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RESEARCH ARTICLE

Discrete Choice Models as a Tool for Interurban Transportation Planning in Argentina: Buenos Aires - Mar del Plata Corridor

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Abstract

In this paper, modeling based on discrete choice methods will be used as a tool for the application of a mixed decision-making strategy (Ortúzar and Willumsen, 1990), where the decision-maker uses it to interact with social pressure factors through rational negotiation, to reach conclusions that maximize benefits under a multimodal perspective.

An empirical estimation of the models developed will be presented, where the data used and the results obtained will be analyzed. Finally, an analysis will be conducted, with a series of suggested actions in terms of proposals for complementary studies and interventions in the current transportation systems.

1. INTRODUCTION

There are numerous definitions of interurban transportation; however, setting aside regulatory-jurisdictional aspects, it could be considered as that which occurs between one or more urban centers. Additionally, it can be classified based on the characteristics of its object: freight transportation or passenger transportation. As we can see, it plays a crucial role in the social and economic development perspectives of the country. Therefore, the efforts made by society (investments) must be channeled in such a way that they lead to a situation increasingly closer to the optimal state of the system.

In the last sixty years, transportation modeling techniques have provided various tools for multimodal analysis focused on project evaluation. However, it is often observed that decisions regarding interventions in transportation modes in Argentina tend to be made from a purely sectoral perspective. This approach leads to biased solutions, without considering all the parameters that influence travel demand. Therefore, there is a need to address the transportation issue from an integrated approach, free from preconceptions about the implementation of one mode or another and ignoring the interrelation that exists with the others.

The decision to focus the study on the Buenos Aires–Mar del Plata route is due to its long tradition in providing rail, air, and road services, with a predominant and easily identifiable travel purpose: tourism. Additionally, it has geographical and spatial characteristics that allow for the potential application of various travel technologies without granting significant advantages to any particular mode.

This work aims to implement a methodology that allows for the weighting of factors influencing passengers' choices along the corridor, with the goal of evaluating policies and investments in the transportation system. To achieve this, discrete choice methods will be explored, which, through the generation of a generalized travel cost function, incorporate the various variables influencing the choice of mode. This function will be used to characterize and then quantify the relative advantages of the different modes of transportation involved in the corridor under study, as well as to assess derived demand forecasts under projection scenarios.

2. METHODOLOGY

As a first stage, an analysis and proposal for a decision-making style were carried out, for which the modeling tool was desiugned. This initial analysis illustrates the requirements expected to be met through modeling. In the case of the Buenos Aires–Mar del Plata corridor, given that its travel dynamics are in a mature stage, the decision was made to provide tools useful within an operational and tactical decision-making framework.

Subsequently, a survey of existing information from both public and private organizations was conducted to describe the current state of the system. Then, zoning and the transportation network were defined, opting to subdivide the Greater Buenos Aires area (AMBA) into seven zones, aiming to maintain political-territorial divisions to ensure consistency with the level of aggregation of the baseline information.

Once the zonal aggregation level was agreed upon, modal share data for the base year (2019) was collected, along with the quantification of travel times and costs for each of the four modes to be analyzed. For road transportation, both public and private, four congestion scenarios were considered.

Chart 1 - Travel costs and fares (in ARS, 2019 value)

	Road				Bus	Train	Airplane	
Origin	SC cost [$]	E1 cost [$]	E2 cost [$]	E3 cost [$]	Characteristic Fare	Characteristic Fare	Traditional Fare	LC Fare
Z1	1776	1935	2103	2321	1643	691	3461	2610
Z2	1484	1624	1773	1966	1451	691	3461	2610
Z3	2046	2217	2399	2634	1773	691	3461	2610
Z4	1848	2004	2170	2383	1612	691	3461	2610
Z5	1887	2052	2227	2453	1706	691	3461	2610
Z6	1872	2031	2199	2416	1640	691	3461	2610
Z7	2086	2266	2456	2703	1859	691	3461	2610

Chart 2 – Travel time [min]

Road Private and Bus						
Origin	No congestion [min]	Scenario 1 (20%)	Scenario 2 (40%)	Scenario 3 (60%)	**Train**	**Airplane**
Z1	294	353	412	470	335	55
Z2	277	332	388	443	335	55
Z3	325	390	455	520	335	55
Z4	290	348	406	464	335	55
Z5	306	367	428	490	335	55
Z6	287	344	402	459	335	55
Z7	344	413	482	550	335	55

The third stage involved proposing discrete choice models that meet the requirements defined in the first stage. To estimate the models, a stated preference survey was designed (Bliemer, 2016, and Sartori, 2013), which strictly served the needs of the proposed models, ensuring the data collection efficiency necessary for the model to be effective.

The fourth stage is the modeling itself and the analysis of the results obtained, along with the application of the method's capabilities for evaluating projected scenarios. These were demonstrated by applying scenarios where rail travel time is reduced, and toll costs are affected.

3. CREATION OF DISCRETE CHOICE MODELS

To evaluate demand capture projects for public transportation, a multinomial Logit model (Train, 2014) with two alternatives was chosen. Given the characteristics gathered in the corridor characterization, it was decided that the model would be sensitive, at a minimum, to the following factors: cost, travel time, and access time.

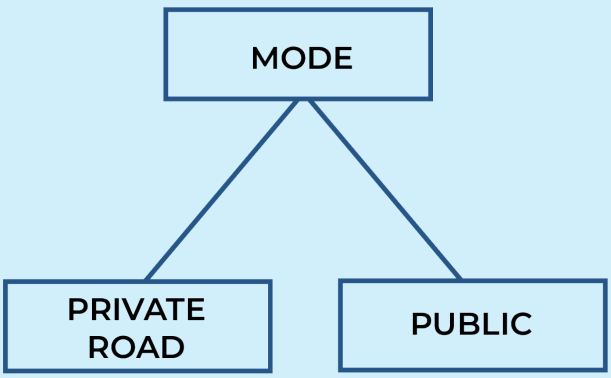
There is a large number of variables that may be of interest for modeling particular scenarios. However, it can be observed how the characteristics of the service and infrastructure are partially reflected in the cost and travel time, making these variables suitable for evaluating the impact of various projects. A particular aspect noted during the characterization was how the urban segment sometimes shares the same order of magnitude as the interurban segment. Therefore, it was decided that this aspect should not be overlooked by our model.

The following formulations were proposed as disutility functions for both modes:

$$V_{priv} = \beta_{cost} X_{cost} + \beta_{\text{travel\_time}} X_{\text{travel\_time}} + \beta_{\text{access\_time}} X_{\text{access\_time}}$$

$$V_{public} = \beta_{cost} X_{cost} + \beta_{\text{travel\_time}} X_{\text{travel\_time}} + \beta_{\text{access\_time}} X_{\text{access\_time}} + Cte_{public}$$

Figure 1-Decision tree for BL model



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In order to provide the capability for modal share forecasting, a two-level hierarchical Logit model (Train, 2014) was chosen. Given the gathered characteristics, it was decided that the model would be sensitive, at a minimum, to the following factors: cost and travel time. To achieve this, the following equations were proposed as disutility functions for the four considered modes of transportation:

$$V_{priv} = \beta_{cost}\, X_{cost} + \beta_{\text{travel\_time}}\, X_{\text{travel\_time}}$$

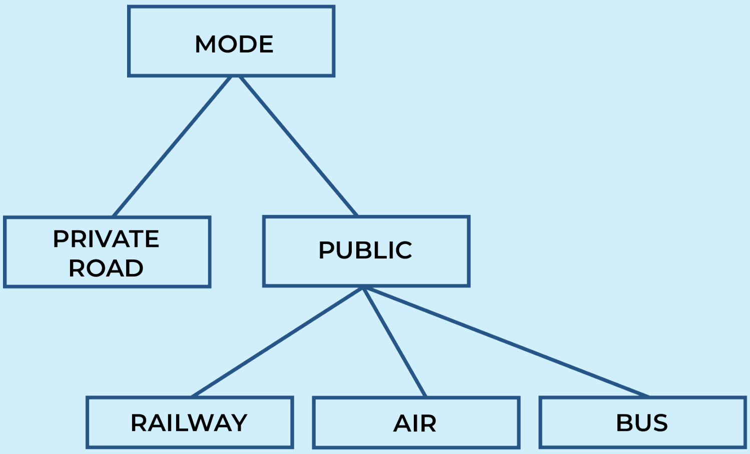
$$V_{Bus} = \beta_{cost}\, X_{cost} + \beta_{\text{travel\_time}}\, X_{\text{travel\_time}} + Cte_{\text{Bus}}$$

$$V_{Aereo} = \beta_{cost}\, X_{cost} + \beta_{\text{travel\_time}}\, X_{\text{travel\_time}} + Cte_{\text{Air}}$$

$$V_{Tren} = \beta_{cost}\, X_{cost} + \beta_{\text{travel\_time}}\, X_{\text{travel\_time}} + Cte_{\text{Train}}$$

Below is the decision tree diagram adopted:

Figure 2 – Decision tree for NL model



A stated preference survey was implemented to serve as input for the proposed discrete choice models. The survey was conducted through a web form, registering a total of 2,214 choices across 25 decision scenarios. The formulation of the choice scenarios was carried out using a pivot design, centered around utility balance situations, calibrated with data from a previous pilot survey (Bliemer, 2006; Sartori, 2013; and Kroes and Sheldon, 1988).

Below, the estimation of the coefficients of the disutility functions obtained through the application of the BL model in R-Studio is presented:

Chart 3 – BL model

Coefficients	Estimate	Std. Error	z-value	Pr(>|z|)
Public: (intercept)	-0,79354722	0,19423961	-40,854	4,4e-05
C	-0,00114772	0,00011917	-96,307	< 2e-16
Tv	-0,00934980	0,00151742	-61,616	7,2e-10
Ta	-0,01248223	0,00500360	-24,947	0,01261

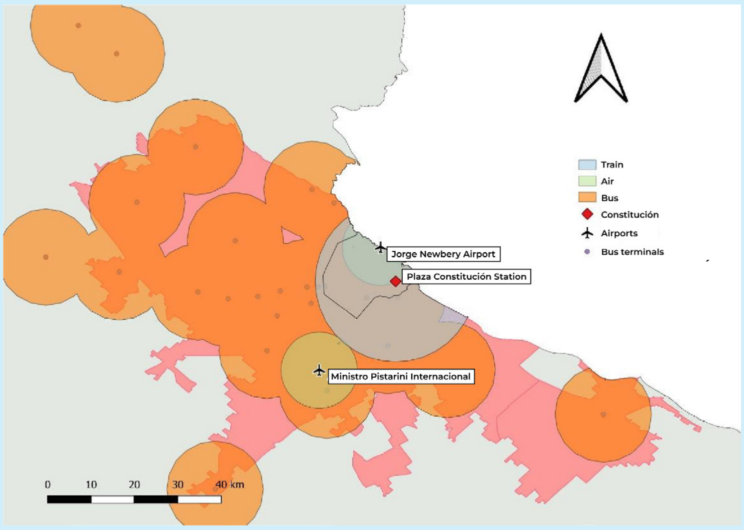
Below, the estimation of the coefficients of the disutility functions obtained through the application of the NL model in R-Studio is presented:

Chart 4 – NL model

Coefficients	Estimate	Std. Error	z-value	Pr(>|z|)
Air: (intercept)	1,19329774	0,65670845	-18,171	0,0692035
Bus: (intercept)	-0,50599541	0,33738180	-14,998	0,1336738
Train: (intercept)	-0,47115348	0,33409124	-14,103	0,1584647
C	-0,00076139	0,00022713	-33,523	0,0008015
Tv	-0,00620968	0,00203969	-30,444	0,0023313
iv	0,60895017	0,19987546	30,466	0,0023141

Based on the estimation of the BL and NL models, an analysis of the factors in the obtained disutility functions was conducted, along with a territorial analysis of access boundaries in public transportation.

Figure 3 – Access boundaries



The NL model formulation was also used for analyzing derived demand for rail transportation across three projection scenarios:

Chart 5 – Modal split

	CurrentE	E1	E2	E3
Pcar	79%	76,4%	79%	75%
Pbus	15%	10,1%	12%	11%
Pair	3%	2,6%	3%	3%
Ptrain	3%	10,8%	6%	11%

E1- In this scenario, the modal split was evaluated considering the characteristics of a higher commercial-speed railway with a travel time of 4.5 hours between terminals, while maintaining the current fare.
E2 - Same as Scenario 1, but doubling the train fare.
E3 - Same as Scenario 1, additionally considering the implementation of a tourist toll for private vehicles with a 100% increase.

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4. CONCLUSIONS

Based on the observed results, it can be seen that the tools obtained from using discrete choice models under the outlined methodology provide an effective technique for evaluating interurban transportation projects in Argentina. This method meets criteria for time and resource efficiency, achieving sensitivity that aligns with the information needs of decision-makers from a tactical or operational perspective. The relatively limited temporal projection of the results was compensated by the adaptability of the method, as its cost-effective application would allow for generating specific models that meet the requirements faced by the decision-maker at the time of project evaluation.

It was noted that in the Buenos Aires – Mar del Plata corridor, there is potential to finance projects that reduce travel time, leveraging the consumer surplus generated by such reductions. Additionally, it was observed that private road transportation users respond inelastically to toll rate changes. This phenomenon could justify implementing higher toll rates for travelers initially moving for tourism purposes, thus providing a funding source for road improvement projects. The projects could focus on reducing travel time, such as building bypasses in areas where the road network intersects with urban areas. This would create a virtuous cycle, as travel time improvements would reduce travel disutility, potentially offsetting the toll increase. At this point, projects could become self-financing without negatively impacting tourism travel demand, while providing much more efficient infrastructure for the other economic activities served by the corridor.

During the development of the work, the complexity of analyzing interurban passenger transport became evident, as well as its close connection with the urban transportation supply structure. From the initial stages of problem definition, the need to incorporate spatial dimensions into the explanatory variables was clear. This approach revealed that in extensive areas of the AMBA, the disutility component related to access to a given mode has values of the same order of magnitude as those of the interurban journey itself. This parameter indicated a relative inelasticity of demand concerning interurban travel characteristics, resulting in a portion of captive demand in both private and public road transportation.

Another important aspect for project evaluation is the territorial analysis of observed sensitive costs. This approach allows for delineating modal influence areas, which illustrate which portion of the population is affected by actions taken in each particular mode. In this case, it was possible to measure the effect of the capillarity of the private road transporation mode compared to, for example, the limited coverage of the rail transportation.

Finally, it is essential to delve into the urban segment, as this aspect has proven to be crucial in the modal choice process for users. In many cases, the monetary and time costs were of a similar magnitude to those of the interurban journey itself, leading to the logical conclusion that a significant portion of the policies affecting the modal split of interurban trips is determined by those policies implemented in the urban segment. This suggests that to ensure the effective implementation of projects in the interurban segment, they must be aligned and coordinated with the stakeholders in the urban segment. When analyzing the scenario of improvements in rail travel time, it was observed that the connectivity features of the Constitución station played a significant role in the overall cost structure. Therefore, in this case, changes in demand capture would be more significantly influenced by improvements in access to the terminal rather than by enhancements in the interurban journey itself.

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