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Impact of aerial cable car in low-income area in Medellín, Colombia

Mihoko Matsuyuki[a]*, Sarika Okami[b], Fumihiko Nakamura[a], Iván Sarmiento-Ordosgoitia[c]

[a]*Faculty of Urban Innovation, Yokohama National University, 79-5 Tokiwadai Hodogaya, Yokohama 2220011, Japan*
[b]*Yachiyo Engineering Co., Ltd, 5-20-8 Asakusabashi Taito-ku, Tokyo 1118648, Japan*
[C]*Faculty of Mines, Universidad Nacional de Colombia, Cl. 80 # 65-223, Medellín , Colombia*

Abstract

In this study, we examine the effect of *Metrocable* cable-car projects and their socio-economic and spatial scope in *Comuna* 1 by two questionnaire surveys administered to residents and *Metrocable* passengers. We found that *Metrocable* commuters are saving time and money. Women in the low socio-economic class who live near a *Metrocable* station and work at safe *Comunas* with a train station likely use *Metrocable* for commuting. In addition, the installation of *Metrocable* in 2004 facilitated vocational job changes, which have led to higher incomes. However, it must be noted that the lowest income and education classes rarely use *Metrocable* for commuting. Besides, our research revealed *Metrocable* has not influenced the amount of crime in the neighborhood area in the last decade, which was perceived as an effect of passengers viewing crime from the air, but it has increased the passengers' senses of pride about their neighborhood. As a part of the integrated urban project (PUI), the *CEDEZO,* and *España* Library are mainly used by women with higher educational background.

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Keywords: Aerial cable-car, Metrocable, low-income area, socio-economic impact, spatial scope, local social development, integrated urban project (PUI)

1. Introduction

1.1. Background and objectives

The relationship between mobility and social exclusion has been an important issue within transport engineering and policy (Ohnmacht et al., 2009). *Metrocable* in Medellín, Colombia is an aerial cable car system running in a low-income neighborhood that connects the hillside area to the main train system running through the river valley, where the city center is located. The first *Metrocable* line launched in 2004 did not have the explicit objective of poverty

* Corresponding author. Tel.: +81-45-339-4244; fax: +81-45-339-4244.
E-mail address: mihoko@ynu.ac.jp

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reduction, but as time passed, expectations increased for *Metrocables* to reduce the poverty in the areas where they were located (Brand, 2013). Presently, the *Metrocable* receives worldwide attention as a project that has successfully changed peoples' lives and their mobility. Cable cars have also been introduced in other South American countries, such as Brazil, Bolivia and Venezuela (Brand and Dávila, 2011), and the *Metrocable* K-line was considered to be a role model for those projects. Therefore, to verify the impact of the *Metrocable* project, especially the impact of *Metrocable* on neighborhood residents, is essential to examine whether the project is contributing to the improvement of residents' lives. Additionally, if we assume that increased mobility is an indicator of poverty reduction, we can quantify these benefits. When we consider the scope of geographical mobility, we should consider two dimensions: spatial and socio-economic. The spatial dimension refers to the locations that are impacted by the project and the socio-economic dimension refers to the demographic being impacted, such as economic condition, gender, occupation, education, and lifestyle. Therefore, the first objective of this study is to identify the type and magnitude of the impact of the *Metrocable* project on neighborhoods with low-income residents in Medellín. The second objective is to identify the spatial and socio-economic scope of the impacted residents.

1.2. *Metrocable* overview

Metrocable is a cable-car public transportation system developed to improve mobility for people living in the economically depressed areas spreading across the hillside and to increase utilization of public facilities in Medellín (2.5 million of inhabitants), the city center of a metropolitan area with 3.8 million of inhabitants in 2018. The metropolitan train (Metro de Medellín) is the backbone of the transportation system (inaugurated in 1995), complemented by the bus rapid transit (BRT) system (2011), light rail transit (LRT, *Tranvia*) and cable cars (*Metrocable*) in different years. Through 2018, four *Metrocable* lines have been built— K-line (2004), J-line (2008), L-line (2010), and H-line (2017) —and another (M-line) is under construction. Now the integrated system has 73 km of routes. The *Metrocable* K-line, shown in Fig. 1, was the first *Metrocable* line and was developed as a branch line to feed train A of the Metro system line running 26 km through the Medellín metropolitan area from north to south. The K-line contains four stations: Acevedo, Andalucia, Popular, and Santo Domingo. Acevedo station is a transfer station to the A-line. It takes 12 min to travel the 2 km from Acevedo station to Santo Domingo station. The interval between each cable car is 12 s and each cable car has a capacity of 10 passengers, including two standing passengers. The K-line transportation capacity is 3,000 persons/hour. The Metrocable fare is 2,300 COP (0.82 US dollar) in 2017, and it is an integrated fare which permits travel along 73 km of the train, Metrocable, BRT and LRT, without any additional payment for transfers. However, if travellers use feeder buses to connect with main lines described, except BRT which has free feeder buses, they have to pay an extra 10% of the fare. Students and older than 60 have some discounts.

Fig. 1. *Metrocable* K-line

1.3. Review of previous studies

There are several papers concerning the various effects of *Metrocable*. Sarmiento et al. (2013) analyzed user's travel patterns along the *Metrocable* K-line and J-line. The main finding was that safety is highly important when people choose their transport mode. Agudelo et al. (2013) conducted two focus group discussions about the K-line, one for adults and another for the young generation, and found that some residents near the J-line walk for a long distance instead of taking *Metrocable* to save money. Heinrichs and Bernet (2014) examined the effect of *Metrocable* on residents' accessibility in Popular and Santa Cruz *Comuna* (district of Medellín, Colombia) by analyzing origin-destination surveys for Medellín from 2005 and 2011 and interviewed 30 female residents. Their findings revealed a reduced travel time, increased reliability, and reduced cost are the main advantages compared to the bus alternative. Brand and Dávila (2013) discussed how mobility affects opportunity and how *Metrocable* contributes to improve income generation and the living condition of the surrounding area population. They point out that the advantage of cost can be better quantified than time, but conventional buses and walking continue to be major transport modes. They also point out that in the immediate vicinity of the stations and upgraded urban areas below the overhead cables, the number of shops, bars and restaurants, workshops, and other small businesses has increased significantly, but outside these areas, small-scale economic activities, house prices, and rent show no significant changes.

Coupé et al. (2013) examined the impact of *Metrocable* on the local economy by analyzing the 'Medellín Quality of Life Survey' and pointed out that incomes of male heads-of-household were below the legal minimum wage in 2004, but in 2009 they were above the statutory minimum level in four *Comunas* along the *Metrocable* K-line and J-line. They also point out that in some *Comuna*, trends of the number of home-based enterprises follows the launch of *Metrocable* and the Integrated Urban Project (IUP or PUI in Spanish), which was completed as an integration of transport planning with other urban planning interventions. However, they say a causal relationship between the two cannot be ambiguously established. Coupé (2013) examined *Metrocable'*s impact on risk, poverty, and inclusion and found from resident interviews that *Metrocable* induced not only new job opportunities, but also some negative impacts for the young generation, such as abandonment of studies to act as local guides and involvement in 'sex tourism.' Bea (2016) examined *Metrocable*'s impact on crime reduction from statistical data, and found that the average homicide rate was reduced by 88% in 2004–2008 compared to 1999–2003 in *Comunas* 1 and 2. However, in other neighborhoods not affected by the *Metrocable*, the reduction rate was less than 20% and even increased in some instances.

Thus, there are a number of researches about the various impacts of *Metrocable*, but most of the researches are based on government statistics, observation, and interviews, and there have been no studies based on a resident survey about the various impacts. Therefore, their study areas were at the macroscopic level. There has been no research that examined the social and spatial scope of impact in the neighborhood area. This study tries to fill this void found in the literature review.

1.4. Methodology

(1) Case study area

Medellín city is divided into 16 districts called "*Comunas*" (Fig. 2) with approximately 100,000–150,000 inhabitants in each. We focus on *Comuna* 1 in this study, which is located along the northern edge of Medellín city (110 km^2 of urban area), because it includes two *Metrocable* stations on the K-line, Popular and Santo Domingo, and it was the first *Metrocable* line developed. *Comuna* 1 is also considered the poorest in the city. *Comuna* 1 has an area of almost 3.1 km^2 and approximately 150,000 inhabitants, denoting a high urban density. *Comuna* 1 is divided into 12 neighborhoods (wards), or sub-districts (Fig. 3). *Comuna* 1 served as a base for a paramilitary group and urban militia (a kind of urban guerrilla) two decades ago. It was referred to as the 'forgotten area' in Medellín and the residential areas are filled with small, roughly-built houses.

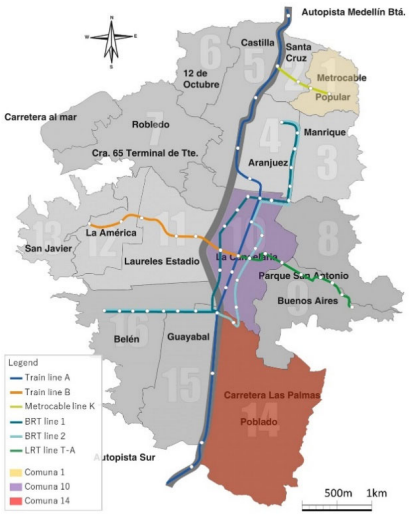

Fig. 2. *Comunas* and transportation in Medellín
Source: based on Gifex (2011)

Fig. 3. *Comuna 1* including two stations of *Metrocable* K-line
Source: EI Comercio (2015)

(2) Questionnaire surveys

This study utilized two questionnaire surveys. The first survey targeted residents who had continuously lived in the same place in *Comuna* 1 and worked continuously before and after the *Metrocable* was introduced in 2004. With the help of local Non-Governmental Organization (NGO) staff, we conducted this survey from October 2016 to May 2017, and identified participants by calculating the proportion of the population in each ward. NGO staff visited each house, where they asked residents to respond to the survey questions. At each house, the highest earning member, or the head-of-household, was interviewed. In this survey, we asked about their socio-economic status, pride in their neighborhood, their experience and frequency using institutions that were developed as subsidiary projects of *Metrocable*, their travel behavior before and after *Metrocable* operation, and their job before and after the *Metrocable*.

The number of samples for the first survey was 368, of which 35.7% were male and 64.3% were female. The average age of respondents was 44.9-years-old. The average income of the head-of-household was 739,697 COP (253 USD), which was quite low compared to the average in Medellín city (332 USD). 28.2% of the respondents were in stratum 1 (lowest socio-economic status) and 71.8% were in stratum 2 (second lowest socio-economic status). We also asked about their educational background and found that 11.1% of them had no education, 23.6% studied until elementary school, 9.2% finished junior high school, 38.5% finished high school, 15.2% completed technical college, 1.4% finished technological college, and only 1.1% graduated from a university.

The second survey gathered information from the residents who used the *Metrocable* to commute. We conducted this survey in September 2017. On weekday mornings, the NGO staff interviewed passengers waiting in the ticket office in the terminal station of the *Metrocable* K-line. The purpose of this survey was to document the characteristics of the actual commuting trip, passengers' personal attributes and workplaces, and their reasons for using the *Metrocable*.

The number of the valid samples was 205, of which 48.8% were male and 50.7% were female (one person did not specify their gender). 6.8% were under 20-years-old, 22.9% were in their twenties, 30.2% were in their thirties, 34.2% were in their forties, and 5.9% were in their fifties. Since this survey was not focused on the heads-of-household, the age is relatively lower than the first survey. We only discuss the result of the second survey in Section 2.1.

(3) Variables

In this study, we applied binary logistical analysis four times to understand factors affecting respondents' decision-making: use of *Metrocable* for commuting, voluntarily changing jobs right after the *Metrocable* operation, use of the

Zonal Business Development Center (*Centros de Desarrollo Empresarial Zonal*; *CEDEZO*), and use of the *España* Library. *CEDEZO* supports start-up businesses and individuals seeking employment. The coefficients were estimated by the maximum likelihood method. The estimation was conducted using the stepwise method with PIN 0.25 and POUT 0.30 by SPSS 24 software. Table 1 lists the variables incorporated in the binary logistical analysis in this study.

In Medellín, all city residents fall into one of six socio-economic stratum, where stratum 1 is the lowest and stratum 6 is the highest income level. Each household is taxed based on this classification. Additionally, the utility rates, such as electricity, water, and gas, are based on a household's stratum. In this study, we define stratum 1 as 'low stratum.' We calculated the shortest walking distance and time from each respondent's house to the nearest *Metrocable* station using Google Maps, and these values were utilized as 'distance to a *Metrocable* station' and 'time to a *Metrocable* station.' We also measured the distance from each respondent's house to the nearest road that has a bus route using Google Maps and used it as the 'distance to bus stop road' because there are no actual bus stops—they stop anywhere to pick up and drop off passengers in this area. We also measured the elevation change a respondent would experience walking up or down from their house to the nearest *Metrocable* station and road with bus routes using Google Maps and used these values as 'up down to station' and 'up down to bus stop road.' In the study area, there are two *Metrocable* stations, Popular and Santo Domingo, and a dummy variable 'Santo Domingo' represents respondents whose nearest *Metrocable* station is Santo Domingo.

Table 1. Modeled variables

	Metrocable	Job change	*CEDEZO*	*España* Library		*Metrocable*	Job change	*CEDEZO*	*España* Library
Objective variable					**Location of current work place**				
Metrocable use for commuting (D)	✓✓	✓	✓	✓	Comuna 1 (D)	✓		✓	✓
Changed job spontaneously (D)		✓✓			Comuna 10 (D)	✓		✓	✓
Used CEDEZO (D)			✓✓		Comuna 14 (D)	✓		✓	✓
Used *España* Library (D)				✓✓	Other Comuna in Medellín (D)	✓		✓	✓
Household characteristics					Have a train station in the Comuna (D)	✓			
Women (D)	✓	✓	✓	✓	**Current type of job**				
Child under 12 years old (D)		✓	✓	✓	Management (D)	✓		✓	
Age	✓		✓		Professional (D)	✓		✓	
Over 65-years-old (D)		✓			Office worker (D)	✓		✓	
Educational background	✓		✓	✓	Physical worker (D)	✓		✓	
High school graduate (D)	✓			✓	Sales staff (D)	✓		✓	
No. of family members	✓				Security staff (D)	✓		✓	
Low stratum (D)	✓				Service staff (D)	✓		✓	
Current household head monthly income in thousands COPS					Transportation staff (D)	✓		✓	
Monthly household head's income	✓				Communication staff (D)	✓		✓	
< 600 (D)			✓	✓	**Type of job in 2003**				
601-650 (D)			✓	✓	Management (D)		✓		
651-700 (D)			✓	✓	Professional (D)		✓		
701-750 (D)			✓	✓	Office worker (D)		✓		
751-800 (D)			✓	✓	Physical worker (D)		✓		
801-850 (D)			✓	✓	Office worker (D)		✓		
≥851 (D)			✓	✓	Sales staff (D)		✓		
Household head's monthly income in 2003 in thousands COPS					Security staff (D)		✓		
<150 (D)		✓			Service staff (D)		✓		
151-200 (D)		✓			Transportation staff (D)		✓		
201-250 (D)		✓			Communication staff (D)		✓		
251-300 (D)		✓			**Current types of employment**				
≥301 (D)		✓			Formal self-employment (D)			✓	✓
Location of current house					Informal self-employment (D)			✓	✓
Distance to a *Metrocable* station (m)		✓	✓		Employment (Full time) (D)			✓	✓
Time to a *Metrocable* station (min)	✓				Employment (Part time) (D)			✓	✓
Up Down to Station (m)	✓				✓✓: Incorporate as objective variable ✓: Incorporate as explanatory variable (D): Dummy variable				
Distance to Bus Stop Road (m)	✓								
Up Down to Bus Stop Road (m)	✓								
Santo Domingo (D)		✓	✓	✓					

1.5. Impact of *Metrocable* projects

As we reviewed previous research about the impact of *Metrocable*, there are primarily two sources of the impacts. The first source of impact is the *Metrocable* project and another source is the Integrated Urban Projects (*Proyectos Urbanos Integrales*: PUI). PUI are projects which were carried out at the same time as the initial *Metrocable* operation in 2004, and *Metrocable* and PUI were developed integrally to improve low-income areas near the *Metrocable* K-line. This approach, which includes development of the facilities and also the capacity development, is called 'social urbanism'. This social urbanism aims to compensate 'historic debt' to the forgotten areas and aims to activate the power of aesthetics as a vehicle for social change. PUI included a variety of urban projects structured around the *Metrocable* involving educational and cultural facilities, environmental upgrading, and new public spaces (Brand and Dávila, 2013). As PUI is an integrated project with *Metrocable* project and inseparable from it, we consider the impact of PUI as one of the indirect impacts by *Metrocable* projects in this study.

We can divide the first source, impacts of *Metrocable,* into three categories. The first one is improvement of mobility, such as more frequent, comfortable, safer, and less expensive transportation service, reduced travel time, and fewer transfers. This improvement of mobility could lead to job changes to obtain a higher salary and a more secure job with better working environment, increased frequency of leaving their neighborhood to travel, and more choice of schools outside of *Comuna* 1.

The second category of *Metrocable* impact is improvement to the local economy, that is improvement of opportunities to open new businesses, increased sales for existing businesses, and more job opportunities in the new or extended businesses. The local economic prosperity leads to increases in property value and it causes positive impact on property owners, though negative impact on the lessee. Also, the opening and extension of the shops and increase in number of commodities improves convenience for the neighborhood residents.

The third category is improvement of local society. Some researchers mention the *Metrocable*'s impact on crime reduction (Bea, 2016; Borraez-Alvarez, 2015). In our interview with the operator, Metro de Medellín, a high-ranked officer mentioned that passengers' eyes above the area has reduced crime. Additionally, the increased number of visitors' eyes from *Metrocable* are expected to reduce crime. Also, the modern aerial cable-car system is expected to enhance regional identity and sense of pride in their neighborhood.

The second source of impact is PUI. In *Comuna* 1, *CEDEZO*, a business start-up center, and *España* Library were developed as a part of PUI near the Santo Domingo station. Visitors to *CEDEZO* can acquire knowledge and information to start their new business and offer position information. *España* Library is a one of the five library-parks in Medellín and it attracts both local residents and visitors due to its architectural features.

The structure of the above expected impacts is shown in Fig. 4. In this study, we focus on impacts of *Metrocable* on improvement of mobility and how it led to vocational change, increased income, and local social development. The impacts of *Metrocable* and PUI we examined in this study are in grey boxes in Fig. 4.

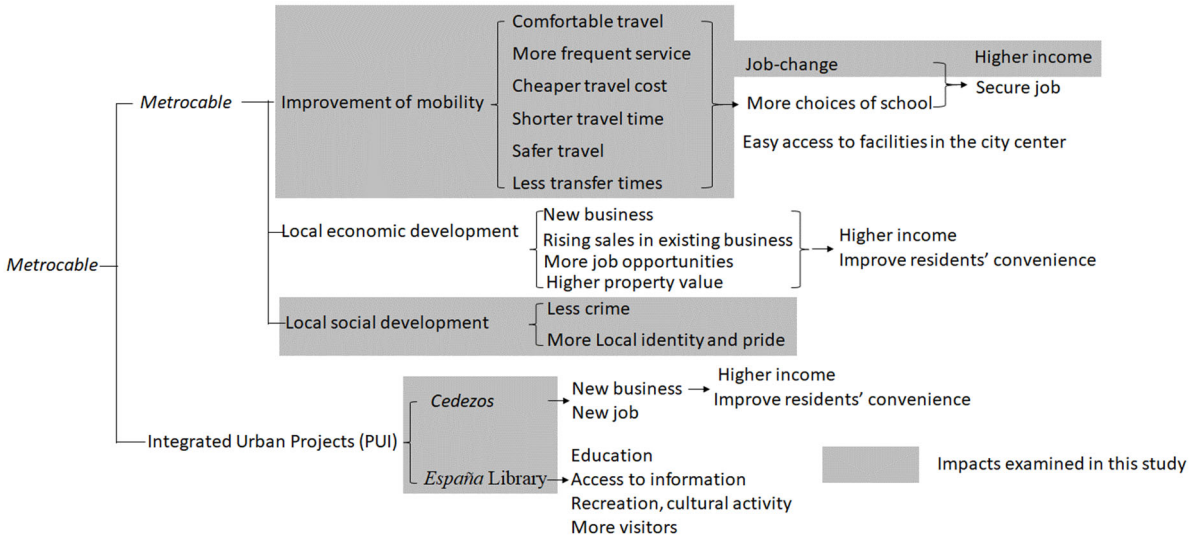

Fig. 4. Expected impacts of *Metrocable*

2. Impacts by *Metrocable* and its scope

2.1. Improvement of mobility

Here, impact on improvement of mobility is examined and we focus on commuting travel because it is the most frequent travel purpose and it would lead to vocational change.

(1) Commuting Travel

From the first survey, we find that, in 368 respondents, 40 respondents (10.9%) work at home, 74 respondents (20.1%) commute and use *Metrocable* for their commute (including combination with other travel modes), and 254 respondents (68.0%) commute but do not use *Metrocable*. In the group that commutes (328 respondents), 22.6 % use *Metrocable* (0.6% use only *Metrocable*, 18.6% combined with the train, 3.4% combined with other modes), 22.5% use bus (20.4% use only bus and 2.1% combined with other modes), 7.3% take the train or BRT or integrated bus or combination of these modes, 18.3% ride motorcycle, 14.3% are passengers in cars, 4.0% are drivers of cars, 0.9% use taxi and 10.1% only walk.

Metrocable stops operation for an entire day for a few days each year for regular maintenance. In the second survey, we asked individuals how they commuted when *Metrocable* was out of service for the maintenance, to clarify the superiority of *Metrocable* compared to other transportation modes. As a result, 8.8% of respondents gave up working or worked from their house. On the other hand, 91.2% changed commuting mode and reached the same workplace. The most popular alternative mode to *Metrocable* is bus (Fig. 5). We can also see that 46.9% of respondents used bus (alone or combined with motorcycle), 28.8% used the bus as a feeder mode connecting to the train. In other words, when the service is normal, most of respondents used the *Metrocable* daily, even though they can reach their workplace by bus.

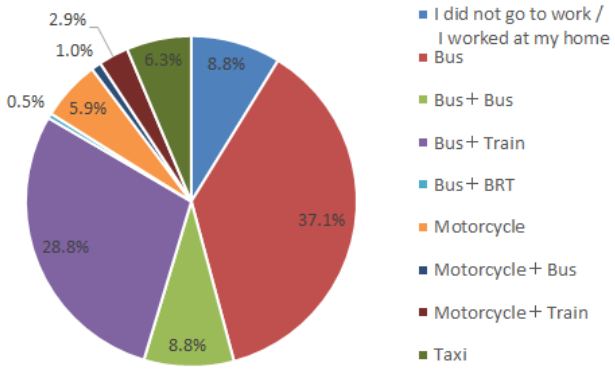

Fig. 5. Alternative commuting mode during *Metrocable* maintenance period

Next, we requested the commuting times when using the typical mode and the alternate mode. We exclude respondents who did not work or worked at home during the maintenance and calculated average commuting time. Travel time by *Metrocable* is longer than by alternative mode and when we tested the difference in average values by a t-test, there was no significant difference at the 1% significance level (Table 2).

Table 2. t-test results on average commuting time

	Typical (Using Metrocable)	During maintenance term (Using the alternate mode)	t value	Significance level (two-tailed)
Commuting time (min)	59.7	57.5	1.358	.000**

** Significant at 1% *Significant at 5%

In the second survey, we asked respondents why they use *Metrocable* as a commuting mode. We showed them each reason we expected, and they selected one choice of following answers: “totally disagree,” “disagree,” “neither,” “agree,” and “totally agree” (Fig. 6). This result shows that the most prominent factor to select *Metrocable* for commuting is its relatively low cost. The one-way bus fare is approximately 2,000 COP (0.69 USD) and the *Metrocable* fare in 2017 is 2,300 COP (0.74 USD), where the latter price includes the train trip into the city. If they need to take two buses, the fare (4,000 COP) is more expensive than the integrated fare for *Metrocable* and the train. The second supported factor is time savings and it is apparently inconsistent with the above discussion. In the term of regular maintenance of *Metrocable*, buses arrive more frequently and passengers wait less time than normal because Metro Company introduces more buses to integrated bus routes towards train station. Therefore, in normal conditions, travel time by bus would be longer than during the maintenance period, and travel time by alternative mode is presumed to be longer than *Metrocable* in normal conditions. On the other hand, security and safety of *Metrocable* are not supported.

As Figure 5 shows, during the maintenance time, 8.8% used two buses, 28.8% used bus and the train, 0.5% used bus and BRT, and all of them paid the fare twice. Furthermore, 1.0% used motorcycle and bus, and 2.9% used motorcycle and the train and, they need to pay both the bus fare and cost of the motorcycle. Finally, 6.3% used taxi which is expected to include the informal public transportation, and it costs higher than the integrated fare. All of them, in total, about 48% paid higher cost during the maintenance time than using *Metrocable*. In this 48%, that is 99 respondents, 98 respondents pay only the integrated fare, so *Metrocable* reduced almost 48% of respondents' travel cost.

From these results, we can say that the commuting benefits of *Metrocable* are lower cost fare and shorter travel time.

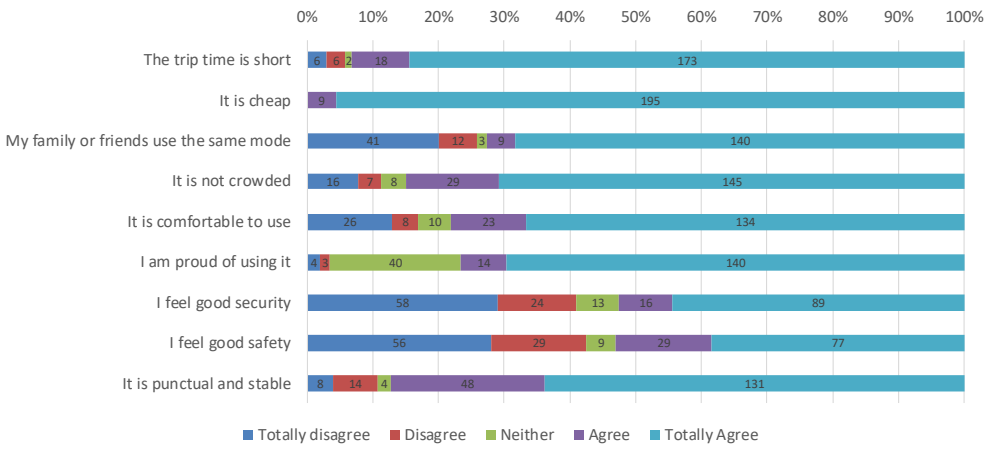

Fig. 6. Respondents' reasons for selecting *Metrocable* for commuting

In the first survey, we asked the 121 respondents who had the same workplace in 2003 as they do now to describe their commuting behavior. Table 3 summarizes the commuting travel modes for 2003 and 2013. From this table, it can be seen that, in 2003, car travel as a passenger (the majority of which was assumed to be informal public transportation) was dominant, where the fraction of car passengers decreased drastically from 48.7% in 2003 to 21.0% in 2013. The second dominant travel mode in 2003 was bus, where the number of bus users decreased from 37.0% to 26.1%. On the other hand, the fraction of train users increased from 7.6% to 22.7%, which was attributed to the easier access to the train station offered by *Metrocable*. In addition, the number of motorcycle and car drivers increased over the studied decade, from 6.7% to 16.8%, and from 1.7% to 4.2 %, respectively. The average one-way travel time to work in 2003 was 59.6 min, while in 2013 it was 44.6 min. This reduction in travel time of about 15.0 min was partially attributed to the *Metrocable*.

Table 3. Commuting travel modes in 2003 and 2013 for respondents who have same workplace (n = 121)

	2003	2013
Bus	37.0%	26.1%
Train	7.6%	22.7%
Metrocable	-	26.1%
BRT	-	2.5%
BRT/train integrated bus	-	7.6%
Car (driver)	1.7%	4.2%
Car (passenger)	48.7%	21.0%
Motorcycle	6.7%	16.8%
Only walking	5.0%	4.2%

There had been changes in the massive transit network from 2003 until 2013. Apart from *Metrocable* K implementation in 2004, a new *Metrocable* J line with 2.7 km (2008) and 12 km of BRT and 2 km of Metro expansion southbound were introduced in 2012. Even though these latest changes are not in the influence area of *Metrocable* K neighbourhood, they can motivate a little more to use *Metrocable* K as part of an integrated system, but our questionnaire does not capture this induced demand. Nevertheless, the main trip destinations from influenced area of *Metrocable* K are different from the areas where the new lines were implemented.

2.2. Impact scope of improving the community

Next, the scope of mobility improvement, especially commuting travel, is examined. At first, cross-tabulation analysis between *Metrocable* usage for commuting and some important variables is examined, and then binary logistical analysis is applied to understand the variable's effect on the decision to use *Metrocable* for commuting.

Fig. 7 shows the respondents' destinations of commuting travel. In this figure, we see that *Comuna* 10 is the most common work place (23.8%) and the second most common is the *Comuna* 1 (22.5%), followed by *Comuna* 14 (14.5%). 10.1% of respondents go out of Medellín city for work. *Comuna* 10 includes a downtown called '*Centro*' and *Comuna* 14 includes the financial center with a luxury residential and shopping area, called '*Poblado.*' *Comunas* 10 and 14 both have a train station. *Comuna* 11 (8.2%), *Comuna* 16 (5.2%), *Comuna* 7 (4.4%), and *Comuna* 15 (3.0%) are following the others. *Comunas* 11, 16, and 15 also have a train station.

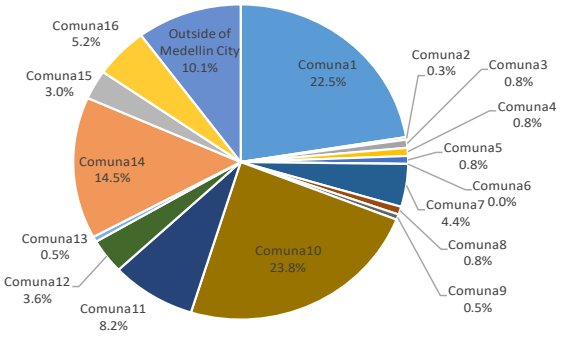

Fig. 7. Respondents' workplace destination

Since almost all of respondents working in *Comuna* 1 do not use *Metrocable* for commuting, we exclude the group *Comuna* 1 and classified them as: "*Comuna* 10", "*Comuna* 14", "Other *Comuna* inside the city", and "Outside Medellín city," which shows whether they use *Metrocable* for commuting or not in each area (Fig. 8). Fig. 8 shows that more than half of the commuters outside of the city use *Metrocable*. It is expected because when they transfer to the train line from the *Metrocable*, they do not need to pay an additional fare, so the total travel cost is relatively inexpensive. Inside the city, fewer commuters to *Comuna* 1 use *Metrocable*. We reviewed this reason with local NGO staff and the community leader pointed out that there is a tendency to avoid walking in *Comuna* 10 due to the inadequate security there. Therefore, people tend to go to their workplace in *Comuna* 1 directly by bus or private vehicle, such as motorcycle or car, although *Comuna* 10 has railway stations.

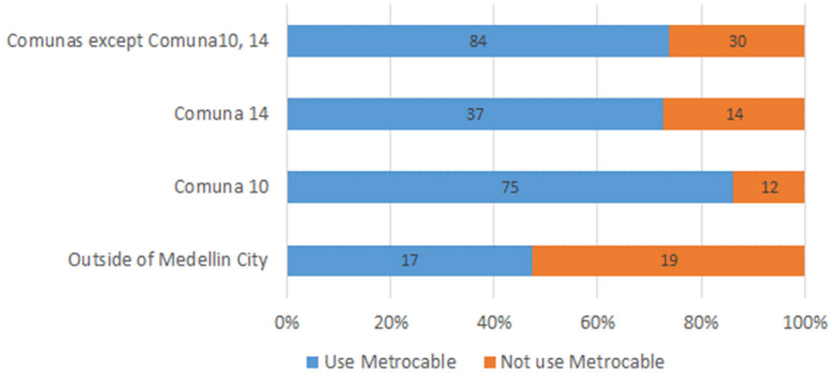

Fig. 8. Workplace and usage of *Metrocable* (except *Comuna* 1)

Fig. 9 shows head-of-household average monthly income and their travel modes for commuting. From this figure, we find that respondents whose monthly income is between 601,000–650,000 COP use *Metrocable* at the highest ratio. If the monthly income is higher than 650,000 COP, the higher the income is, the less use of *Metrocable*. Among people with an income higher than 801,000 COP, almost no one uses *Metrocable*. One of the reasons is that around 40% of this demographic group work at home or within walkable distance, and many of them likely have their own business. On the contrary, in the income group lower than 600,000 COP, the ratio of *Metrocable* users is very small. This is because in this group, most of the respondents are supposed to be informal workers who work at home or within walkable distance.

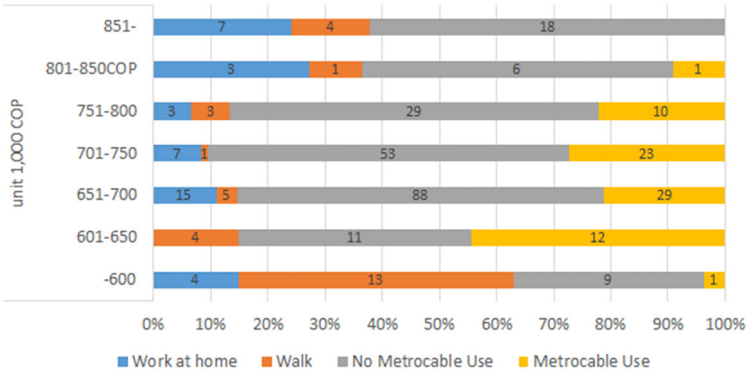

Fig. 9. Monthly head-of-household income and *Metrocable* usage for commuting

Fig. 10 shows the relationship between the respondent's' educational backgrounds and *Metrocable* usage for commuting. Fig. 10 looks very similar to Fig. 9. Junior high school graduates use *Metrocable* at the highest ratio and the ratio decreases as the amount of education increases or decreases. No university graduates and technical college graduates use *Metrocable*. One of the factors is that 20–40% of them work within walking distance. On the contrary, people with the lowest amount of education tend to work at home or within walking distance, and the percentage of *Metrocable* use is low.

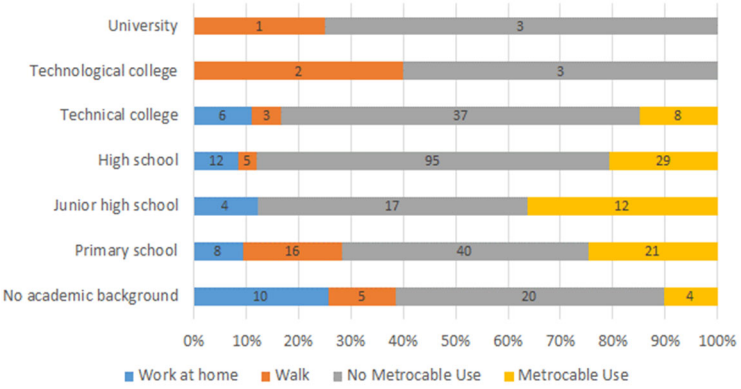

Fig. 10. Educational background and *Metrocable* usage for commuting

Then, binary logistical analysis is applied to understand all factors affecting modal choice. The incorporated variables are listed in Table 1, and the best set of predictors are described in Table 4. As shown in Table 4, the variables of women, low stratum, time to a *Metrocable* station, working in *Comuna* 1 and train station is in *Comuna* 1, and job type is physical worker, service staff, or office worker are significant at the 5% level. This means that women, low social-economic class, living close to a *Metrocable* station, not working in *Comuna* 1 but in a *Comuna* with a train

station, and unskilled workers are most likely to take *Metrocable*. The head-of-household income is in the model, but it is not significant at the 5% level.

From these results, we can say that *Metrocable* is used by socially vulnerable groups, such as women, low economic class, and unskilled workers, but we should take notice that the lowest income and lowest educational background groups do rarely use *Metrocable* as a commuting mode because most of their jobs are supposed to be informal work at home or near their house.

Table 4. Estimated value of the model's coefficients for *Metrocable* usage for commuting

Variables	Coefficient (B)	p-value	Odds ratio, Exp (B)
Household characteristics			
Women	1.251	.027*	3.492
No. of family members	.289	.113	1.335
Low stratum	1.984	.000**	7.271
Current head-of-household monthly income			
Head-of-household income	-.004	.078	.996
Location of a current house			
Time to a Metrocable station (min)	-.246	.001**	.782
Elevation change to station (m)	.012	.172	1.012
Distance To bus (m)	.004	.094	1.004
Elevation change to bus (m)	-.027	.083	.973
Current work place			
Comuna 1	-1.474	.096	.229
Comuna 10	-1.779	.003**	.169
Comuna 14	-.873	.185	.418
Train station in Comuna	1.152	.031*	3.166
Current types of job			
Physical worker	2.239	.005**	9.386
Office worker	1.917	.016*	6.802
Sales staff	.965	.179	2.625
Service staff	1.433	.044*	4.192
Communication staff	1.433	.180	4.191
CONSTANT	-.335	.863	.715
Number of cases	273		
-2 Log likelihood	161.483		
Cox & Snell Square	.303		
Nagelkerke R Square	.493		
% of Cases correctly predicted	87.9		

** Significant at 1% *Significant at 5%

2.3. Vocational change

Next, we examine whether *Metrocable* has led to vocational change and if that vocational change has increased their income. In the first questionnaire survey, we asked whether they changed their jobs after *Metrocable* opened and their reasons. 33.3% of respondents answered that they changed their job and 66.7% answered they had not changed. The main reason of the vocational change is shown in Fig. 11. From this figure, we can find that most of the vocational change is a 'spontaneous' vocational change. We classify vocational job change due to higher salary, higher position, better social security, attractive location, and closer location as 'spontaneous vocational change' and vocational job change for other reasons and no vocational change as 'no spontaneous job change.' 30.8% of respondents are classified as 'spontaneous vocational change' and 69.2% are classified as 'no spontaneous job change.'

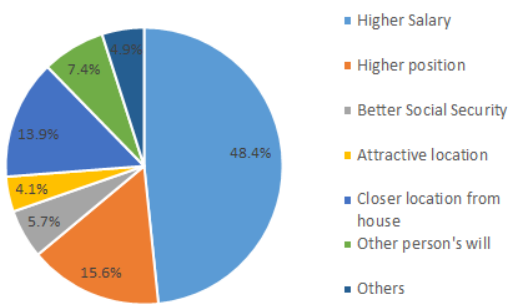

Fig. 11. Main reason for job change

At first, we examine whether spontaneous vocational change caused income increase. Table 5 shows the spontaneous and non-spontaneous vocational change and average income increase and the result of the t-test. Both groups increased their income dramatically in the 13 years. One of the causes of this income increase is the rapid economic development in Colombia. According to the '*Encuesta Calidad de Vida* (Quality of Life Survey) 2004' by Medellín City and '*Encuesta Calidad de Vida* 2015', the average head-of-household monthly income increased from 515,000 COP to 1,137,000 COP in Medellín city. As Table 5 indicates, lower income residents as of 2003 likely changed their job spontaneously and residents who changed their job spontaneously increased their income more than residents who did not change their job spontaneously and both the difference of income increase and the increase rate between 2003 and 2016 are significant at the 5% level. Therefore, we can say that spontaneous vocational change has led to income increase.

Table 5. Average monthly head of household income in 2003 and 2016, average increase and result of t-test

	Average monthly head-of-household income in 2003 (a) (1,000 COP)	Average monthly head-of-household income in 2016 (b) (1,000 COP)	Monthly head-of-household income increase (c=b-a) (1,000 COP)	Monthly head-of-household income increase rate (c/a)
No spontaneous vocational change	323	748	437	3.16
Spontaneous vocational change	222	722	498	4.18
t-value	6.251	1.667	-3.309	-4.850
Significance level (two-tailed)	.000**	.096	.001**	.000**

** Significant at 1% *Significant at 5%

Next, to analyze the factors affecting the decision to make a spontaneous vocational change, the binary logit model is applied. The best set of predictors was found, and they are described in Table 6. Of the variables listed in Table 6, existence of a child; distance from a *Metrocable* station; monthly head-of-household income in 2003 was less than 150,000 COP, 151,000–200,000 COP, 201,000–250,000 COP; occupation in 2003 is management, physical work, sales staff, security staff, service staff, transportation staff, and communication staff are significant at the 5% level. The signs of the estimated coefficient of a child is positive, which indicates that respondents having a child in their household changed their job spontaneously. This could be because households with a child are eager to change their job for better income. Also, the coefficient of distance from a *Metrocable* station is negative and it indicates that good access to the *Metrocable* station promoted their vocational change, that is introduction of *Metrocable* affected the spontaneous vocational change. As we categorized monthly head-of-household income as less than 150,000, 151,000–200,000, 201,000–250,000 251,000–300,000 COP and higher than 301,000, therefore lower and middle-income respondents changed their job spontaneously. The estimated coefficient of the explanatory variable for types of job in 2003 are management and unskilled workers, such as physical worker, sales staff, security staff, service staff, transportation staff, and communication staff. The other variables of types of job in 2003, which are excluded from this model, are professional and office worker, which are skilled workers.

Table 6. Estimated value of the model's coefficients for spontaneous vocational change

Variables	Coefficient (B)	p-value	Odds ratio Exp (B)
Household characteristics			
Have child under 12-years-old	1.247	.024*	.287
Over 65-years-old	-.816	.223	.442
Monthly head-of-household income (1,000 COP)			
Less than 150	2.243	.000**	9.426
151–200	2.654	.000**	14.211
201–250	.880	.044*	2.410
Location of a current house			
Distance from a station (m)	-.287	.018*	.750
Types of jobs in 2003			
Management	3.066	.015*	21.449
Physical worker	3.374	.000**	29.189
Sales staff	2.822	.000**	16.808
Security staff	2.901	.000**	18.186
Service staff	2.261	.000**	9.595
Transportation staff	3.051	.000**	21.128
Communication staff	1.406	.050	4.078
CONSTANT	-3.548	.000**	.029
Number of cases	348		
-2 Log likelihood	306.380		
Cox & Snell Square	.307		
Nagelkerke R Square	.431		
% of Cases correctly predicted	81.3%		

** Significant at 1% *Significant at 5%

In summary, we can consider that *Metrocable* usage promoted spontaneous vocational change, especially for lower and middle income and unskilled workers who have a child and live close to a *Metrocable* station, and the spontaneous vocational change has led to a higher income increase. Therefore, we can consider that *Metrocable* has indirectly increased monthly income.

3. Improvement of local society

Next, we examine *Metrocable*'s indirect impact on improvement of local society, that is the reduction of crime and improvement of their pride in their neighborhood.

3.1. Crime reduction

At first, we examine the effect of reduction of crimes in the area. In the questionnaire survey, we asked the frequency of criminal occurrence in their neighborhood in 2003 and 2016. To investigate the effect of people watching from the cable car, we make a 100-m buffer from the *Metrocable* line and examine the difference of the average number of crimes reduced and crime reduction ratio between the inside and outside of the buffer area by t-test (Table 7). The average number of crimes reduced inside of the buffer is more than outside of the buffer and the average ratio of crime reduction outside of the buffer is higher than inside of the buffer. From the t-test, both the average number of crimes reduced and crime change ratio between the inside and outside of the buffer do not have a significant difference at the 5% level. From this result, we cannot find the effect of viewing from the air on crime reduction.

Table 7. The average of crime reduction and crime reduction ratio in 2003 and 2016 inside and outside of the 100-m buffer and results of the t-test

	Crime 2003(a)	Crime 2016 (b)	Average no. of crime change (c=b-a)	Average crime change ratio (c/a)
Outside 100-m-buffer (n=316)	13.76	1.66	-12.10	-85.75%
Inside of 100-m-buffer (n=49)	19.04	1.29	-17.76	-77.94%
t-value	-1.226	.392	1.330	-1.453
Significance level (two-tailed)	.225	.695	.189	.152

** Significant at 1% *Significant at 5%

Then, we examine the effect on the increase of the number of visitors. We divide the walking time from their houses to a *Metrocable* station into five groups and examine the difference of the average number of crimes reduced and the crime reduction ratios between the groups by one-way analysis of variance (ANOVA) (Table 8). Table 8 shows that there is no clear correlation between distance from a station and change in the average number of crimes. According to the one-way ANOVA, there is a significant difference between less than 5 min and 5–10 min, and 5–10 min and longer than or equal to 20 min at the 5% significance level. On the other hand, we can find the tendency that the longer the time it takes to walk from the station, the higher the crime reduction rate. Results of the one-way ANOVA show that there is a difference between less than 5 min and 10–15 min, 15–20 min and longer than or equal to 20 min at the 5% significance level. The tendency is opposite our expectation that the visitors' eyes from the air would reduce crime. In summary, our analysis reveals that *Metrocable* did not contribute to crime reduction.

Table 8. The average of crime reduction and crime reduction ratio in 2003 and 2016 by distance from a *Metrocable* station and result of one-way ANOVA

	Crime 2003 (a)	Crime 2016 (b)	Average no. of crime change (c=b-a)	Average crime change ratio (c/a)
<5 min. (n=64)	7.42	1.50	-5.92	-73.17%
5–10 min. (n=79)	21.72	1.86	-19.86	-83.28%
10–15 min. (n=86)	17.48	2.20	-15.28	-87.31%
15–20 min. (n=98)	11.65	1.28	-10.38	-89.13%
≥20 min. (n=34)	10.74	0.71	-10.03	-90.24%
f-value			4.945	5.981
Significance level (two-tailed)			.001**	.000**

** Significant at 1% *Significant at 5%

3.2. Improvement of sense of pride of their neighborhood

Next, the effect of *Metrocable* on improvement of sense of pride in their neighborhood is examined. We asked the level of pride that they feel about where they live on a five-point scale (1=totally not proud of, 2=not proud of, 3=moderate, 4=proud, 5=very proud) and Fig. 12 shows the distribution of their answer by *Metrocable* users/non-users for commuting. From this figure, we can understand residents have a high sense of pride in their neighborhood regardless of *Metrocable* usage for their commuting. Comparing the two groups, *Metrocable* users for commuting have a higher sense of pride than non-users.

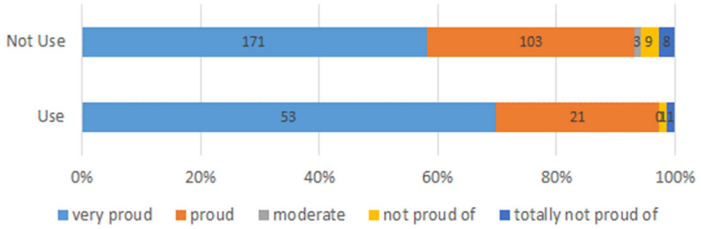

Fig. 12. Pride of neighborhood and *Metrocable* usage

Next, the average score of users and non-users are compared. Table 9 shows the average scores of the two groups and the result of the t-test. From the t-test, we can find that the average score of *Metrocable* users for commuting is higher than the non-users at the 5% significance level. It suggests that the frequent use of *Metrocable* tends to enhance people's pride in their neighborhood.

Table 9. The average of pride score by *Metrocable* users/non-users for commuting and result of t-test

	Average no. of crime change
Metrocable non-users (n=294)	4.43
Metrocable users (n=76)	4.63
t-value	-2.187
Significance level (two-tailed)	.030*

** Significant at 1% *Significant at 5%

4. Impact of PUI

Next, the impact of PUI is examined. As noted, near Santo Domingo station, *CEDEZO* and the *España* Library were developed as parts of the PUI (Figs. 12 and 13). *CEDEZO* is an employment and entrepreneur support center.

Fig. 12. *CEDEZO* near Santo Domingo station

Fig. 13. *España* Library

4.1. Usage of *CEDEZO*

In our questionnaire survey, 23.2% of respondents have used the *CEDEZO*. To analyze the factors affecting usage of *CEDEZO*, the binary logit model is applied. The best set of predictors was found and are described in Table 10. Of the variables listed in Table 10, women, educational background, current monthly head-of-household income is between 651,000–700,000 COP, distance from a *Metrocable* station, nearest station is Santo Domingo station, working place in *Comuna* 1, current type of job is physical worker, office worker, security staff, and communication staff and a part-time job for employment are significant at the 5% level. From this result, we can say that women with higher educational background who live close to Santo Domingo station likely use *CEDEZO*. Although, it is not clear whether *CEDEZO* contributed to their current job, their current job is likely to be office work, or some type of non-skilled work and part-time job.

Table 10. Estimated value of the model's coefficients for *CEDEZO* usage

Variables	Coefficient (B)	p-value	Odds ratio Exp (B)
Household characteristics			
Child under 12-years-old	.798	.222	.450
Women	1.318	.006**	3.735
Age	-.027	.273	.974
Educational background	.631	.002**	1.879
Current monthly head-of-household income (1,000 COP)			
Less than 600	-1.919	.156	.147
651–700	-1.096	.015*	.334
Location of current house			
Distance from a Metrocable station	-.452	.010*	.636
Santo Domingo Station	1.005	.039*	2.733
Current work place			
Comuna 1	1.266	.035*	3.545
Comuna 14	-1.106	.139	.331
Work inside city other than 11014	-.456	.273	.634
Current types of job			
Management	1.749	.216	5.746
Physical worker	1.816	.042*	6.148
Office worker	1.838	.020*	6.285
Sales staff	.897	.199	2.453
Security staff	2.635	.009**	13.940
Service staff	1.052	.141	2.862
Transportation staff	1.617	.148	5.040
Communication staff	2.564	.026*	12.990
Types of employment			
Formal self-employment	1.380	.211	3.973
Employment (part-time)	1.705	.016*	5.504
CONSTANT	-3.834	.041*	.022
Number of cases	355		
-2 Log likelihood	393.908		
Cox & Snell Square	.194		
Nagelkerke R Square	.265		
% of Cases correctly predicted	72.7%		

** Significant at 1% *Significant at 5%

Next, usage of the *España* Library is examined. 63.4% of the respondents do not use the library, 26.3% of them use it a few times each year, 9.1% use it a few times each month, and only 1.1% use it a few times each week. To understand the factors affecting the *España* Library usage, a binary logit analysis is applied and the variables in the model are described in Table 11. The 5% significant variables are *Metrocable* usage for commuting, child under 12-years-old, women with educational background, and current head-of-household income is between 651,000–799,000 COP. All of the coefficients except head-of-household income have positive signs. It indicates women who have a child, high educational background, commute by *Metrocable,* and whose income is lower, tend to use the library. No spatial characteristics of their house location affect their usage of the library.

Table 11. Estimated value of the model's coefficients for *España* Library usage

Variables	Coefficient (B)	p-value	Odds ratio Exp (B)
Household characteristics			
Metrocable usage for commuting	.757	.020*	2.132
Child under 12-years-old	.949	.047*	.387
Women	.693	.026*	2.001
High school graduate	-.617	.298	.540
Education background	.933	.000**	2.541
Current monthly head-of-household income (1,000 COP)			
Less than 600	-.866	.304	.420
651–700	-.859	.006*	.423
CONSTANT	-4.372	.000	.013
Number of cases	355		
-2 Log likelihood	321.340		
Cox & Snell Square	.172		
Nagelkerke R Square	.259		
% of Cases correctly predicted	79.7%		

** Significant at 1% *Significant at 5%

5. Conclusion

In this study, we examine the effect of *Metrocable* projects and their socio-economic and spatial scope in *Comuna* 1 by two questionnaire surveys to residents and passengers of *Metrocable*. We find that about 21.0% of respondents use *Metrocable* for commuting and their main benefits of choosing *Metrocable* are saving money and time. The impact mainly covers residents who are female, low socio-economic class, live near a *Metrocable* station and work in safe *Comunas* with a train station. The impact covers socially vulnerable groups, such as women and low socio-economic class, but we should take notice that the lowest income and lowest educational background groups rarely use *Metrocable* for commuting. The installment of *Metrocable* has led to vocational job change and this vocational job change has led to higher income increase. Mainly, residents who have a child and earned lower to middle income and were non-skilled workers before *Metrocable* installation mainly changed their job spontaneously after *Metrocable*. Therefore, the past vulnerable group has earned the indirect benefit of *Metrocable*. At present, the lowest income and lowest education groups are considered to be a group left behind and did not benefit from the *Metrocable*. Therefore, if installation of an aerial cable car in a low-income area is planned as a strategy for reducing poverty, specific measures should be taken to target the most vulnerable groups, for example, vocational training and discounted cable car and train tickets.

Our research revealed *Metrocable* has no influence on crime reduction in the neighborhood area. This result is opposite of political publicity of *Metrocable*. On the other hand, usage of *Metrocable* increases passengers' senses of pride in their neighborhood. As Medellín seemed to awaken from a dark period marked by economic stagnation, a lack of social cohesion and a sense of hopelessness arising from the violence that characterized the daily life of its inhabitants, especially the poorest (Coupé et al, 2013), this increase in sense of pride is expected to contribute to further development of this area.

As a part of the integrated PUI, *CEDEZO* and *España* Library were developed in *Comuna* 1. About 23% of respondents have used *CEDEZO*. Residents who are female, have higher educational background, and live near Santo Domingo station are likely to use *CEDEZO*. On the other hand, about 26% of our respondents visit *España* Library at least once a year. Residents who are female, with a child, higher educational background, and commute by *Metrocable* likely visit the library. Unlike *CEDEZO*, there are no spatial factors affecting the usage of *España* Library. The common factors using PUI projects are women and higher educational background.

Thus, we find that *Metrocable* has various impacts on various types of residents. Commonly, it has a positive impact on women. The *Metrocable*'s impact on improvement of mobility and indirect impact on increase of income are mainly for the lower-income group, except the lowest group and PUI's impact is for higher class residents. We need to consider this positive impact fits with each group's demand to apply this measurement to other cities.

In this study, we only targeted residents who have continuously lived in *Comuna* 1 and worked since before *Metrocable* operation. As statistical data shows, the population in *Comuna* 1 has increased since *Metrocable* installation. Thus, this study overlooks the impact of the *Metrocable* project on the new residents and further study of the effect on them is necessary to be conducted to understand the overall impact of *Metrocable.*

Acknowledgements

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