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Performance Contributors of Bus Rapid Transit Systems within the ITDP BRT Standard: An Ordered Choice Approach

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TITLE: **Performance Contributors of Bus Rapid Transit Systems within the ITDP BRT Standard: An Ordered Choice Approach**

ABSTRACT: Bus rapid transit (BRT) is a mode of public transportation with relatively fast, flexible, comfortable, affordable and environment-friendly services. In this paper, the potential contributors to BRT performance are investigated within an ordered choice modelling framework, in which the dependent variable is the BRT standard (Gold, Silver, Bronze or Basic), developed by the Institute for Transportation and Development Policy (ITDP). The evaluation of an ordered logit model and an ordered probit model shows that the performance of the former is slightly better, which is chosen for the empirical application. The identified significant predictors are peak-hour speed, peak frequency, the average distance between stations, the length of dedicated busway, passing lanes at BRT station, covered station access, enhanced station environment, pre-board and automated fare collection and fare verification, and network integration. Based on a business-as-usual prediction and what-if analysis, this paper offers information for decision makers to plan a high-standard BRT system in line with the ITDP BRT standard.

KEY WORDS: ***ITDP BRT standard; performance; system design; operations; ordered choice modelling; decision support***

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1. Introduction

Bus rapid transit (BRT) is an innovative mode of public transportation (PT). BRT is defined by the Institute for Transportation and Development Policy (ITDP) as "a bus-based rapid transit system that can achieve high capacity, speed, and service quality at relatively low cost by combining segregated bus lanes that are typically median aligned with off-board fare collection, level boarding, bus priority at intersections, and other quality-of-service elements (such as information technology and strong branding)" (ITDP, 2016, p.4). BRT has a number of advantages including low cost, operating flexibility, rapid implementation, high performance and environmental benefits (Deng and Nelson, 2011; Nikitas and Karlsson, 2015). It has been gaining in popularity as a sustainable transportation mode for urban mobility; in 2016, the global bus rapid transit network increased by 163.2 kilometers, over twice the growth of light rail transit (ITDP, 2017). Currently, BRT systems are operating in approximately 200 countries, across Latin America, Asia, Europe, North America, Africa and Oceania.

Currie and Delbosc (2011) and Hensher and Li (2012), among others, have investigated the performance drivers of BRT patronage and found that the key influences are fare, service frequency, infrastructure, connectivity and accessibility. In order to define a common understanding of BRT across regions, in 2012, ITDP introduced the BRT Standard (see below) which recognised the essential elements of best practice in BRT systems throughout the world. The early version of the BRT Standard (ITDP, 2012) only considered the design features of BRT systems. The latest version of the BRT Standard takes into account the actual operations of a BRT system (ITDP, 2016). They combine the design features (static) with operations (dynamic) to obtain the full score of the BRT Standard 2016, consisting of a range of indicators on BRT design and operations. This offers a set of benchmarks for BRT performance. ITDP has only scored a small proportion of operating BRT systems, given the difficulty in obtaining full information on all dimensions for all BRT systems.

In this paper we use ordered choice modelling to identify, for a sample of BRT systems, the statistically significant influences that contribute to the probability of a specific BRT system complying with the defined levels of the ITDP BRT standards. The estimated parameters are then used to predict the BRT standards for unscored systems and to identify the major limitations associated with the design features and operations of existing systems. This approach provides decision support for policy makers to guide strategies that provide alignment with the supported ITDP standards for classifying BRT systems. To the authors' knowledge, this paper is the first empirical study which applies ordered choice models to predict the standard of various BRT systems and to establish the veracity of the criteria used by ITDP in defining the range of standards. This study compares two forms of standard ordered choice models, ordered logit and ordered probit (e.g., ordered probit models: Lemp *et al.*, 2014; Gogas *et al.*, 2014; Pietrovito *et al.* 2016; Lee *et al.* 2018; ordered logit models: Srinivasan, 2002; Eluru *et al*., 2008; Hoffman and Post, 2014). We select the model form with the better statistical performance for the empirical application.

This paper is organised as follows. First, we provide an overview on the ITDP BRT Standard, followed by the brief introduction of the ordered choice model. The next section describes the data used in this study. This is followed by model estimation and interpretation of findings which are used to provide a business-as-usual prediction and what-if analysis to illustrate the application of the approach to establish how well the ITDP BRT standards assigned to a sample of BRT systems can be replicated by a formal statistical prediction. The final section provides the key conclusions.

2 The ITDP Approach

The ITDP evaluation system (i.e., the BRT Standard) provides guidelines on the role of BRT design and operations. Table 1 summarises the latest BRT Standard including the criteria and corresponding point values (ITDP, 2016). This system is based on the award of points to design elements which are positive to system performance and the deduction of points according to a BRT's actual operations that impair its performance or quality of service. The former is referred to as the *design score*; while the *full score* is the combination of the design score and the operations' deductions. The deductions are based on a BRT system's actual operations, assessed six months after its launch. As an example, if the actual speed of a system is no less than 20 kilometres per hour, the corresponding deduction is zero, a three-point deduction for its commercial speed being 16-19 kilometres per hour, a six-point deduction for its commercial speed being 13-16 kilometres per hour; and a maximum deduction of 10 points would be applied if its speed is below 13 kilometres per hour.

The *final score* determines the standard of a system (Gold = 85 or more points, Silver = 70-84.9 points, and Bronze = 55-69.9 points). ITDP (2016) defines a Gold Standard BRT as the international best practice with the highest level of operational performance, efficiency and service quality. Before receiving a gold, silver, or bronze ranking, a BRT system must satisfy the minimum requirements of the Basic BRT standard including (1) at least 3 kilometres (1.9 miles) in length with dedicated lanes; (2) a score of four or more points in a dedicated right-of-way element; (3) a score of four or more points in the busway alignment element; and (4) a score of 20 or more total points across all five BRT basics elements.

Table 1: The BRT Standard Scorecard

Category	Maximum	Category	Maximum	Category	Maximum
BRT Basics	**38**	**Stations**	**10**	***Operations Deductions***	***-63***
Dedicated Right-of-Way	8	Distances between Stations	2	*Commercial Speeds*	*-10*
Busway Alignment	8	Safe and Comfortable Stations	3	*Peak Passengers per Hour per Direction Below 1,000*	*-5*
Off-Board Fare Collection	8	Number of Doors on Bus	3	*Lack of Enforcement of Right-of-Way*	*-5*
Intersection Treatments	7	Docking Bays and Sub-stops	1	*Significant Gap Between Bus Floor and Station Platform*	*-5*
Platform-level Boarding	7	Sliding Doors in BRT Stations	1	*Overcrowding*	*-5*
				Poorly Maintained Infrastructure	*-14*
Service Planning	**19**	**Communications**	**5**	*Low Peak Frequency*	*-3*
Multiple Routes	4	Branding	3	*Low Off-Peak Frequency*	*-2*
Express, Limited-Stop, and Local Service		Passenger Information	2	*Permitting Unsafe Bicycle Use*	*-2*
Control Center	3	**Access and Integration**	**15**	*Lack of Traffic Safety Data*	*-2*
Located in Top Ten Corridors	2	Universal Access	3	*Buses Running Parallel to BRT Corridor*	*-6*
Demand Profile	3	Integration with Other Public Transport	3	*Bus Bunching*	*-4*
Hours of Operations	2	Pedestrian Access and Safety	4		
Multi-Corridor Network	2	Secure Bicycle Parking	2		
		Bicycle Lanes	2		

Infrastructure	**13**	Bicycle-Sharing Integration	1		
Passing Lanes at Stations	3				
Minimizing Bus Emissions	3				
Stations Set Back from Intersections	3				
Center Stations	2				
Pavement Quality	2				

Source: ITDP (2016, p. 25)

According to the design attributes and actual operations of a BRT system, ITDP assigned the corresponding points to the individual attributes listed in Table 1, and then aggregated the point values of all dimensions into the final score; that is, its BRT standard. The ITDP scorecard approach is straightforward; however, it requires BRT experts' observation, evaluation, discussion and judgement, as well as a large amount of data (see Table 1). In this paper, an econometric approach is employed to identify the statistically significant influences on the BRT standards as a way of seeing whether the expert assignment might be replaced with (or supported by) a more formal statistical assessment. These sources of systematic variation are then used to predict the corresponding standard of a BRT system: Gold, Silver, Bronze or Basic.

3. The Ordered Choice Model

The ordered choice model adopts a latent regression approach, in which the thresholds are used to define the ranges of the categories on the underlying latent scale. The ordered choice model is capable of accommodating ordered preferences or ordered outcomes with unequal differences among these preference scales or outcomes. It has a wide range of applications such as interest rate decision (e.g., Bräuning and Fendel, 2018), user experience (e.g., Hensher *et al.*, 2010), bank rating (e.g., Bellotti *et al*., 2011), customer valuing (e.g., Verhoef and Donkers, 2001), investor belief (Hoffman and Post, 2014) and injury severity (e.g., Eluru *et al.*, 2008). We are unaware of any empirical study which has used the ordered choice approach to analyse compliance with levels in the BRT standard. The simple ordered choice model is based on the following specification.

$$y^* = \boldsymbol{\beta}'\mathbf{x}_\mathrm{i} + \varepsilon_i \qquad (1)$$

The latent preference variable, y*, is continuous, and its observed counterpart is y_i in discrete form shown in equation (2):

$$\begin{aligned} y_i \; &= 0, \text{if } y^* \le \mu_0; \\ &= 1, \text{if } \mu_0 < y^* \le \mu_1; \\ &= 2, \text{if } \mu_1 < y^* \le \mu_2; \\ &\;\;\;\dots \\ &= \mathrm{J}, \text{if } y^* > \mu_{J-1} \end{aligned} \qquad (2)$$

where $\boldsymbol{\beta}$ is the set of parameters of the explanatory variables $\mathbf{x}_\mathrm{i}$**;** μ_j are the threshold parameters, estimated in conjunction with $\boldsymbol{\beta}$ based on maximum likelihood; ε_i are the disturbance terms where a normal distribution assumption defines the ordered probit model and a logistic distribution assumption defines the ordered logit model. For detailed information on the ordered choice model, see Greene and Hensher (2010).

4. Data

Detailed information on BRT systems operating in different cities (see table 2) across 19 different countries such as Australia, China, Colombia, France and South Africa is obtained mainly from ITDP-China[1]. All these observations are used to estimate the parameters within the ordered choice modelling framework, in which the dependent variable is the BRT standard (Gold, Silver, Bronze or Basic). The candidate explanatory variables in this study can be classified into seven major categories: *BRT Basics*, *Operation and Service*, *Station Characteristics*, *Infrastructure*, *Information and Communications*, *BRT Vehicle Characteristics*, and *Access and Integration*. *BRT Basics* include: the number of BRT terminals, the total length of dedicated busway, pre-board fare collection and fare verification, level boarding and alighting, and location of busway lanes. *Operation and Service* include: the number of corridors, system passenger-trips per day, peak frequency, median fare, peak-hour speed and whether there is an integrated network of routes and corridors. *Station Characteristics* include the number of BRT stations, the number of substops at most stations, whether there are sliding doors in BRT stations, and location of bus doorways. *Infrastructure* includes the proportion of stations with functioning passing lanes, automated fare collection and fare verification system, and enhanced station (more than just a bus shelter). *Information and Communications* include whether there is high-quality passenger information at stations, high-quality passenger information on buses, distinctive BRT buses, and distinctive marketing identity for system. *BRT Vehicle Characteristics* include the number of doors in BRT buses, high capacity BRT buses, and BRT bus fuel type. *Access and Integration* include segregated bike lanes along main corridor, wheelchair accessible stations and bike sharing in vicinity of BRT stations. In this dataset, BRT systems in Amsterdam, Nagoya, Paris, Utrecht, Pune, Shaoxing and Guiyang have not been ranked by the ITDP (Table 2).

Table 2: The dependent variable – the BRT standard

Standard	BRT system
Gold	Bogotá, Lima, Yichang
Silver	Cali, Istanbul, Johannesburg, Leon, Chengdu, Mexico City, Brisbane, Curitiba, Lanzhou, Xiamen, Guangzhou,
Bronze	Ahmedabad, Los Angeles, Nantes, Quito, Yancheng, Zhongshan, Cape Town, Jakarta, Kuala Lumpur, Lianyungang, Bangkok, Buenos Aires, Guayaquil, Islamabad, Jinan, Nanning, Yinchuan, Zhengzhou, Changzhou
Basic	Beijing, Dalian, Hefei, Zaozhuang, Zhoushan, Changde, Seoul

5. Revealed Predictors of the BRT Standard

After assessing the candidate explanatory variables introduced in the earlier section, the final ordered logit and ordered probit models are determined, which have the same explanatory variables. Two models' predictions are compared in Table 3. The ordered logit model overestimates the number of Bronze Standard by one respectively and underestimates the number of Gold Standard by one respectively; while the ordered probit model overestimates the number of Sliver Standard

[1] Accessed on 3 May, 2018.

by one and underestimates the number of Gold Standard by one. The difference of two models' prediction is that the over prediction of the former is in the Bronze Standard while the over prediction of the latter is in the Silver Standard. The forecasting performance of the ordered logit model is relatively better given that its error is less significant (i.e., a lower standard). Moreover, its goodness of fit is marginally better. The ordered logit model is chosen for the applications in this study. In a rare application, Bellotti *et al*. (2011) applied both models to predict bank ratings and also found that the ordered logit model has a slightly better in-sample prediction relative to the ordered probit model.

Table 3: Ordered logit vs. ordered probit

	Gold	Silver	Bronze	Basic	Log-likelihood	Pseudo-R^2
Actual standard	*3*	*11*	*19*	*7*	n/a	n/a
Ordered logit prediction	2(+1)	11	20(-1)	7	-17.395	0.640
Ordered probit prediction	2(+1)	12(-1)	19	7	-17.445	0.638

Note: Forecasting errors (=Actual - Prediction) in parentheses

In the final ordered choice model (Table 4), the dependent variable is a five-point scale of the BRT Standard with Basic=0, Bronze=1, Silver=2 and Gold=3. This model reveals four quantitative variables and six qualitative variables which have statistically significant impacts on the BRT standard. The potential role of socio-economic characteristics such as GDP per capita and population density was also investigated, as well as the geographic location effect; however, they were not statistically significant, suggesting that the BRT standard is influenced by the BRT design features and operations themselves, rather than the economic and spatial base of a metropolitan area. A normalisation is required so that a constant can be identified. We set the threshold parameter for between levels 0 and 1 equal to zero (Mu0) and estimate the parameters between levels 1 and 2 (Mu(1)) and levels 2 and 3 (Mu(2)), which are the threshold values for the ITDP BRT standards, that is, value<0: Basic; 0<value<Mu(1): Bronze; Mu1<value<Mu(2): Silver; and value>Mu(2): Gold.

Table 4: BRT Standard - the ordered logit model

Variable	Coefficient	*t*-Ratio
Constant	-38.2799	-4.13
Peak-hour speed (km/h)	0.8280	4.50
Peak frequency (bus/hour/direction)	0.0268	2.84
Length of dedicated busway (km)	0.0473	2.15
Average distance between stations (m)	-0.0048	-1.82
Over 50% of stations with passing lanes (Yes)	2.5507	1.80
Pre-board fare collection and fare verification at all stations (Yes)	11.8419	4.39
Fully integrated network of routes and corridors (Yes)	7.0538	3.78
All stations being enhanced station, not just bus shelters (Yes)	9.3139	2.79
Automated fare collection and fare verification at all stations (Yes)	5.1833	2.44
Covered station access at all stations (Yes)	3.5787	1.93
Threshold parameters		
Mu (1)	12.1830	5.02
Mu (2)	18.3130	5.45

Log-likelihood	-17.395
Pseudo-R^2	0.640

Quantitative variables	Mean	Std.Dev.
Peak-hour speed (km/h)	21.81	5.06
Peak frequency (bus/hour/direction)	79.55	78.55
Length of dedicated busway (km)	35.98	27.40
Average distance between stations (m)	932.13	419.91
Qualitative variables (Dummy variable: 1=yes, 0=No)	Percentage as "Yes"	
Over 50% of stations with passing lanes	30.0%	
Pre-board fare collection and fare verification at all stations	87.5%	
Fully integrated network of routes and corridors	67.5%	
All stations being enhanced station, not just bus shelters	90.0%	
Automated fare collection and fare verification at all stations	85.0%	
Covered station access at all stations	17.5%	

In Table 4, the four quantitative variables are peak-hour speed, peak frequency, the total length of dedicated busway and average distance between BRT stations. The parameter estimates of peak-hour speed and frequency are positive, suggesting that faster speed or more frequent service would have a positive influence on the BRT standard. The average distance between BRT stations has a negative sign for the parameter estimate, which implies that the shorter distance between stations (i.e., better accessibility) would improve the BRT standard. These findings illustrate the significant role in promoting PT of three core elements of service quality: speed, frequency and accessibility. The length of dedicated busway, which represents a dimension of the capacity of a BRT system, is positive to the BRT standard.

In addition to these four continuous variables, this model also identifies six categorical variables (coded as dummy variables: yes=1 vs. no=0) which are statistically significant at the 95 percent confidence interval including: (1) over 50% of stations with passing lanes, (2) all stations being enhanced station, (3) pre-board fare collection and fare verification at all stations, (4) automated fare collection and fare verification at all stations, (5) all stations being covered station accessible, and (6) fully integrated network of routes and corridors. These findings reinforce that infrastructure (passing lane and enhanced station environment), equipment (pre-board/automated fare collection and fare verification), and network integration play a significant role in BRT system performance.

Given that there is no previous investigation of BRT standards based on ordered choice modelling, a direct comparison with existing evidence is not possible. In the transport literature, several studies investigated which BRT attributes significantly promoted patronage, in which different types of regression models (e.g., ordinary least square and random effects regression) were estimated where the dependent variable is the number of daily passengers. For example, Hensher and Golob (2008) analysed 44 BRT systems and found several significant influences on BRT patronage including fare, peak service frequency, the number of stations and trunk vehicle capacity. Hensher and Li (2012) collected information on 46 BRT systems from 15 countries and revealed a number of sources of systematic variation such as headway, the length of the BRT network, the number of corridors, the average distance between stations, network integration, modal integration at BRT stations and pre-board fare collection and fare verification. Hensher *et al*. (2014) estimated a joint model with 54 BRT observations in which frequency is treated as an endogenous effect on ridership, and they found that frequency, pre-board fare collection, and the location of with-flow bus lanes and the location of doorways of a bus significantly influence BRT ridership; and the number of trunk lines, bus priority and overtaking lanes at stations have a significant impact on frequency. Although this study adopts a different approach (i.e., ordered choice modelling) and has a different focus (i.e., the BRT standard), some findings of this research are in line with these existing regression studies on BRT patronage. The BRT features that significantly promote BRT patronage while positively influencing the BRT standard include frequency, the length of BRT network, station spacing, network integration, overtaking lanes at BRT stations and pre-board fare collection and fare verification.

6. Applications: Business-as-Usual Projection and What-If Analysis

BRT systems in Amsterdam, Nagoya, Paris, Utrecht, Pune, Shaoxing and Guiyang have not been formally evaluated and ranked by ITDP. The parameter estimates in Table 4 can be used to predict the corresponding standards for these BRT systems under a business-as-usual scenario. Table 5 provides the projection, in which Columns A-J are the observed values or levels of the corresponding attributes; for example, the value of A, *Peak-hour speed*, is 34 kilometres per hour for the Amsterdam BRT. y^* is calculated and then compared with the threshold values so as to determine its corresponding BRT standard. This model estimated one Silver BRT system (Guiyang), two Bronze BRT systems (Nagoya and Paris) and four Basic BRT system (Amsterdam, Utrecht, Pune and Shaoxing). In this dataset, two systems (i.e., Huangzhou and Urumqi both in China) have been ranked as 'non-BRT' by ITDP, as they did not fully satisfy the four requirements of the Basic BRT standard listed in Section 2. We also used the ordered choice approach to estimate their standards, that is, Basic for Hangzhou and Bronze for Urumqi.

Table 5: Forecasting of BRT standards

	A	B	C	D	E	F	G	H	I	J	y*	Threshold	Predicted Standard
Amsterdam	34	18	45	1750	0	0	0	0	1	0	-10.69	y*<0	Basic
Nagoya	25	12	7	810	0	0	1	1	1	1	4.33	y*<12.183	Bronze
Paris	25	52	19	620	0	0	1	1	1	0	3.29	y*<12.183	Bronze
Utrecht	23	8	8	680	0	0	1	0	1	0	-9.63	y*<0	Basic
Pune	22	40	23	990	0	0	1	1	0	0	-6.26	y*< 0	Basic
Shaoxing	15	15	12	1,580	0	1	0	1	1	0	-6.10	y*< 0	Basic
Guiyang	31	16	31	1,250	0	1	0	1	1	1	13.25	y*<18.3130	Sliver

A: Peak-hour speed (km/h)
B: Peak frequency (bus/hour/direction)
C: Length of dedicated busway (km)
D: Average distance between stations (m)
E: Over 50% of stations with passing lanes (1 or 0)
F: Pre-board fare collection and fare verification at all stations (1 or 0)
G: Fully integrated network of routes and corridors (1 or 0)
H: All stations being enhanced station (1 or 0)
I: Automated fare collection and fare verification at all stations (1 or 0)
J: Covered station access at all stations (1 or 0)

Under this approach, we can establish what is required for a BRT system to be elevated to a higher class on the standard. For example, a slow speed (15 km/h) for Shaoxing BRT and the lack of equipment for Pune BRT will need to be improved to gain reclassification. If the running speed of the Shaoxing BRT could be increased to 25 kilometres per hour from its actual speed of 15 kilometres per hour, it would advance to a Bronze standard from Basic BRT. If all stations of the Pune BRT system were equipped with either pre-board or automated fare collection and verification, the model predicts that it could be upgraded to the Bronze standard.

Relative to the above direct interpretation using the parameter estimates in Table 4, a more informative way is to use the marginal effects, which are the derivatives of the choice probabilities. For a continuous variable, a marginal effect represents the influence on the choice probability of a particular outcome of one-unit change in an explanatory variable. For a dummy variable, the marginal effects are the derivatives of the probabilities given a change in the level of the dummy variable from '0' to '1'. Table 6 presents the identified marginal effects for the ordered choice model. The sum of marginal effects of each explanatory variable is zero across all levels of the dependent variable.

Table 6: Marginal effects for the ordered probit model

Variable	P(y=0) Basic	P(y=1) Bronze	P(y=2) Silver	P(y=3) Gold
A: Peak-hour speed (km/h)	-0.0002	-0.0192	0.0194	.443D-04
B: Peak frequency (bus/hour/direction)	-.557D-05	-0.0006	0.0006	.143D-05
C: Length of dedicated busway (km)	-.983D-05	-0.0011	0.0011	.253D-05
D: Average distance between stations (m)	.989D-06	0.0001	-0.0001	-.255D-06
E: Over 50% of stations with passing lanes (Yes vs. No)	-0.0004	-0.1162	0.1163	0.0003
F: Pre-board fare collection and fare verification at all stations (Yes vs. No)	-0.8680	0.7704	0.0973	0.0002
G: Fully integrated network of routes and corridors (Yes vs. No)	-0.0237	-0.1720	0.1951	0.0005
H: All stations being enhanced station (Yes vs. No)	-0.4760	0.4172	0.0586	0.0001
I: Automated fare collection and fare verification at all stations (Yes vs. No)	-0.0167	-0.0339	0.0504	0.0001
J: Covered station access at all stations (Yes vs. No)	-0.0004	-0.3070	0.3063	0.0010

The marginal effects can be either positive or negative. If it is negative under a particular level of the dependent variable, a one-unit increase in the explanatory variable would reduce the choice probability by a certain amount, *vice versa*. For example, an additional increase in peak-hour speed would reduce the likelihood of being a Bronze-standard BRT by 1.92% (-0.0192 in Table 6) and increase the chance of being a Silver BRT by 1.94% (0.0194 in Table 6). In general, the influence of one-unit change in the continuous explanatory variables (frequency, length and station spacing) is rather marginal, with the exception of speed.

For the dummy variables, relative to none or a part of stations equipped with pre-board fare collection and fare verification, the advancement of all stations with pre-board fare collection and fare verification would reduce the probability of being a Basic BRT by 86.80%, and would increase the probability of being Bronze and Silver by 77.04% and 9.03% respectively. An upgrading from unintegrated or partially integrated network of routes and corridors to ful integration would increase the chance of being a Silver standard by 19.15%. Covered station access at all stations (relative to none or partial stations) has a very strong impact on the probability of being Silver standard (+30.63%). In reality, given different budgets, it is not realistic for all BRT systems to reach Silver or Gold standards. If the target is a Bronze standard BRT, these marginal effects suggest that pre-board and automated fare collection and verification need to be accommodated in the system. To reach an even higher standard further requires covered station access and network integration.

7. Conclusions

A BRT system has the potential to offer significant benefits such as reduced congestion, less pollution and land value uplift while accommodating urban travel demand in a sustainable way, if it is carefully planned, designed and implemented (Abdelghany *et al*., 2007; Deng and Nelson, 2012). Using recent information on global BRT systems, this paper has presented a statistical analysis to identify which BRT attributes have a significant influence on its standard or performance, as defined by the ITDP BRT standard and to see how well a formal statistical model might replicate the subjective assignments to the levels of the Standard as determined by experts. The key contributors include: peak-hour speed, peak frequency, accessibility (station spacing and covered station access), system capacity (the length of dedicated busway), infrastructure (passing lanes and enhanced station environment), equipment (pre-board/automated fare collection and fare verification), and network integration. These identified BRT standard drivers need to be addressed systematically, given that no feature by itself is enough to result in high performance.

This study has compared the predictive performance of the ordered probit model and the ordered logit model. For this dataset, the order logit model outperformed the corresponding ordered probit model in terms of modelling performance. Using the parameters estimated by ordered logit, we predicted the corresponding BRT standards for the scored and unscored systems and used the findings to identify the major changes required to have existing BRT systems moved from one level of the standard to a higher level. This study uses a decision support tool that can be used to establish where a BRT system might be positioned in the ITDP standards table, which is a useful way of promoting the specific offering of a BRT system against other systems. For policy makers this provides an appealing way of promoting the virtues of BRT against best practice.

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