Implementing Macroscopic Simulation Models To Evaluate Complementary Waterbus Routes

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Abstract

This work analyzes the impact of incorporating waterbus routes into the existing public transport network by means of implementing macroscopic simulation models. The research is carries out following a classic 4-stages structure: analysis, design, construction, and validation. During the construction, the classical 4-step travel forecast model was applied. Initially a base model to represent the actual public transport network of Valdivia (Chile) is constructed. Updated origin-destination matrices along with new measurements taken in-situ were used to calibrate and validate the virtual model. Then a second model that includes the proposed waterbus routes is constructed. Both models were implemented in PTV Visum. Simulation results revealed that only a fraction that barely reached a 1.8% of all trips was made through the proposed water bus routes. In conclusion, with an estimated error of 9.3%, the work suggest that the proposed waterbus routes might be a complement to the existing transport network, but they would not be the traveler's favorite option.

Keywords
Macroscopic Simulation, PTV Visum, Public Transport Network, Sustainable Urban Traffic.

1. Introduction
It has been observed that during the last decades the population in large cities has incremented significantly. People move in the search for new opportunities and better living conditions. It is not common that the growing in the population comes along with more infrastructure to satisfy the new housing and transportation needs. Also, recent favorable economic cycles have made possible that many families acquire one or more vehicles, which sooner or later will end up giving rise to traffic congestion problems. Usually, centralized governmental urban traffic planning offices are responsible for designing alternatives to make traffic flow on a road network more efficient. Along with the private transport means, the public transport system plays an important role in the dynamics of cities. Although in many cases public transport lines do not obey centralized planning since it might be under the control of private corporations, it usually covers great areas connecting distant districts and transporting thousands of people every day. A special case are those cities crossed by rivers and whose connectivity depends greatly on the existence of bridges, which are commonly the center of serious traffic congestion problems. This research is focused on the possible implementation of waterbus lines to complement the public transport network of Valdivia, Chile.

1.1 Objective
Analyze the impact of incorporating waterbus routes as a complement to public transport network of Valdivia by means of implementing macroscopic simulation models.

2. Literature Review

2.1 Simulation
The simulation process involves the creation of virtual models to imitate the behavior real systems and their subsequent study under specific conditions. Urban traffic simulation models require several specific objects such as zones, centroids, nodes, arcs, connectors, routes, bus lines and stops for the public transport network.

2.2 Urban traffic simulation

The simulation of urban traffic can be classified in three mayor types: microscopic, mesoscopic, and macroscopic, which differ mainly in the approach used. While a macroscopic simulation focuses on the flows, the microscopic simulation focuses its attention on the movement of individual vehicles (Figure 1).

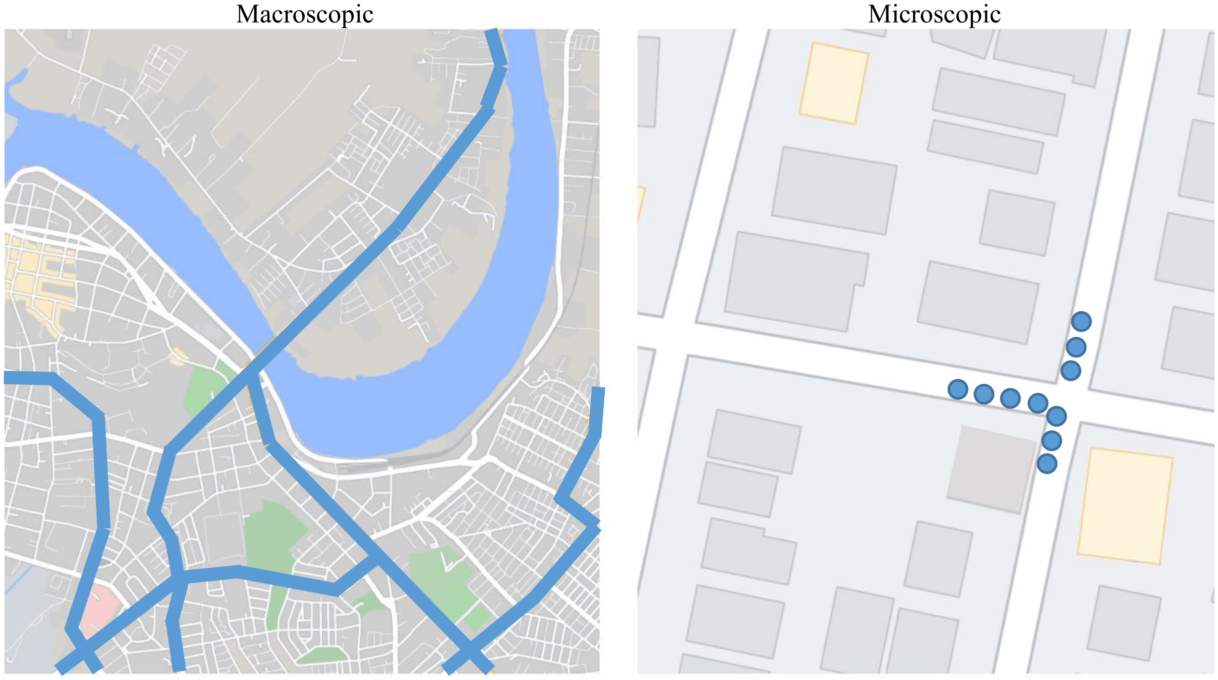

Figure 1. Macroscopic and microscopic modelling

2.3 Classical travel forecast model

Classical traffic simulation models are based on the Principle of Wardrop, which states that individuals make rational decisions and will choose routes that minimize travel time. The travel forecast model uses origin-destination matrices to characterize the travels that take place in an area of interest. They indicate trips' origin and destination, its travel time and the means of transport used by travelers (Barceló 2010, Ortúzar Willumsen 2011, Meyer 2016). The construction of OD matrices requires a previous step called zoning, in which the area is divided into zones to symbolize the origin and destination of the trips. Figure 2 presents the 4 steps of the classical modelling.

Step 1: Generation / attraction. In this stage, the number of trips generated and attracted to each zone in which the city has been divided is determined.

Step 2: Distribution. In this stage, the pair origin-destination is matched and then incorporated into the origin-destination matrix.

Step 3: Modal selection. In this stage, trips are classified according to the transport mode (public, private), generating an origin-destination matrix for each mode.

Step 4: Travel assignment. In this stage, the trips contained in the OD matrices are assigned to the available networks or routes.

Figure 2. Classical travel forecast 4-step model

3. Methods
The present work was carried out following a traditional 4-stage approach (Figure 3): analysis, design, construction, and validation.

Figure 3. Tradicional 4-stage methodology

3.1 Analysis
During the analysis, bibliography, previous studies, and diverse information are reviewed along with the selection of the simulation software PTV Visum. Potential waterbus routes and boarding point are identify using the existing infrastructure and the actual public transport network as references. Consequently, the new information need is determined and a set of control points for in-situ observations is defined. For the purposes of this article, besides the travel speed and the passenger capacity all technical specifications of the water buses will not be explained in detail (Int. Assoc. Public Transport 2013, Stenius et al. 2017).

3.2 Design
During the design, existing OD matrices created in 2013 are used to define the zone of the virtual models to be constructed (Trasa Ingeniería 2013, Sectra 2018). Even though they are out of date, OD matrices can be updated by means of a coefficient that represent the annual rate of increment in the number of travels. A total of 12 zones are defined for the area of study, each of them counts with a centroid which represents the point of generation and attraction of trip from and to a given zone (Figure 4).
Initially, a base model to simulate the actual public transport network, consisting of 9 bus lines, is constructed. During the virtual model set up OD matrices corresponding to the public transport trips are used during the model calibration. Afterwards, starting from the base model a new virtual model is constructed. The new model incorporates the proposed waterbus routes into the existing public transport network. To design the waterbus routes requires the review of the availability of boarding points and their potential use depending on their proximity to the bus stops of the city's bus lines (Figure 5).

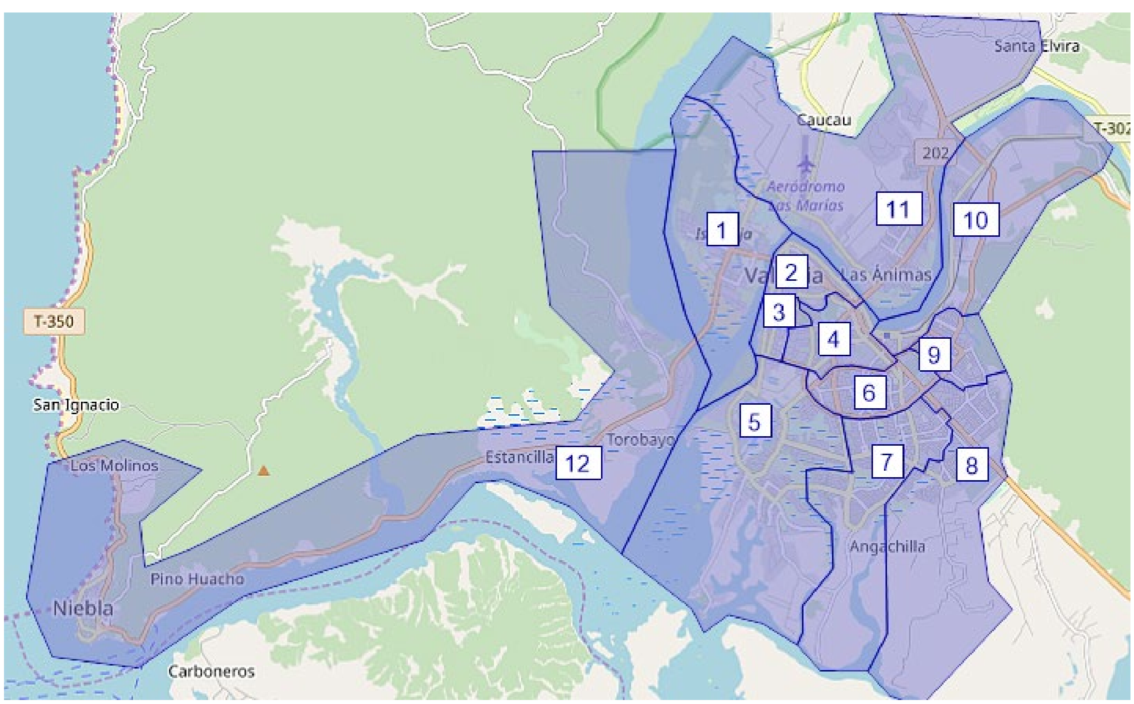

Figure 4. Valdivia's twelve zones

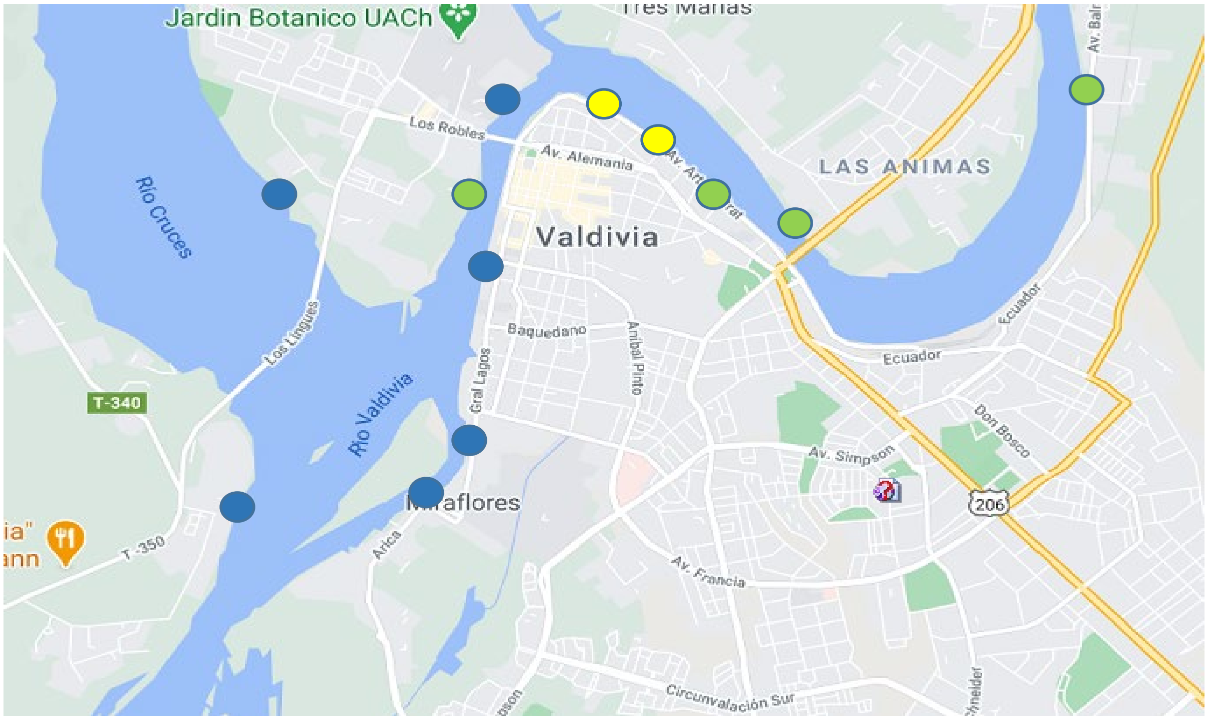

Figure 5. Boarding points (blue: private, green: public, yellow: in construction)

To compare both the base model and the waterbus route model the indicators in Table 1 were selected:

Table 1: Key indicators to compare models' performance

JRT	Journey Time	Travel time in minutes from origin to destination
PJT	Perceived Journey Time	Travel time in minutes perceived by the traveler.
JRD	Journey Distance	Distance in km covered from origin to destination.
CI	Complement Indicator	Fraction of trips made through waterbus routes

3.3 Construction

The construction is carried out entirely in the working environment of PTV Visum, a world class traffic simulation software. The construction begins with the setup of the OD matrices and the creation of the objects corresponding to both the private and public transport networks. Most important objects are zones, centroids, nodes, arcs, connectors, turns, bus lines and stops. In the case of arcs several attributes are needed: length, lanes, direction of flow, and capacity. For the purposes of this research two virtual model are to be compared. Once the base model is constructed, calibrated, and validated, a new model with waterbus routes is constructed (Figure 7 and Figure 8). The base model considers only the public transportation network, which consists of 9 bus lines (Figure 6). It contains the objects summarized in Table 2.

Table 2: Base model – Objects summary

Object	Quantity	Description and attributes
Arcs	1282	Speed limit 50 km/h. Avenue capacity 1400 veh/hr. Street capacity 700 veh/hr
Nodes	410	Cross road or turning point (left o right)
Bus stops	227	For travelers.
Bus lines	9	Allocation method: Time Table Based
Boarding points	14	For travelers.

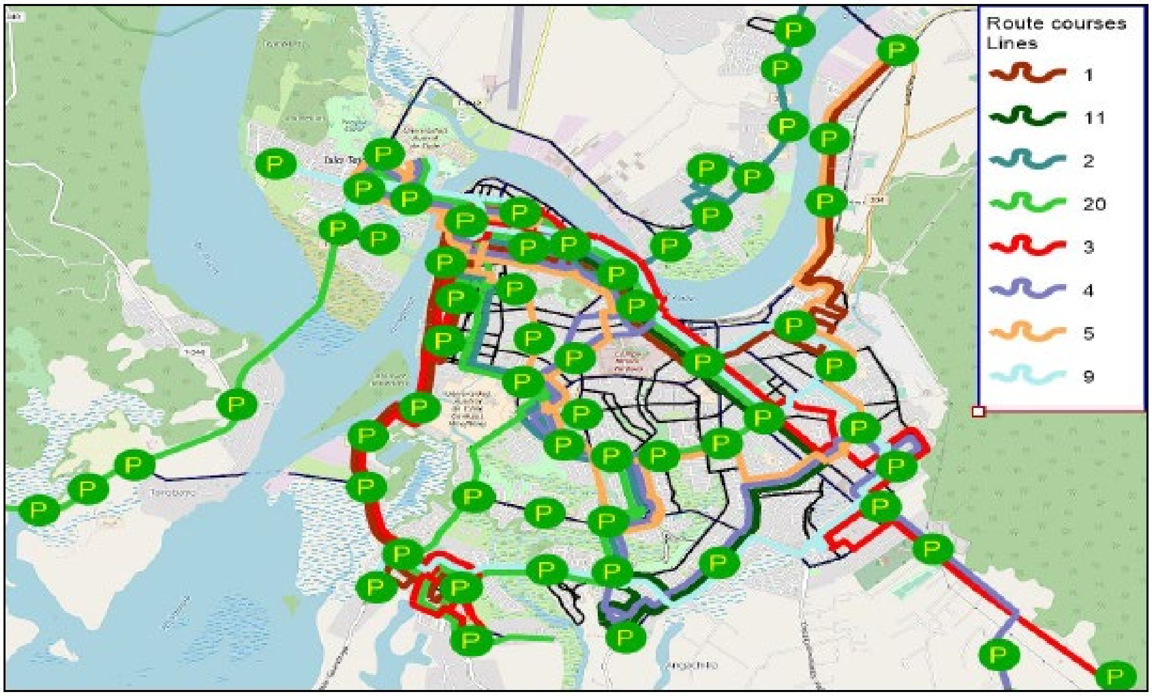

Figure 6. Base model – Public transport network – 9 bus lines and 227 bus stops

For the purposes of this work, it is assumed that water buses are propelled by electric power source and that they can transport 15 passengers at a speed of 6 nautical knots.

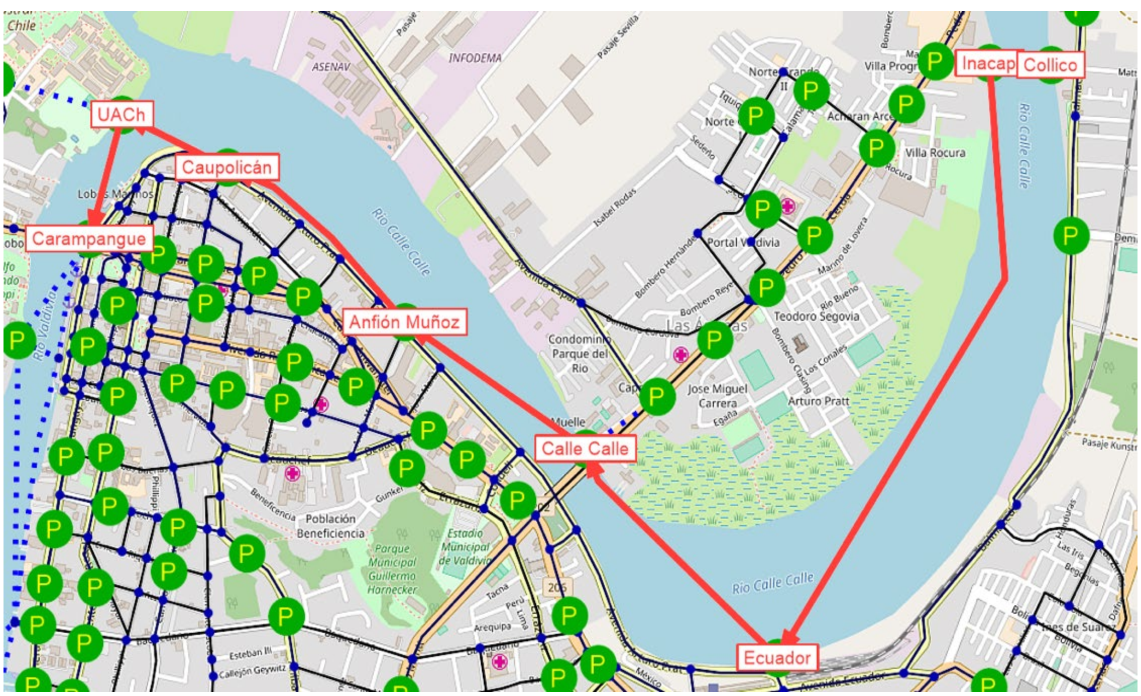

Figure 7. Waterbus route model – Route 1

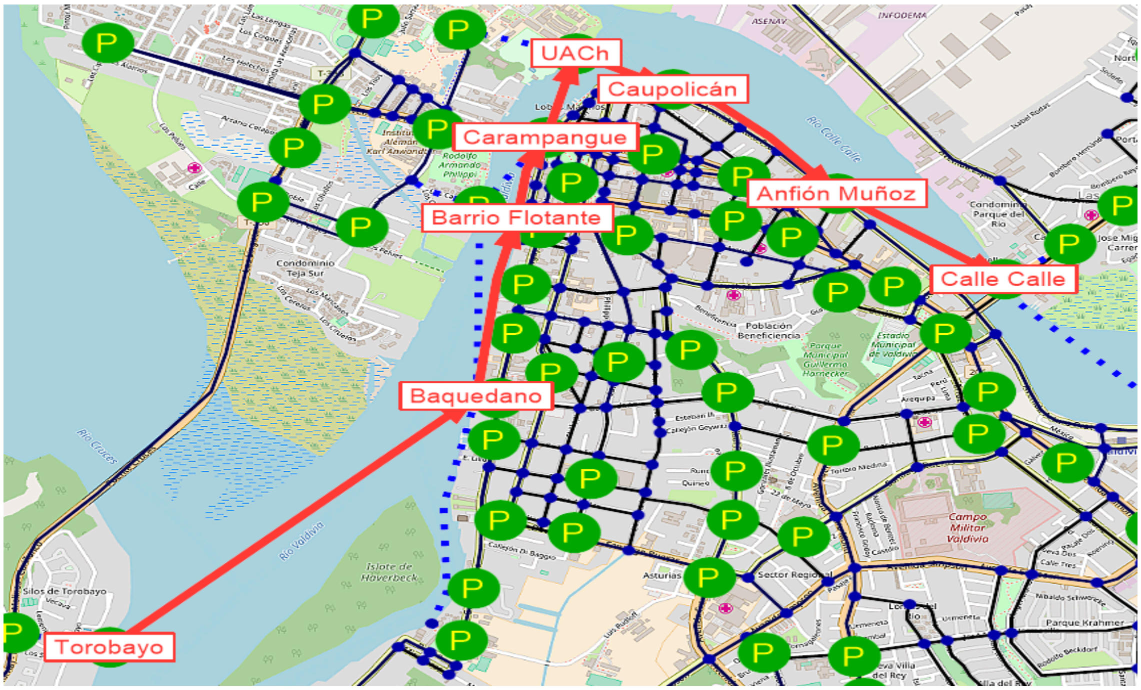

Figure 8. Waterbus route model – Route 2

3.4 Validation

During the validation, a comparison between the flow generated by the virtual models' simulation and those observed at the control points is carried out. There is a range of tolerance when comparing flows. The causes for such differences are diverse: the update of the OD matrices from 2013, new infrastructure projects built after the creation of the original OD matrices, change of speed limit in the country and variations in the bus lines' frequencies through the years.

4. Data Collection

To carry out the calibration and validation of the base model a good number of observations at specific control points nearby bridges, Figure 9, were made (Solutiva Consultores 2015).

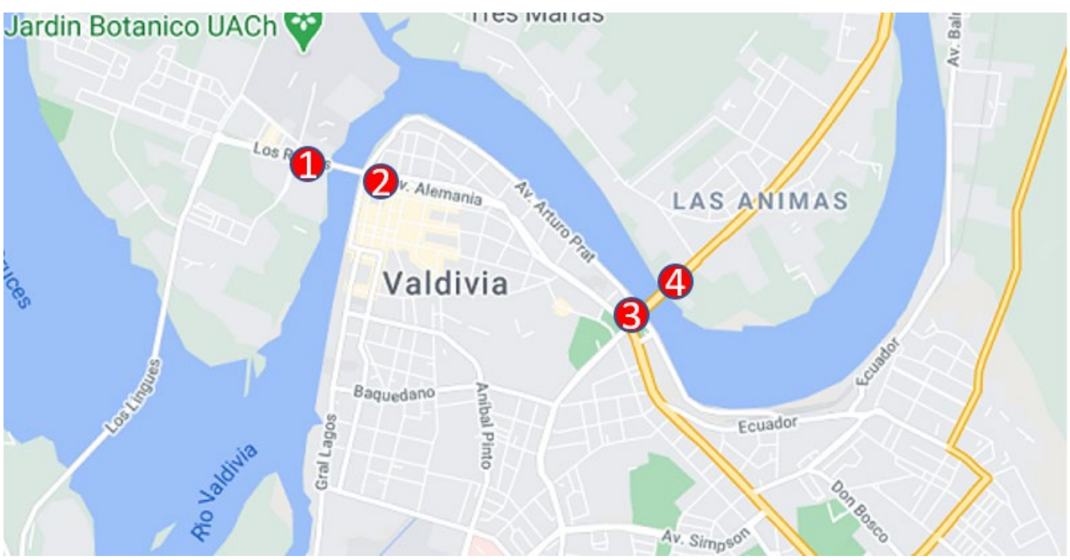

Figure 9. Control points

The result of the calibration and validation is presented in Table 3 and Table 4 respectively.

Table 3. Base model calibration

Control point	OD Matrix - Public transport	Base model simulation
1	1.747	1.747
2	639	639
3	923	924
4	563	577

Table 4. Base model validation

Control point	Base model simulation	Observed flow
1	1.747	1.872
2	639	655
3	924	780
4	577	416

5. Results and Discussion

5.1 Numerical Results

Waterbus route model's simulation results are summarized in Table 5, Table 6, and Table 7. All numbers represent the variation in the key indicator with respect to the simulation result of the base model.

Table 5. JRT variation with respect to base model [min]

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	-1,34	0,09	-1,24	0,00	-1,25	0,00	0,00	-0,25	-16,04	-22,23	-1,81	-5,30
2	0,02	0,01	0,00	0,16	0,00	-0,24	-0,05	0,01	0,34	-0,88	0,00	-6,00
3	-0,23	0,03	0,01	-0,84	0,00	-0,70	0,01	-0,13	0,26	-0,88	-0,16	-22,01
4	0,73	-0,10	-0,51	0,00	0,16	0,00	0,22	1,93	0,73	-0,98	-0,02	-5,97
5	-1,66	0,00	0,00	-1,34	0,00	-1,41	0,46	-0,14	0,15	-0,88	-2,39	-8,08
6	-0,06	-0,36	-0,55	0,00	2,83	0,00	0,50	1,78	0,50	-2,61	-2,35	-8,01
7	0,00	0,12	0,11	0,46	-1,78	0,41	0,45	0,00	0,16	-1,09	-0,02	-5,99
8	-0,12	-0,30	-0,28	0,23	-0,29	1,00	0,00	0,00	-0,41	-2,94	-3,43	-6,09
9	0,41	0,08	0,11	-0,38	0,02	-0,16	0,08	0,31	-7,23	-0,44	-17,57	-5,59
10	-19,29	-0,88	-0,88	-2,90	-0,88	-3,18	-0,55	-1,56	-0,15	-9,35	-22,56	-8,62
11	-3,05	0,00	-0,22	-1,17	-2,62	-3,88	-1,73	-1,44	-13,29	-20,77	-2,99	-7,93
12	-5,98	-5,98	-11,41	-7,09	-9,08	-7,91	-6,05	-6,17	-5,59	-8,16	-8,01	-10,18

Table 6. PJT variation with respect to base model [min]

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	2,27	2,85	0,09	5,77	2,67	6,13	9,24	7,51	-14,09	-21,48	2,33	-1,82
2	1,68	1,16	1,17	2,83	3,78	3,06	6,11	6,95	3,56	7,73	3,85	0,17
3	2,41	1,15	1,16	1,89	2,62	1,92	4,51	8,52	4,74	8,95	4,62	-24,42
4	5,06	2,31	2,17	0,18	6,13	0,35	3,49	7,88	2,03	5,73	2,32	1,94
5	1,39	3,55	2,33	4,03	2,48	3,51	1,02	10,91	6,85	11,28	0,78	-1,52

6	4,84	3,17	1,98	0,00	3,86	0,18	2,93	3,77	1,23	4,51	3,89	2,12
7	7,57	5,50	4,38	2,58	1,87	2,49	2,71	4,42	2,54	5,21	9,15	5,91
8	6,06	7,32	8,37	6,13	11,00	2,18	4,42	4,42	2,17	3,41	1,02	4,45
9	4,89	3,73	4,72	0,82	7,30	0,59	2,81	2,47	-5,92	0,79	-23,27	3,57
10	-19,27	7,95	9,12	3,98	11,73	2,92	7,43	3,75	1,29	-9,20	-24,31	0,42
11	0,78	3,93	5,33	1,42	0,84	2,21	8,08	0,49	-20,06	-24,54	-2,84	-3,03
12	-3,30	-1,03	-6,14	-0,27	-5,21	1,37	5,31	3,72	2,63	-0,24	-3,82	-4,34

Table 7. JRD variation with respect to base model[km]

Zone	1	2	3	4	5	6	7	8	9	10	11	12
1	0,07	0,06	0,25	0,00	0,26	0,00	-0,03	-1,14	-3,14	-4,28	0,28	-1,87
2	0,07	0,00	0,00	0,01	0,00	-0,03	-0,04	-0,13	-0,33	0,00	0,00	-1,05
3	0,24	0,00	0,00	-0,06	0,00	-0,17	-0,19	-0,05	-0,13	0,00	0,02	-6,46
4	-0,18	-0,17	-0,41	0,00	-0,25	0,00	-0,06	-3,41	-0,73	0,03	0,02	-1,39
5	0,27	0,00	0,00	0,08	0,00	-1,50	-1,26	-0,05	-0,14	0,00	-0,02	-1,60
6	-0,01	-0,09	-0,25	0,00	-3,81	0,00	-0,18	-4,22	-0,64	-0,32	-1,28	-1,64
7	-0,01	0,08	-0,24	-0,20	0,24	-0,18	-0,18	0,00	-0,07	0,04	-0,07	-1,19
8	-0,08	-0,01	0,00	-3,02	0,00	-2,24	0,00	-1,07	-0,23	-0,40	-1,12	-1,13
9	-0,49	-0,33	-0,17	-0,60	-0,01	0,00	-0,15	-0,57	-0,32	-0,21	-2,36	-1,54
10	-4,04	0,00	0,00	0,03	0,00	-0,05	-0,03	-0,13	-0,35	-1,63	-3,73	-1,06
11	0,05	0,00	-0,04	0,07	-0,06	-1,90	-1,81	-0,90	-2,28	-5,21	-2,02	-1,16
12	-1,19	-1,19	-1,16	-1,12	-2,39	-1,69	-1,34	-1,01	-1,54	-1,12	-1,19	-1,57

6. Conclusion

The simulation results obtained during both calibration and validation of the base model suggest that the model was constructed correctly and that the base model represents the actual system and therefore it can be used to explore alterations to the existing transport network.

The simulation results produced by the waterbus route model showed that a fraction of all trips was made through the proposed water bus routes. However, the percentage barely reached a 1.8%.

Finally, the selection of key indicators to compare both virtual models revealed that the incorporation of waterbus routes modifies in some extent the distribution of trips in the city.

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Biographies

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