

POLITECNICO DI TORINO

Master's Degree Course in Automotive Engineering

Design and Simulation of a Battery Swapping System for Public Transport

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Agenda



Challenges of E-Mobility



Battery Swapping Station(BSS)



Thesis Objectives



Model Building and Simulation



Thesis Outcomes



Future Work

Challenges of E-Mobility

As a result of increasing concerns about dependancy on petroleum and greenhouse gas emissions, many governments and automotive manufacturers across the world have increased the attention on eco-friendly vehicles.

There are still some major challanges;



Insufficient Charging
Infrastructure



Battery Performance
Degradation



High Cost of Batteries



Long Charging Times

Battery Swapping Station(BSS)

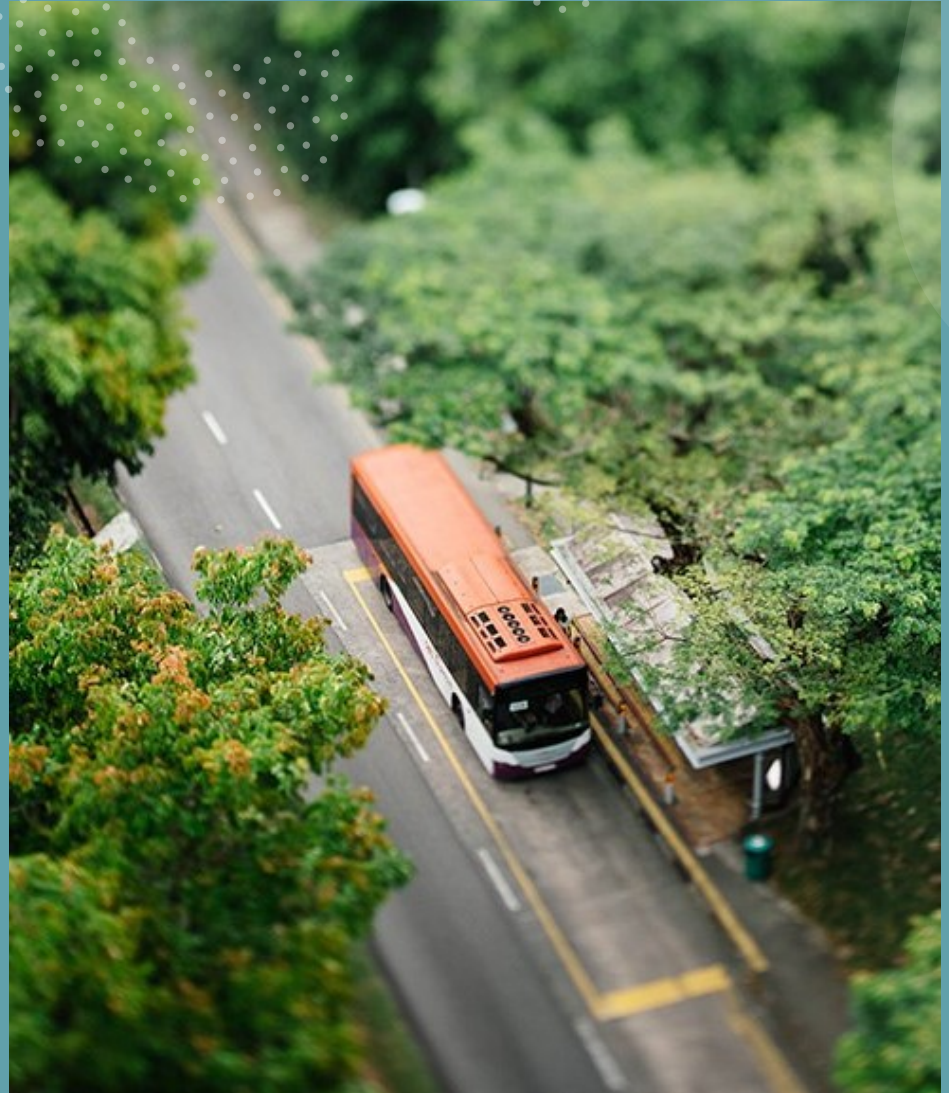
- What is BSS?

A battery swapping (or switching) station is a place at which a vehicle's discharged battery or battery pack can be immediately swapped for a fully charged one, eliminating the delay involved in waiting for the vehicle's battery to charge



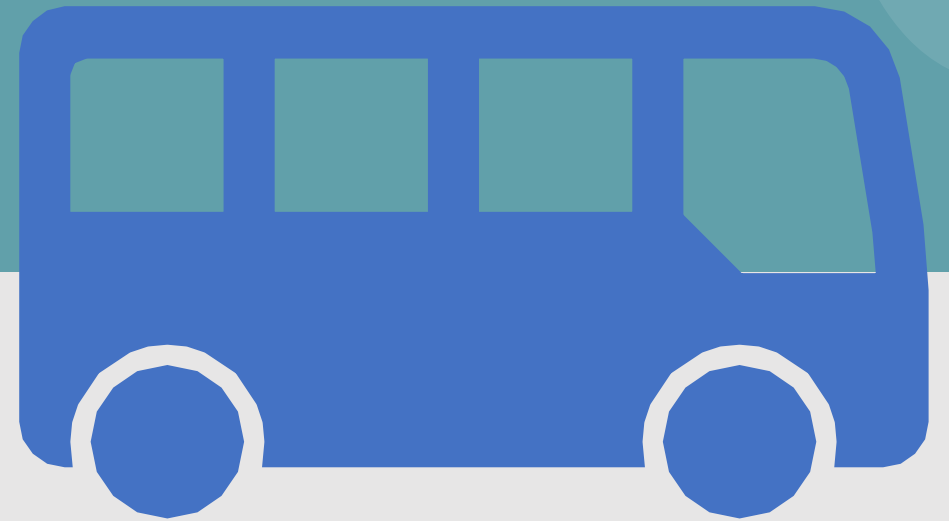
Adoption of BSS: Opportunities

- Increased Battery Lifetime
- High Level of Autonomy
- Reduced Range Anxiety
- Reduced Purchase Price
- **Quick Replacement of Depleted Battery Packs**

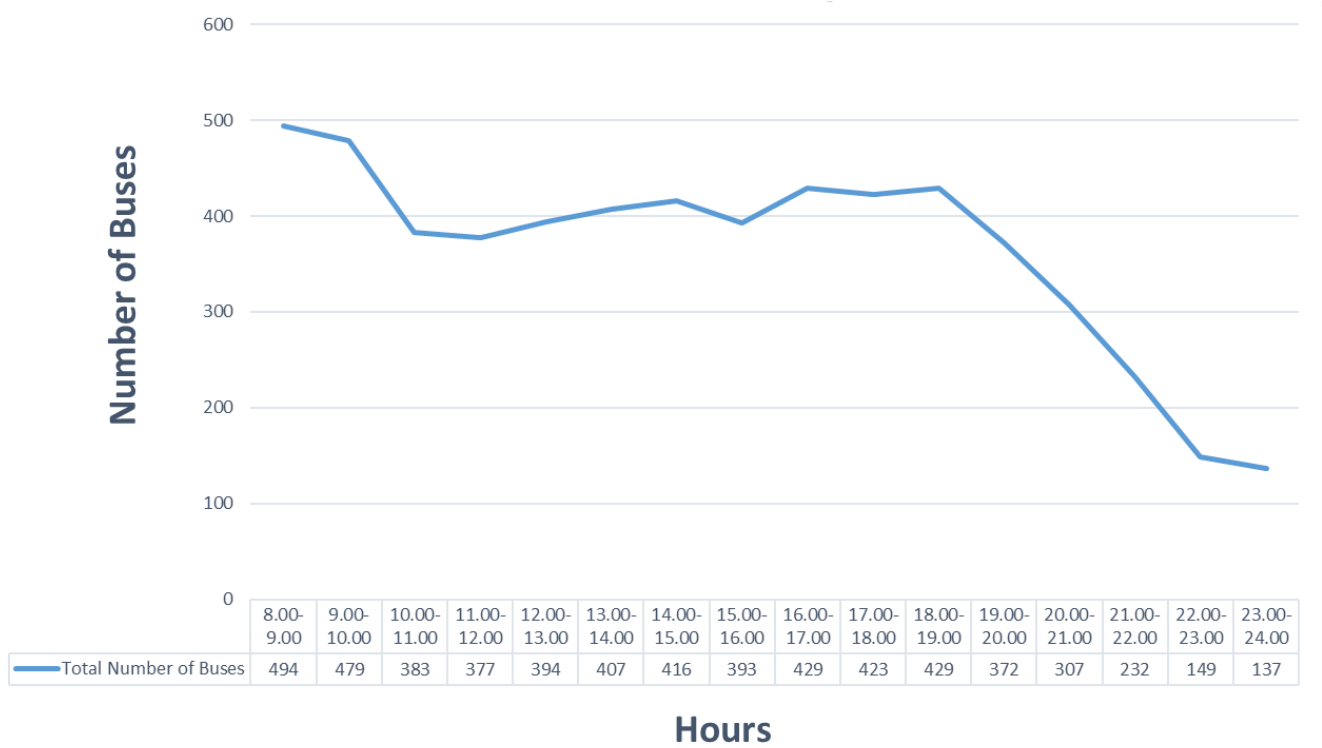


Thesis Objectives

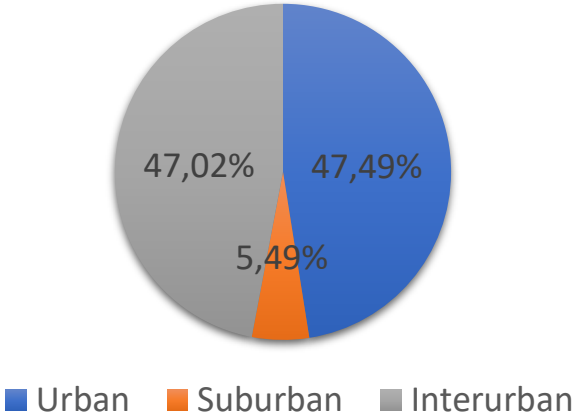
- Analysis of Turin's Public Transportation System
- Prediction of Hourly Battery Swapping Demand in the City of Turin
- Design and Simulation of BSSs for Turin's Public Transportation
- Generation of Different Scenarios through a Configurable Simulation Model
- Selection of the Most Suitable Solution through Multiple Criteria Decision Analysis



Analysis of Turin's Public Transportation System

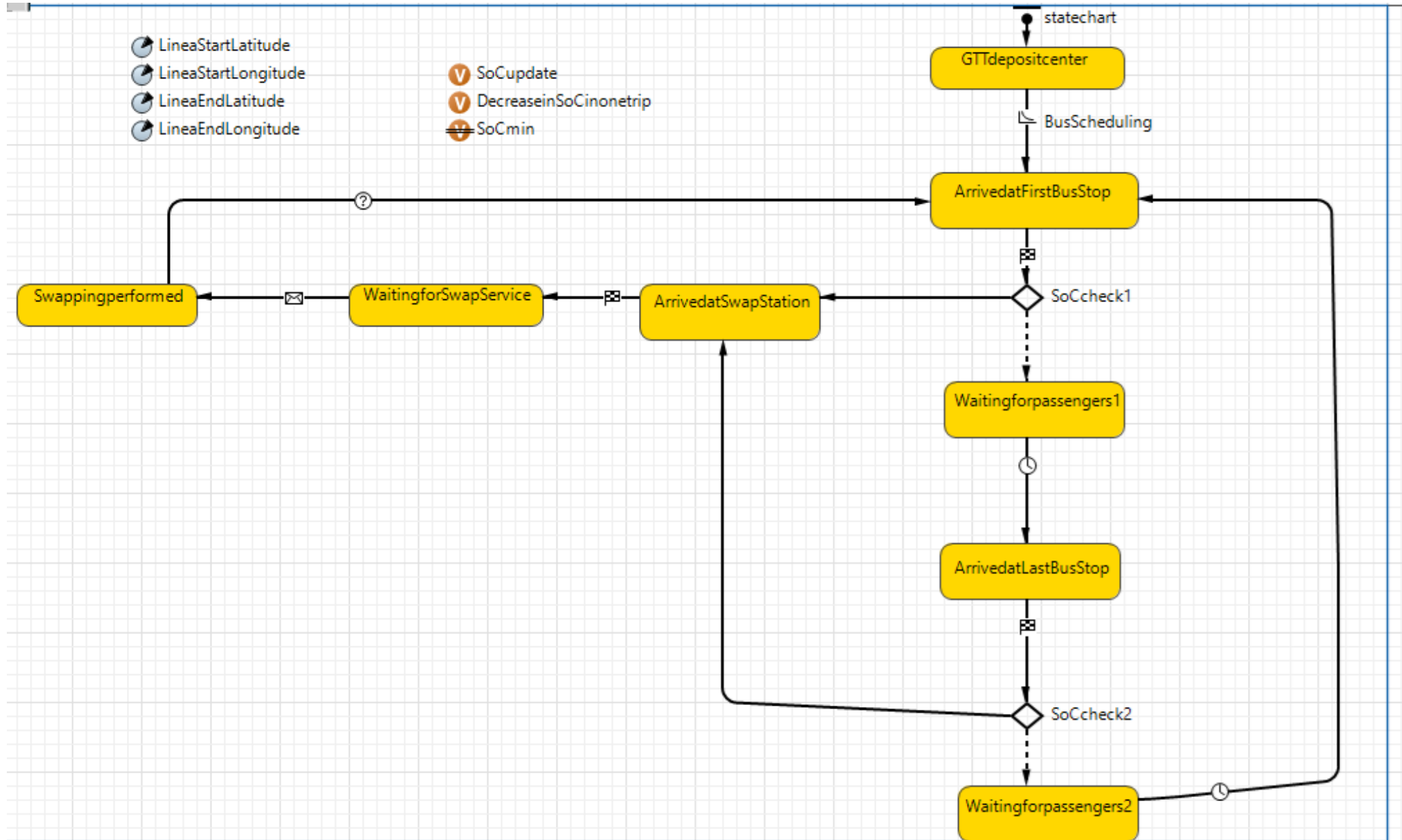


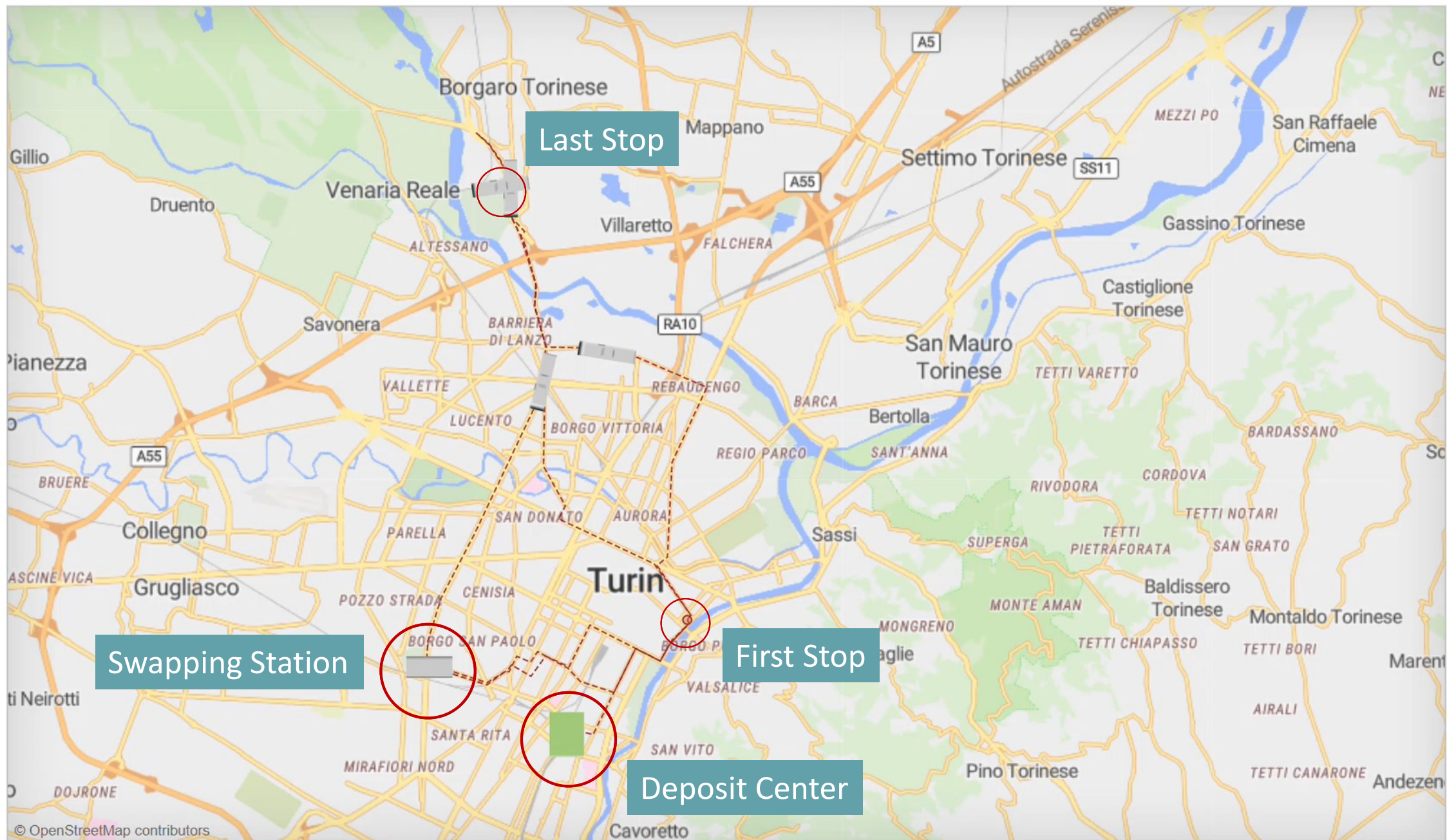
Average # of buses per day



Network	Number of lines	Percentage	Average # of buses per day	Percentage	Average km traveled
Urban	42	40,78%	199	47,49%	18,91093023
Suburban	14	13,59%	23	5,49%	18,66357143
Interurban	47	45,63%	197	47,02%	25,05137255
Total	103		419		

Prediction of Hourly Battery Swapping Demand

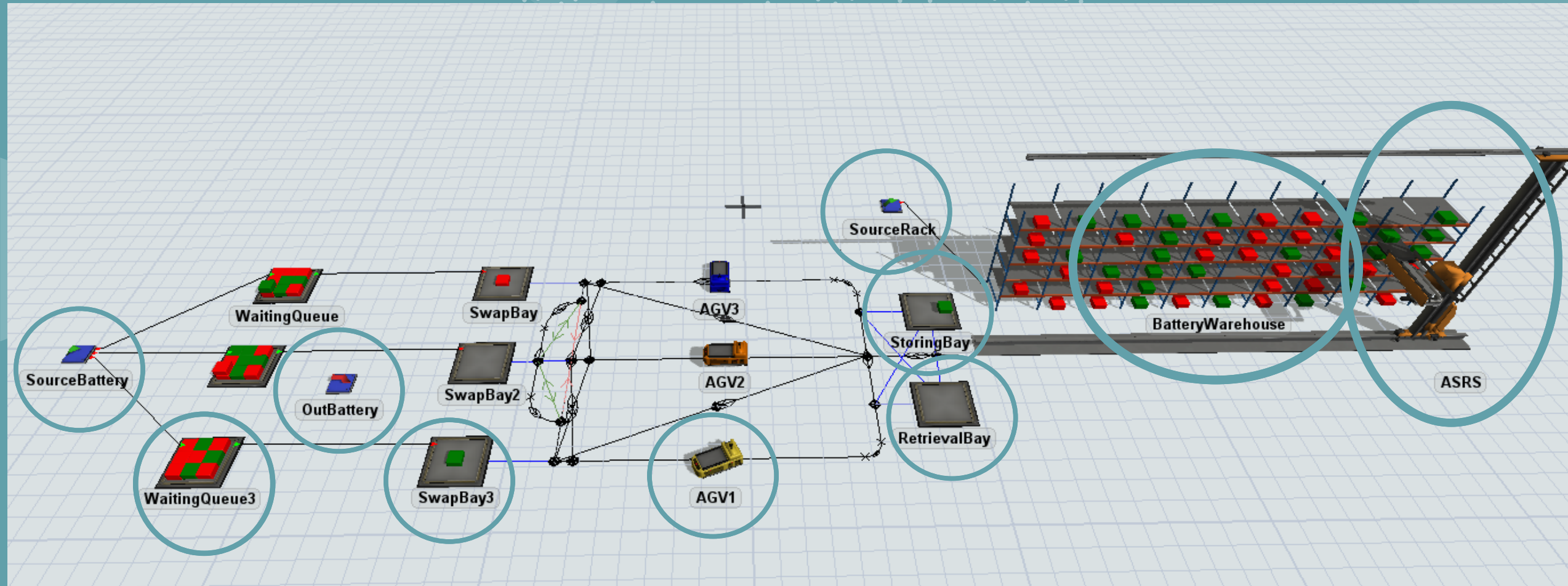




Schedule of Hourly Battery Swapping Demand

	Number of BSS=2		Number of BSS=3		Number of BSS=4	
	# of arriving buses		# of arriving buses		# of arriving buses	
Time Table						
08:00-09:00	0		0		0	
09:00-10:00	0		0		0	
10:00-11:00	5		3		2	
11:00-12:00	28		19		14	
12:00-13:00	65		43		33	
13:00-14:00	69		46		34	
14:00-15:00	49		33		25	
15:00-16:00	29		19		14	
16:00-17:00	41		27		21	
17:00-18:00	42		28		21	
18:00-19:00	39		26		19	
19:00-20:00	61		40		30	
20:00-21:00	45		30		23	
21:00-22:00	39		26		20	
22:00-23:00	41		27		20	
23:00-24:00	47		31		23	

Station Simulation



FileEditViewExecuteStatisticsDebugHelp

ResetRunStopStep

Run Time: 1166.05 to 88000.00

Run Speed: 13.03

Library

Fixed Resources

Task Executors

Travel Networks

Conveyors

Warehousing

Visual

Model

PowerTable

TypeTable

BatteryTable

WaitTable

CustomersTable

Model

SourceBattery

WaitingQueue

WaitingQueue2

WaitingQueue3

OutBattery

SwapBay

SwapBay2

SwapBay3

AGV2

AGV3

AGV1

SourceRack

StoringBay

RetrievalBay

BatteryWarehouse

ASRS

System Console

Compiler Console

Output Console

Script

Quick Properties

Statistics

State: generating

Throughput: 0.00 / 7.00

Content: 0.00 / 0.00 / 0.00 / 0.00

Staytime: 0.00 / 0.00 / 0.00

General Properties

SourceBattery

fs3d\Source\Source.3ds

X: -30.47, Y: -10.49, Z: 0.00

0.00, 0.00, 0.00

1.06, 1.06, 0.52

Labels

Automatically Reset

Source

FlowItem Class: Box

Arrival at time 0

Inter-Arrivaltime: Hourly Rates, Custom Daily R

Output

Send To Port: Shortest Queue if Available

Use Transport: current.centerObjects

Model LimitReached



Experimental Plan

The experimental plan involves the variation of the following elements:

- The number of battery packs in the warehouse; 20...50
- The number of battery swap Workstation; 1...3
- The number of AGV used; 1...3
- The arrival rate of battery swap request; 2BSSs,3BSSs,4BSSs

Thesis Outcomes



Key Performance Parameter Analysis

- Mean Waiting Time of the Buses; 88.81 seconds
- Mean Service Time; 131.63 seconds
- Mean SoC of the Provided Battery Packs; 79.65 %
- Stay Time of Fully Charged Batteries in the Warehouse; 40 minutes
- Mean Charging Time of Battery Packs; 50 minutes
- Daily Energy Consumption per Station; 32863.67 kWh/day
- Utilization of AGV and ASRS; 38% and 35%



Required Sizing of the Warehouse

- Each warehouse should accommodate; 35 Battery Packs

Thesis Outcomes



Number of Stations Needed

- The number of stations Turin needs is; 4BSSs



Best Station Configuration

- 2 Battery Swap Workstation operated with 2 AGV




Cost Analysis

- 43 Million Euro without including the acquisition cost of Electric Buses
- 226 Million Euro with including the acquisition cost of Electric Buses

Future Work

- Evaluation of use of the renewable energy infrastructure as a second source for charging
- 'Parallel Swapping Technique'
- Implementing the possible maintenance and breakdown events on the simulation model
- Introduction of advanced codes monitoring continuously the degradation level





THANK YOU FOR YOUR
ATTENTION