in high travel times. This reduction in travel time allows users to be more productive in performing their daily activities to achieve well-being.

On the other hand, the transport station trip model shows that ride-sourcing users who carry various goods to station node locations tend to have previously used PV. Furthermore, it was also found that people who had cars tended to be PV users before ride-sourcing existed. This shows that ride-sourcing substitution impacts PV, especially for higher-income people [2]. In addition, people who ride alone are more associated with people who used PT before ride-sourcing existed. This is related to transport station trips, which continue with other modes of transportation, like most non-commuting trips. Therefore, the use of PV itself is inefficient because it requires parking for a long duration, causing it to have greater cost consequences.

Moreover, there are several findings when we compare the attitude towards the ride-sourcing effect based on the trip type. Fare savings are found to be more significant for commuting trips than transport station trips, which might be related to the frequency of the trip. Commuting trips are performed more frequently than transport station trips, and thus the fare savings will be more significant. On the other hand, service availability is more significant for transport station trips than commuting trips. As punctuality is required for transport station trips, better availability of the services will give users a higher probability of arriving at the desired time. Interestingly, it is found that this is one of the reasons that ride-sourcing is a substitute for PV for transport station trips. Moreover, the attitude towards productivity during the trip is more significant for commuting trips than for transport station trips.

The commuting travel model shows that ride-sourcing users at higher economic levels tend to be PV users rather than PT users. Based on the travel characteristics, respondents with a travel time of more than 30 minutes or a fare of more than 30 thousand IDR tend to be users of private vehicles rather than public transportation. Users of ride-sourcing for commuting trips that use ride-sourcing services because of fare savings tend to have previously used PV rather than PT. Ride-sourcing users who experience increased productivity and lack access to other transportation modes tend to be associated with PT users. Increased productivity can be experienced significantly by PT users because of the significant reduction of travel time through ride-sourcing.

The modeling of station trips shows that ride-sourcing users who carry various goods on their way to station locations tend to have been PV users previously. Users who drive alone are more associated with people who used PT in the days before ride-sourcing existed. Based on the reasons for use, it was found that a lack of access to PT is more associated with PT users. Meanwhile, service availability at various times and places are more associated with private vehicle users. This finding is thought to be related to the efficiency of ride-sourcing at certain times, such as at night, which requires more driving concentration. The findings in the model also emphasize PT access as a reason for shifting from PT to ride-sourcing. This shows that ride-sourcing significantly replaces PT in cities with insufficient PT accessibility.

This study's findings lead to several suggestions to improve ride-sourcing services and increase the demand for PT. First, ride-sourcing management needs to focus on substituting PV to reduce the number of vehicles, and the model finds that the shifting of PV users tends to occur for trips of long durations. This finding indicates that ride-sourcing needs to be regulated as long-distance transportation, such as from outside the city of Bandung, into the city of Bandung. Second, another reason for PV users to shift to ride-sourcing is fare savings. Increasing transportation costs, such as parking rate policies for PV, can encourage PV users to become not only ride-sourcing but also PT users. Third, based on the reasons for use, the decrease in PT use due to the shift to ride-sourcing can be minimized by increasing the access to or quality of PT. The development of reliable PT that provides access to residential and activity locations needs to be a priority for the Bandung city government. Lastly, increasing the shift from PV to ride-sourcing for transport station trips can also be achieved by managing costs and accessibility at the transportation station node. Fare management and the provision of an 'in-and-out' place for ride-sourcing users are measures that can be implemented at transportation stations.

ACKNOWLEDGMENT

This research was funded by the International Publication Research Grant of the Institut Teknologi Nasional Bandung. The authors thank all parties who have participated in the data collection. All statements and interpretations in this study are the authors' responsibility and only reflect the authors' view.

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