

**SMART CITY MODELING: USING GIS CAPABILITIES FOR URBAN AREAS**  
**ZACHARY CRAWFORD**

**SECTION: DR. GANAPATHY MAHALINGAM**  
**ARCH 771**  
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# TABLE OF CONTENTS

## **I. Introduction**

- A. Background p.1-2
- B. Problem Statement p.3
- C. Research Objectives p.4

## **II. Methodology**

- A. Data Collection p.5-7
- B. Model Development p.8-9
- C. Model Validation p.10
- D. Scenario Analysis p.11

## **III. Results**

- A. Model Performance p.12-16
- B. Spatial Analysis p.17-24
- C. Temporal Analysis p.25-30
- D. Impact Assessment p.31

## **IV. Conclusions**

- A. Future Directions p.32
- B. Challenges p.33
- C. Closing Remarks p.34

# I. INTRODUCTION - BACKGROUND

This research aims to show the capabilities of smart city modeling using GIS and other accessible information to provide accuracy and precision. Through this data collection, architects and urban planners can strategically alter urban areas to promote user experience and contentment. Current well-established cities can become known as smart cities, or cities that are data driven. This collection of data, such as traffic control, can be used to improve the user experience through efficiency and correct implementation. The idea of a “walkable city” is also reinforced as an important design solution that directly impacts the user experience in this urban environment. To do this, urban planners must use data from smart cities to make these decisions.

To find the most effective solution to the urban design problem of pedestrian flow, multiple simulation methods are explored. In this way, each simulation will be compared distinctly to strengthen the result. Through this comparison, simulation and modeling will be valuable in comparing each solutions' features. Areas of analysis in the aspect of walkability and traffic efficiency are targeted to the user of the urban setting in order to improve their health and wellness of their urban environment. Future solutions will be built upon these past design solutions moving forward.

# I. INTRODUCTION - BACKGROUND

More specifically, the focus is on the Midwestern downtown urban setting: Fargo, North Dakota. The primary analysis is to develop multiple simulations to improve user circulation and traffic flow. This includes circulation through downtown and the efficiency of vacating the downtown area. Through smart city models and data collection, a walkable city can be effectively defined.

Pedestrian mapping is a beneficial method to collect or simulate possible scenarios in established cities. Pedestrian mapping is primarily conducted in this research to simulate present transportation methods and find alternate solutions to urban transportation. These transportation methods include walking, biking, and public transportation, in which each method has distinct characteristics to examine.

# I. INTRODUCTION - PROBLEM STATEMENT

This exploration aims to provide possible simulation methods for current smart city implementations and improvements. The impact of this project is to find that computational simulations and modeling can improve the overall health and well-being of users in an urban environment. Through this, architects and urban planners may use this workflow in future design projects that focuses on user experience and engagement. Rather than designing for the client, striving for user experience would change the design solution and result in better user wellness. In a broader sense, the impact of designing for the user experience could develop a more sustainable environment in an urban area. Urban layouts have become more congested and focused on population density because of population growth. Urban layouts have also become more one-dimensional and plotted in a grid-like pattern. Through this design method, urban layouts could become more interesting regarding design choices to improve the health of the urban users.

# I. INTRODUCTION - RESEARCH OBJECTIVES

In order to simulate possible urban traffic scenarios, ArcGIS and AnyLogic are used to accurately model the downtown Fargo environment.



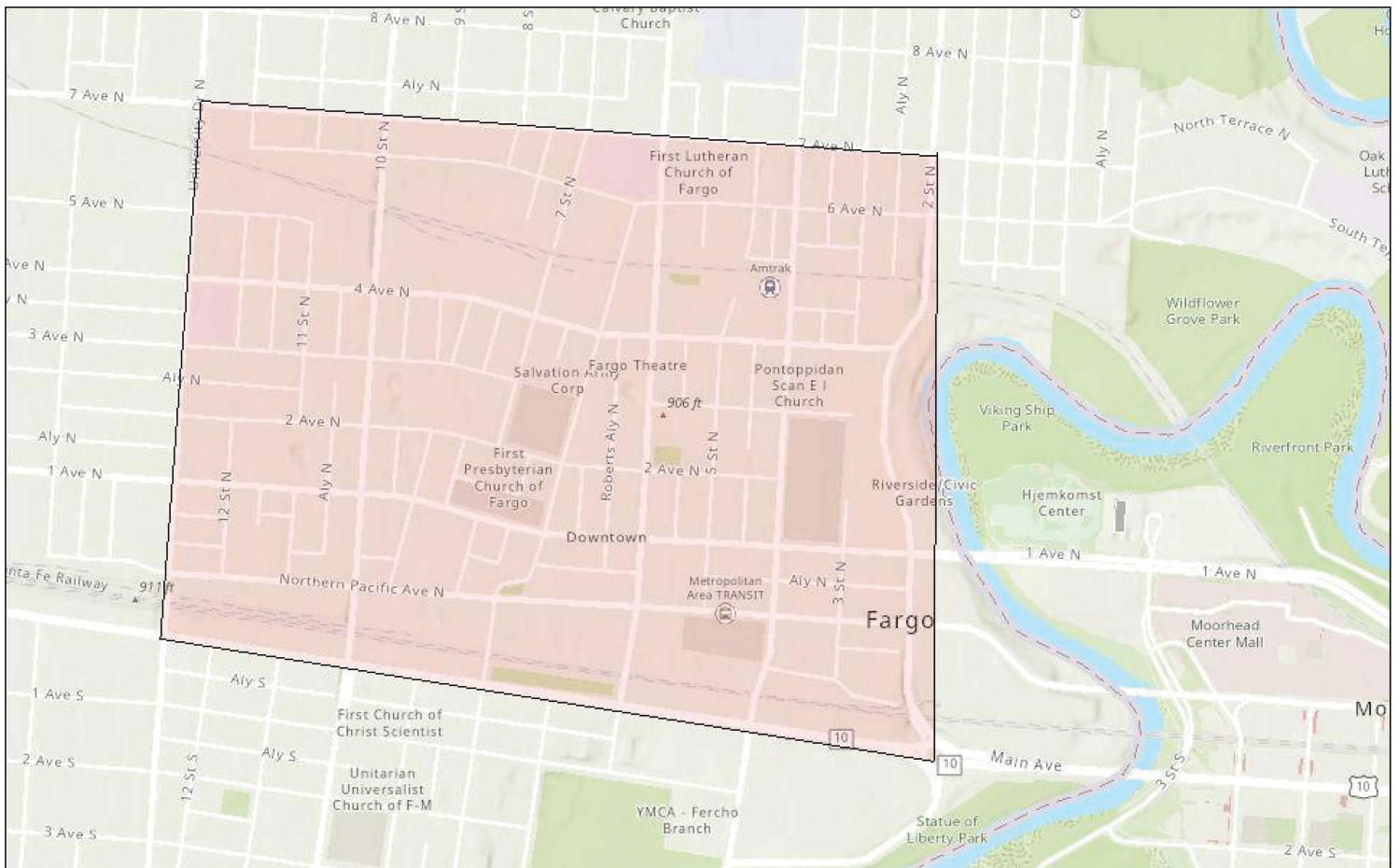
ArcGIS is a geographic information software used to complete mapping and analysis solutions. ArcGIS can provide exploration and visualization through smart mapping. Analysis of data includes locating prime locations, optimal routes, and patterns to make predictions. As a result, this tool can be used to discover optimal and strategic locations of interest through circulation studies.



AnyLogic is a general-purpose simulation software that uses agent-based modeling. Agent-based modeling is computational modeling used to simulate interactions of autonomous agents, such as people. As such, AnyLogic can simulate scenarios of pedestrian flows from different buildings and urban layouts to develop an efficient and effective outcome. From this data, urban planners can find an effective solution of urban planning primarily to the pedestrians' movement. Additionally, ArcGIS can integrate with AnyLogic to provide an easier workflow within a single platform.

# II. METHODOLOGY - DATA COLLECTION

Simulating Fargo's downtown urban area was done possible by reaching out to city departments in order to get public assembly permits. The two primary departments that had the accessible information was the Building Inspections Department and the Fire Department. These permits contain the address, name, and occupancy of the building. Being a public assembly means that these locations are open to the public, which include restaurants, university departments, and other places of gathering. The following information outlines the area of research and the information necessary to create the model:



# II. METHODOLOGY - DATA COLLECTION

PERMIT NUMBER	DATE	OCCUPANT	ADDRESS	Permit	TYPE
23892	1/1/2023	Wasabi/Poke Bowl	560 2 Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 81	PA
23904	1/1/2023	Wild Terra Cider and Brewery	6 12 St N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 80	PA
23001	1/1/2023	46 N Pints & Provisions	635 2 Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load 216	PA
23643	1/1/2023	Pixeled Brewing Co.	1100 NP Ave, Ste 101	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load 217	PA
23261	1/1/2023	Drunken Noodle	414 Broadway N	Occupant Load 1st Floor - 58 Rooftop - 49	PA
23093	1/1/2023	Black Coffee & Waffle Bar	550 2 Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL=136	PA
23081	1/1/2023	BernBaum's	402 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL=90	PA
23189	1/1/2023	Cowboy Jacks	506 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load: 1st and 2nd Floor - 350 Outdoor patio - 106	PA
23075	1/1/2023	Beer and Fish Company	230 Roberts Aly N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 198	PA
23821	1/1/2023	Taco Shop	117 Broadway	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL 94	PA
23709	1/1/2023	Rough Cut Axe Throwing Bar (Rough Cut Social)	1100 NP Ave Suite 102	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 134	PA
23888	1/1/2023	Vinyl Taco	520 1 Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 77	PA
23795	1/1/2023	Stone Event Center	613 1 Ave N	Occupant load 1st Floor - 281 2nd Floor - 235	PA
23251	1/1/2023	District 64	64 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 1st Floor - 204 2nd Floor - 80	PA
23105	1/1/2023	Boss Pizza & Chicken	228 Broadway	Occupant Load Upper Level - 116 Lower Level - 82	PA
23373	1/1/2023	Havoc House	222 Broadway N #200	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load - 193	PA
23480	1/1/2023	Little Brother	117 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load - 94	PA
23696	3/20/2023	Dempsey's expansion	222 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 120	PA
23944	7/19/2023	Mezzaluna	309 Roberts St N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Maximum Occupant Load - 99	PA
23948	8/7/2023	The Four & Four	404 4 Ave N, #203	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL - 209	PA
23719	1/1/2023	Sanctuary Events Center	670 4 Ave N	Occupant Load Basement reception - 438 First floor events center - 476	PA
23833	1/1/2023	Teddy's Eatery and Parlor	212 Broadway	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL-69	PA
23666	1/1/2023	Proof Artisan Distillers	414 4 Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 88	PA
23887	1/1/2023	VFW Club	607 2 Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load Lower Level - 185 Main level - 179	PA
23094	1/1/2023	Blackbird Woodfire	206 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL 67	PA
23571	1/1/2023	No Bull	609 NP Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL=63	PA
23641	1/1/2023	Pho D'Licious	623 Northern Pacific Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load 66 (39 East dining, 27 West dining)	PA
23653	8/9/2023	Pounds	6 Broadway N #100	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL - 104	PA



# II. METHODOLOGY - DATA COLLECTION

23844	1/1/2023	The Toasted Frog	305 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL=120	PA
23708	1/1/2023	Rooter's Bar	107 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load=200	PA
23775	1/1/2023	Sons of Norway	722 2 Ave N	OL - Lounge 61 Dining 121	PA
23646	1/1/2023	PLAINS ART MUSEUM	704 1 Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2015 Edition. To store and use flammable or combustible Liquids as per Section 5701.4 IFC 2015 Edition.	PA/FL/SP
23843	1/1/2023	The Northern	325 10 ST N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant load=265 upper, 150 lower	PA
23756	1/1/2023	Sidestreet Bar and Grill	404 4 Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. OL - 314	PA
23914	1/1/2023	Wurst Bier Hall	630 1 Ave N - Suite 1	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 128 East Room Occupant Load = 100 West Room	PA
23339	1/1/2023	Fort Noks	52 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load=103	PA
23241	1/1/2023	Dempsey's Public House	226 Broadway N	Occupant Load: Main Floor 209 Second Floor 258	PA
23091	1/1/2023	Bismarck Tavern	522 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load 104	PA
23297	1/1/2023	Fargo Civic Memorial Auditorium	207 4 ST N	To conduct hot work as per Section 3501.2 IFC 2021 Edition. Civic Memorial Auditorium - 3337	PA
23276	1/1/2023	Empire Tavern	424 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 85	PA
23161	1/1/2023	CHUB'S PUB & PACKAGE PLACE	421 University Dr N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant load=185	PA
23320	1/1/2023	FARGO THEATER	314 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant load = 870	PA
23609	1/1/2023	OLD BROADWAY CORP	22 Broadway N	City Club = 310 OL Grill = 151 OL Sports zone = 70 OL	PA
23788	1/1/2023	Spicy Pie	322 Broadway N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant load=72	PA
23790	1/1/2023	Sports Bar Inc	619 Northern Pacific Ave N	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant load = 165	PA
23625	1/1/2023	Paradox Event Center	26 Roberts St N - Suite A-117	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant load = 120	PA
23837	1/1/2023	The Boiler Room	210 Broadway	To operate a place of assembly as per Section 105.5.39 IFC 2021 Edition. Occupant Load = 280	PA
		Renaissance Hall			200
		Klai Hall			200
		Barry Hall			150
		First Lutheran Church			3000

# II. METHODOLOGY - MODEL DEVELOPMENT



**Agent:** A component that can be static or non-static in the simulation. It can be the component that is “moving” through the simulation. In this case, it is a pedestrian (FargoPedestrian)



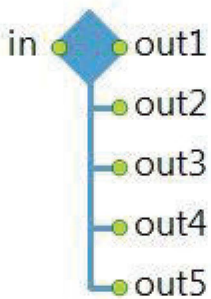
**Source Block:** Where the Agent begins from the model. Sources can be a region (entire of downtown Fargo) or a specific location (a specific building)



**MoveTo Block:** A specified location where the Agent moves to or towards.



**Delay Block:** When the Agent passes through this block, it rests for a specified period of time. In this case, it is used to simulate the time the pedestrian stays within a building.



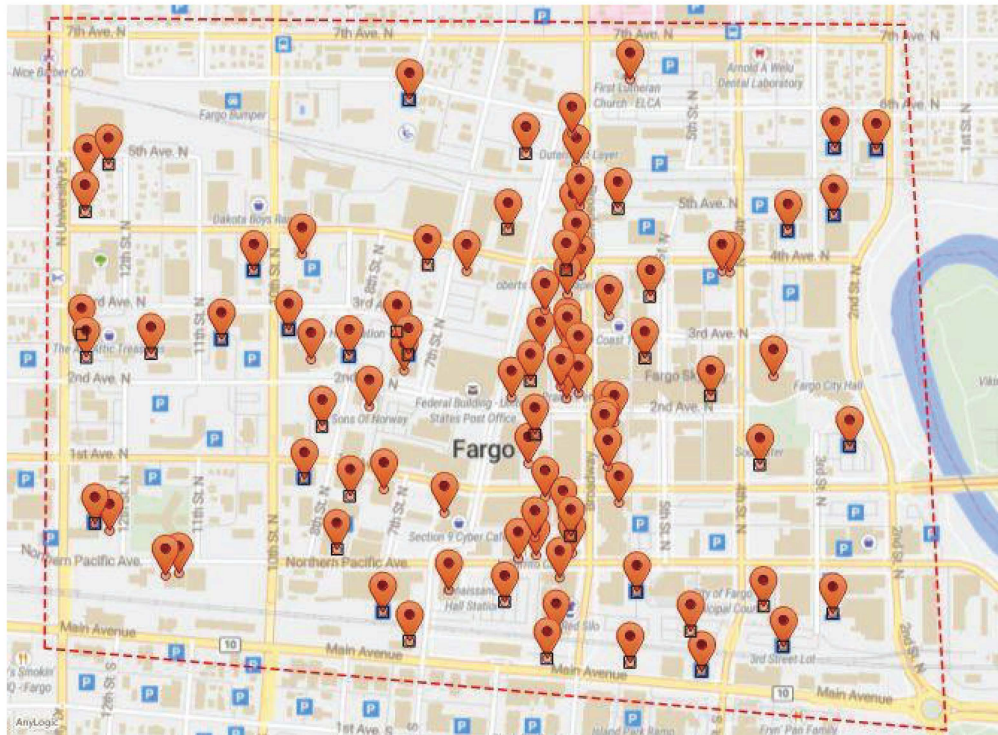
**SelectOutput5 Block:** Upon entering this block (from the the left), the agent can move up to one of the five choices. This blocked is especially useful for randomizing where each pedestrian goes. It is also used to loop the model in where the Agent goes to a previous step in the model.



**Sink Block:** This marks the end of simulation, where the Agent is disposed of, or leaves the simulation.

# II. METHODOLOGY - MODEL DEVELOPMENT

With AnyLogic's GIS capabilities, a map of the simulation is easily accessible. The orange points, also known as GIS Points, can be placed to mark any location throughout the model. It can also be used to mark up routes, boundaries, and differentiate between GIS Points.



**agent.moveToNearestAgent(parkingSpots);**

This line of code tells the Agent (FargoPedestrian) to move to the nearest (moreToNearest) parking location (parkingSpots).

**if (agent.distanceTo(RobertsAlley)<=0) RobertsAlley.occupiedSpots++;**

This line of code sees if the Agent (FargoPedestrian) is at a specific location (RobertsAlley) (<=0 means the distance between the agent and the location is zero). If this is true, the graph that is tracking RobertsAlley (RobertsAlley.occupiedSpots) is added by 1 (++). Essentially, this line of code marks when a pedestrian is at a location.

# II. METHODOLOGY - MODEL VALIDATION

Within each block holds adjustable variables that impact the model's performance. Additional code can also be added for advanced models. Each block can be changed separately to become unique. For example, two Delay blocks can have different locations with different capacities. Major variables include the location, rate, probability, speed, capacity, and delay time.

**sourceDrunkenNoodle - Source**

Name:   Show name  Ignore

Arrivals defined by:

Arrival rate:

Set agent parameters from DB:

Multiple agents per arrival:

Limited number of arrivals:

---

Location of arrival:

Node:

Speed:

**destinationDrunkenNoodle - MoveTo**

Name:   Show name  Ignore

Agent:  moves to  is placed (jumps) to

Destination:

Node:

... with offset:

Straight movement:

**toParking - SelectOutput5**

Name:   Show name  Ignore

Use:  Probabilities  Conditions  Exit number

Probability 1:

Probability 2:

Probability 3:

Probability 4:

Probability 5:

**waitDrunkenNoodle - Delay**

Name:   Show name  Ignore

Type:  Specified time  Until stopDelay() is called

Delay time:

Capacity:

Maximum capacity:

Agent location:

**Actions**

On enter:

On exit 1:

On exit 2:

On exit 3:

On exit 4:

On exit 5:

# II. METHODOLOGY - SCENARIO ANALYSIS

**Hierarchical Model:** Start at Downtown Building -> Move to another Building -> Loop or go to nearest Parking Lot

**Distributed Model:** Start at Downtown Building -> Move to another Building -> Loop or go to a Parking Lot

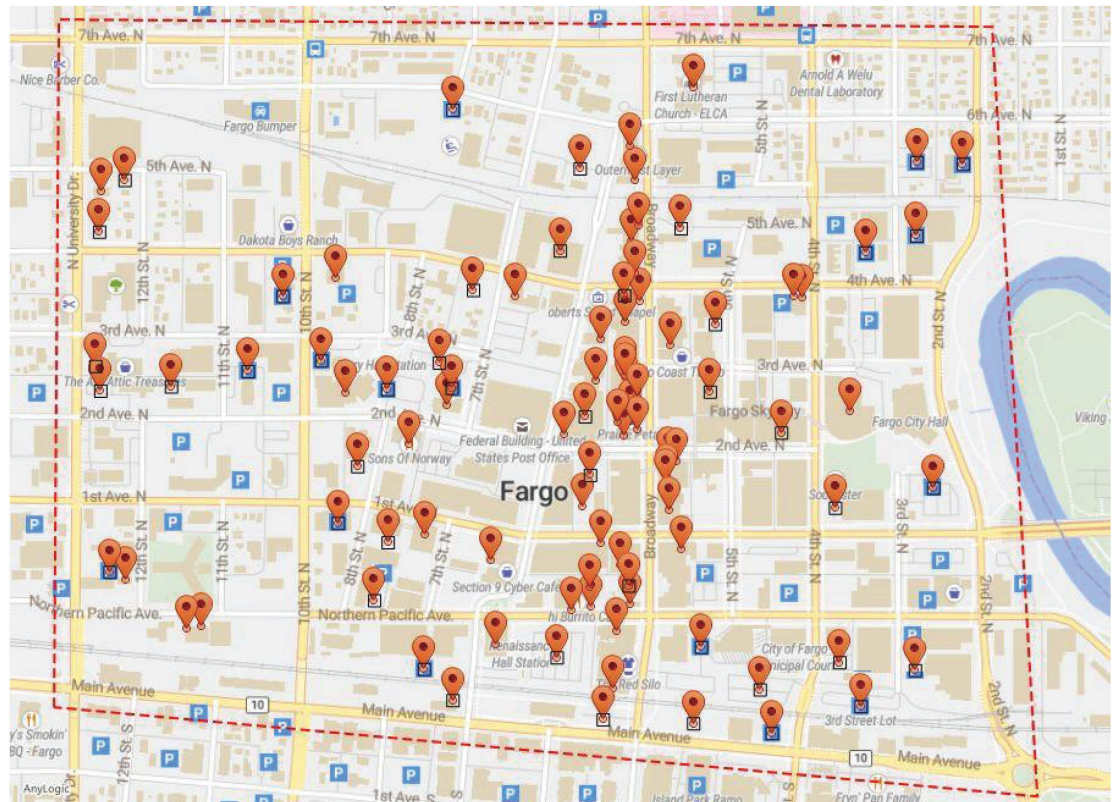
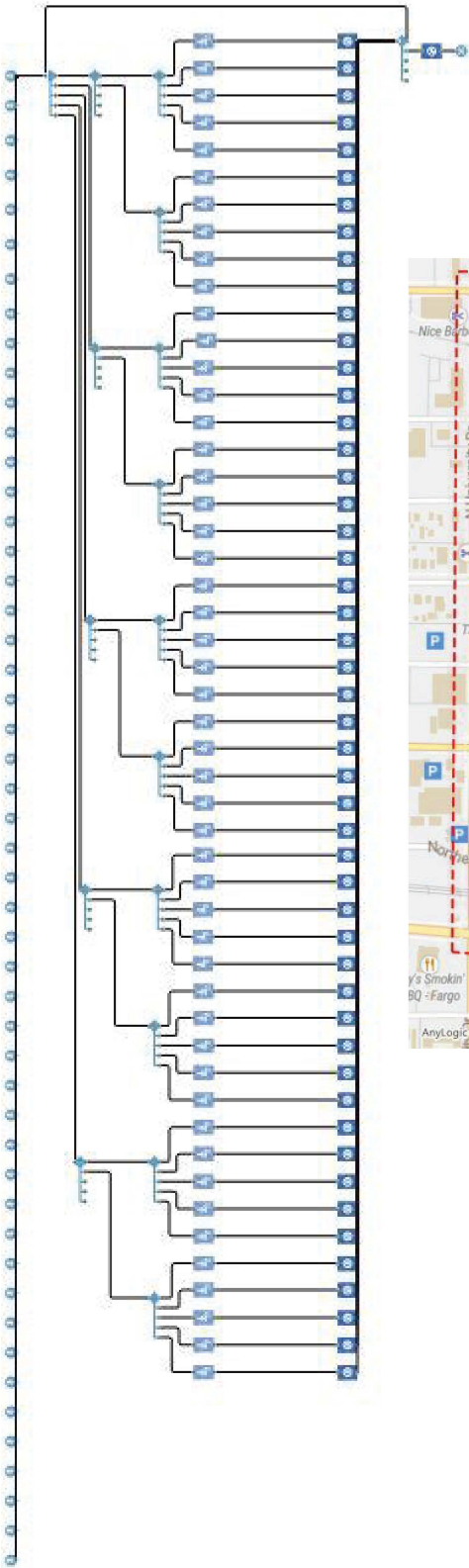
**Intersectional Parking Model:** Start at Downtown Fargo -> Move to nearest intersection -> Move to nearest Parking Lot -> End

**Centralized Parking Model:** Start at Downtown Building -> Move to nearest Bus Stop -> Move to Central Parking Location -> End

**Bike Traffic Model:** Start at Downtown Fargo -> Move to Building -> Move to Building -> Loop or End

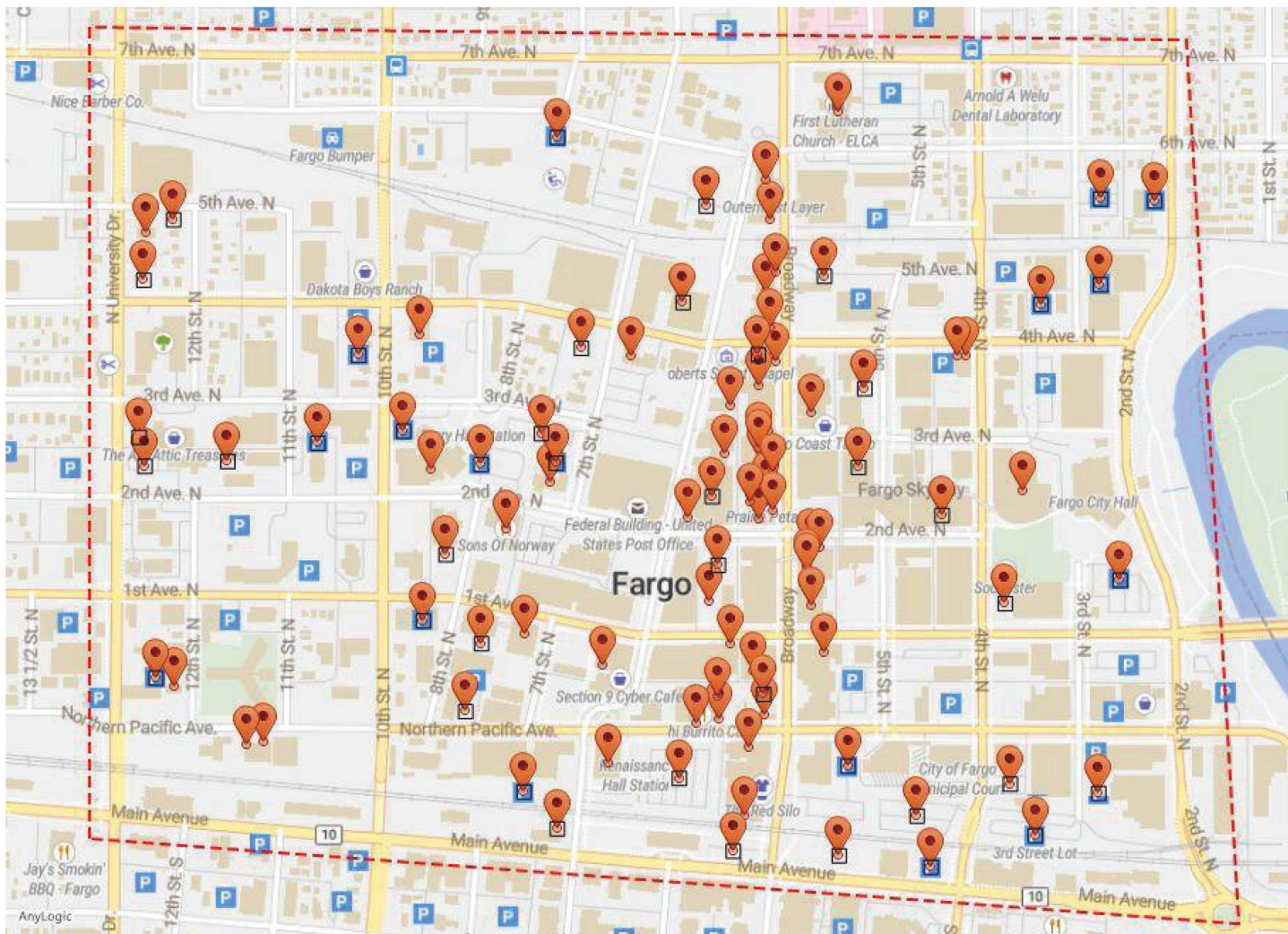
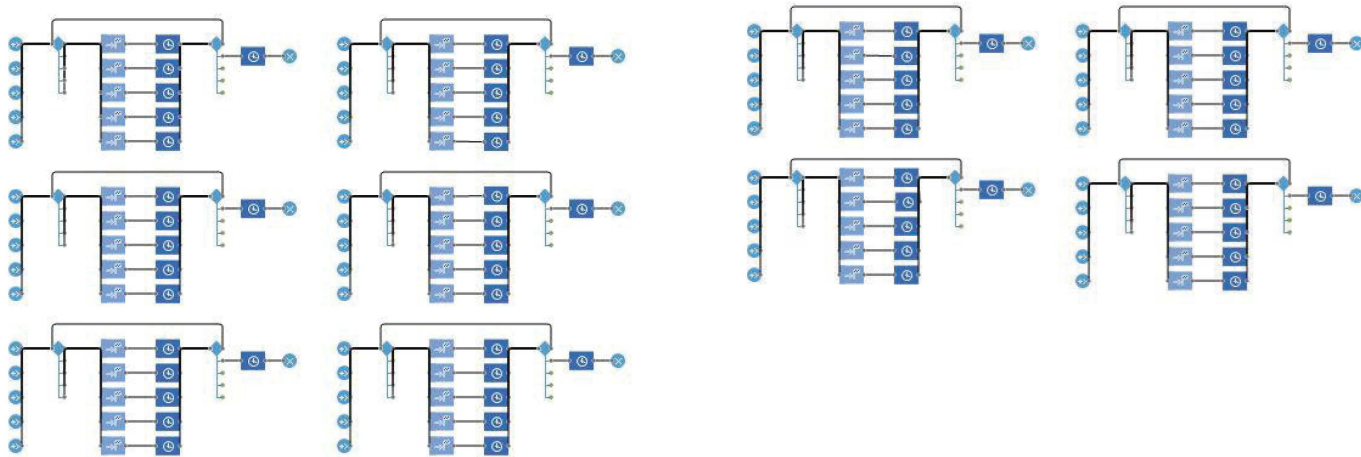
# III. RESULTS - MODEL PERFORMANCE

## Hierarchical Model



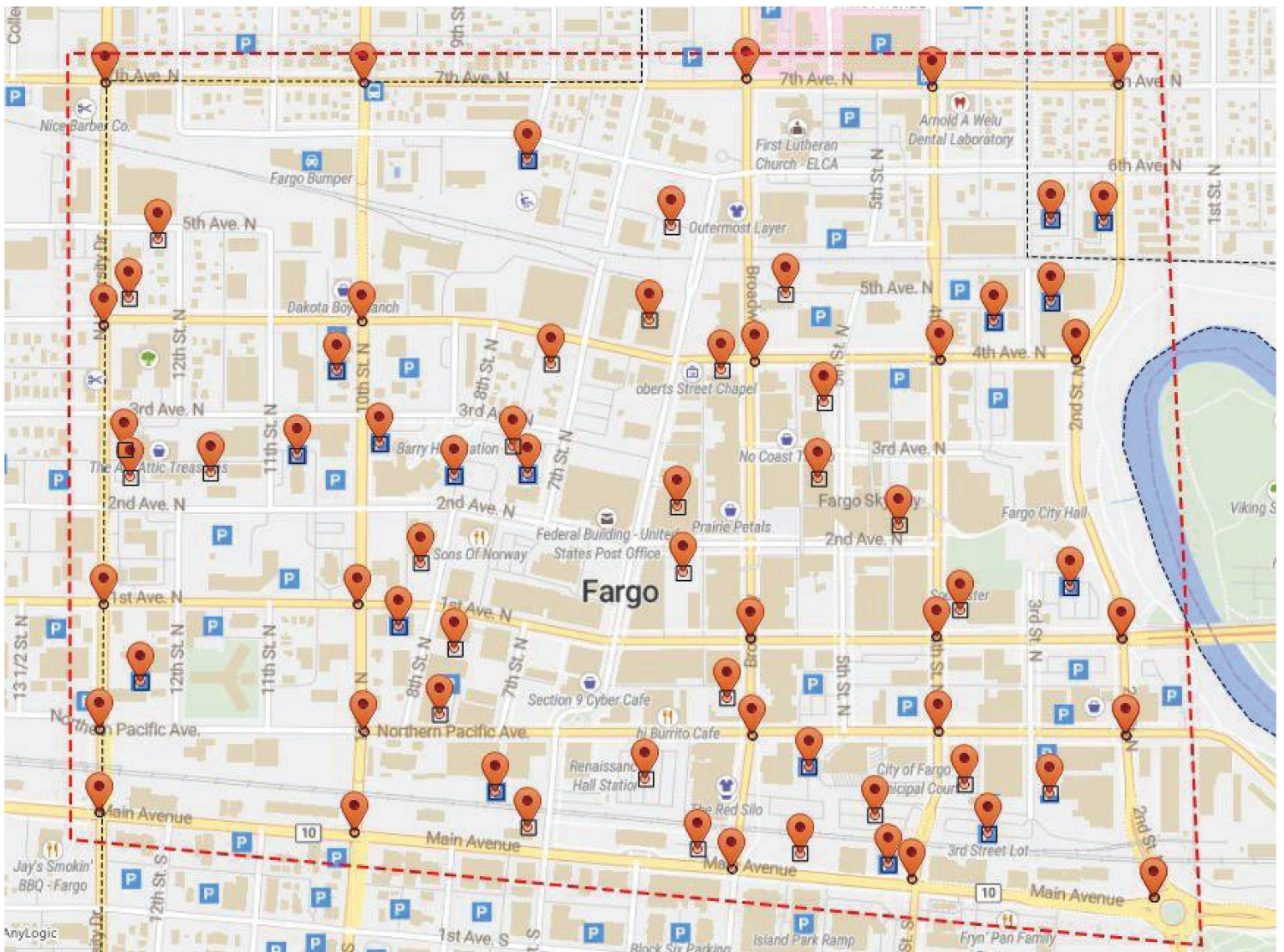
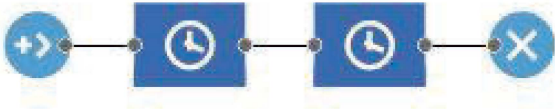
# III. RESULTS - MODEL PERFORMANCE

## Distributed Model



# III. RESULTS - MODEL PERFORMANCE

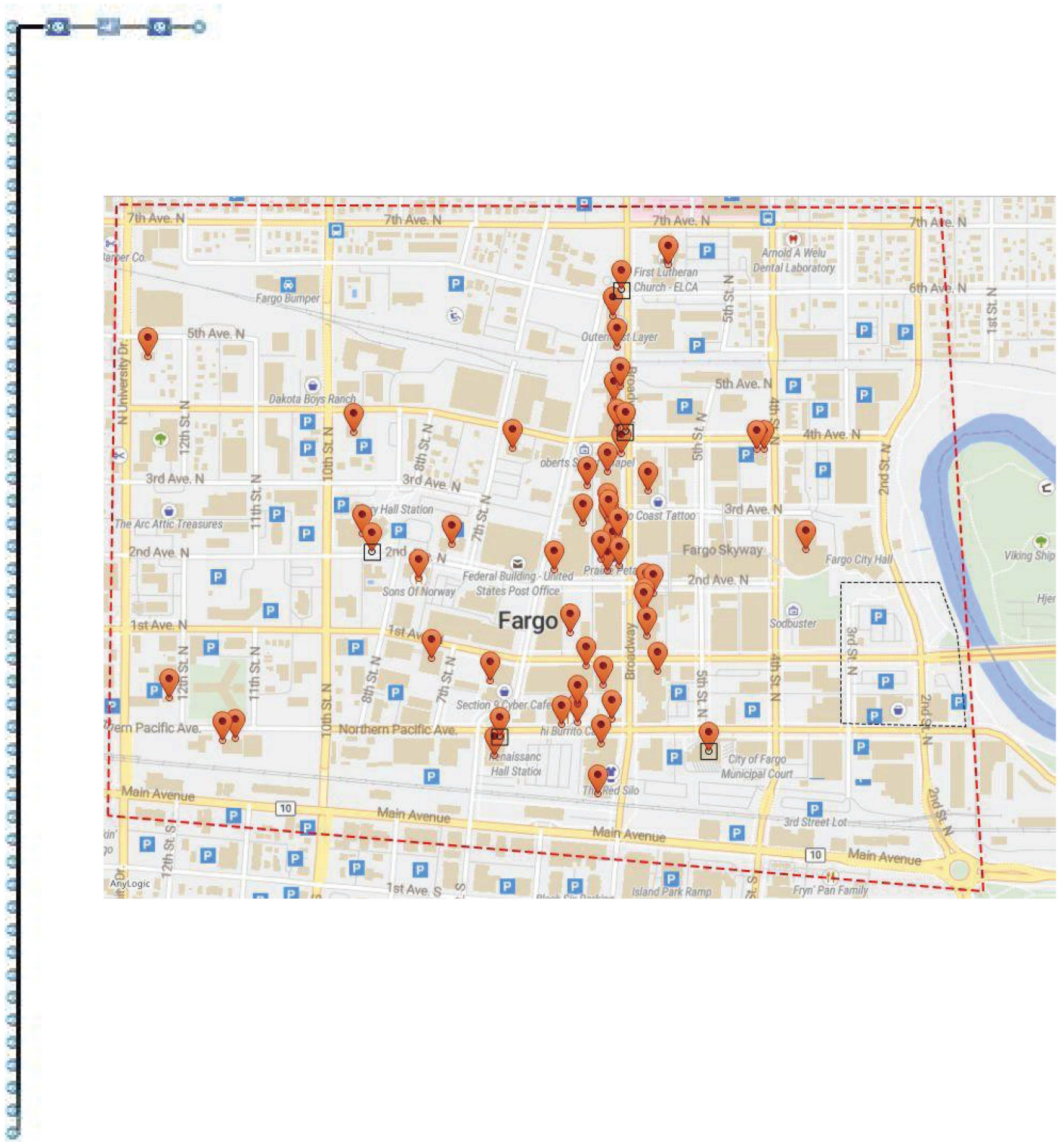
## Intersectional Parking Model





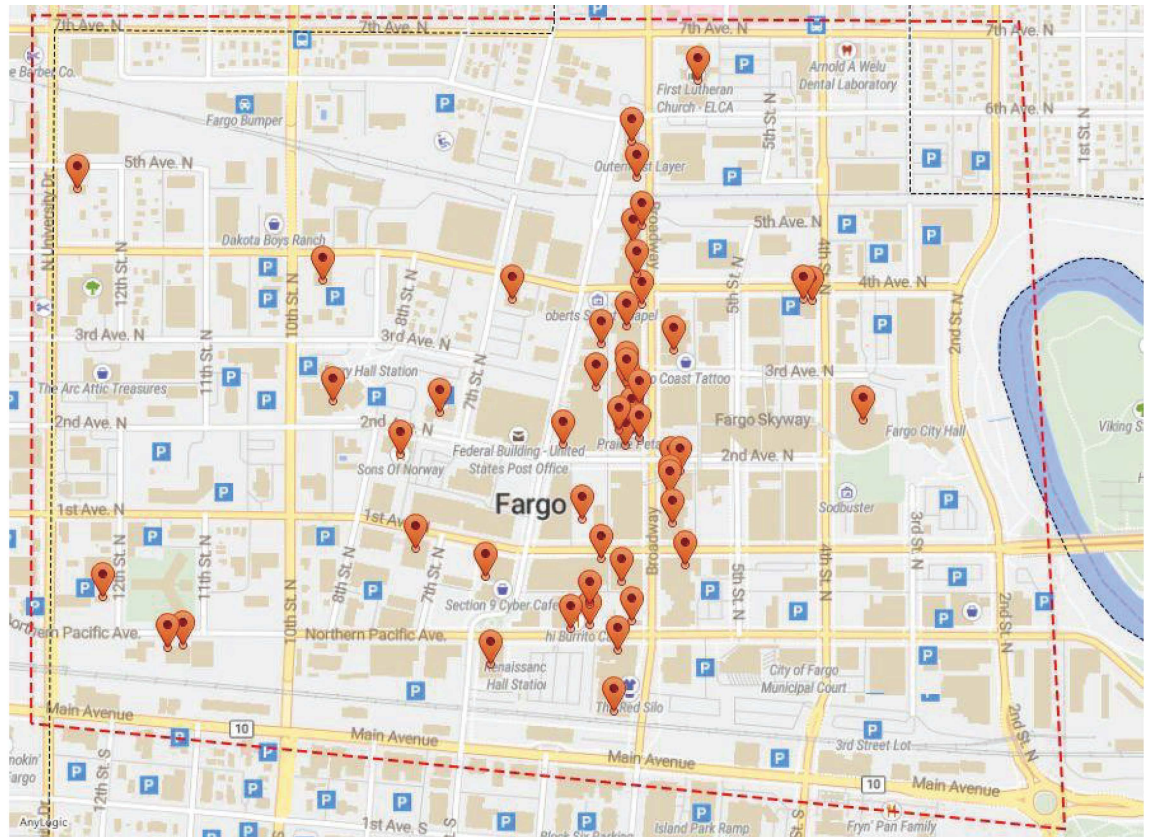
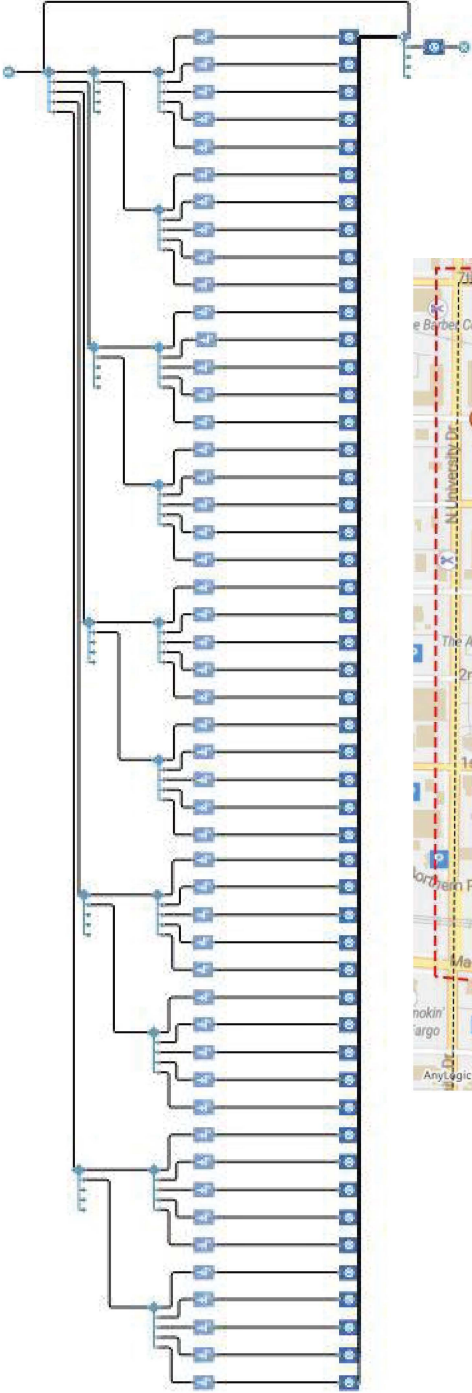
# III. RESULTS - MODEL PERFORMANCE

## Centralized Parking Model



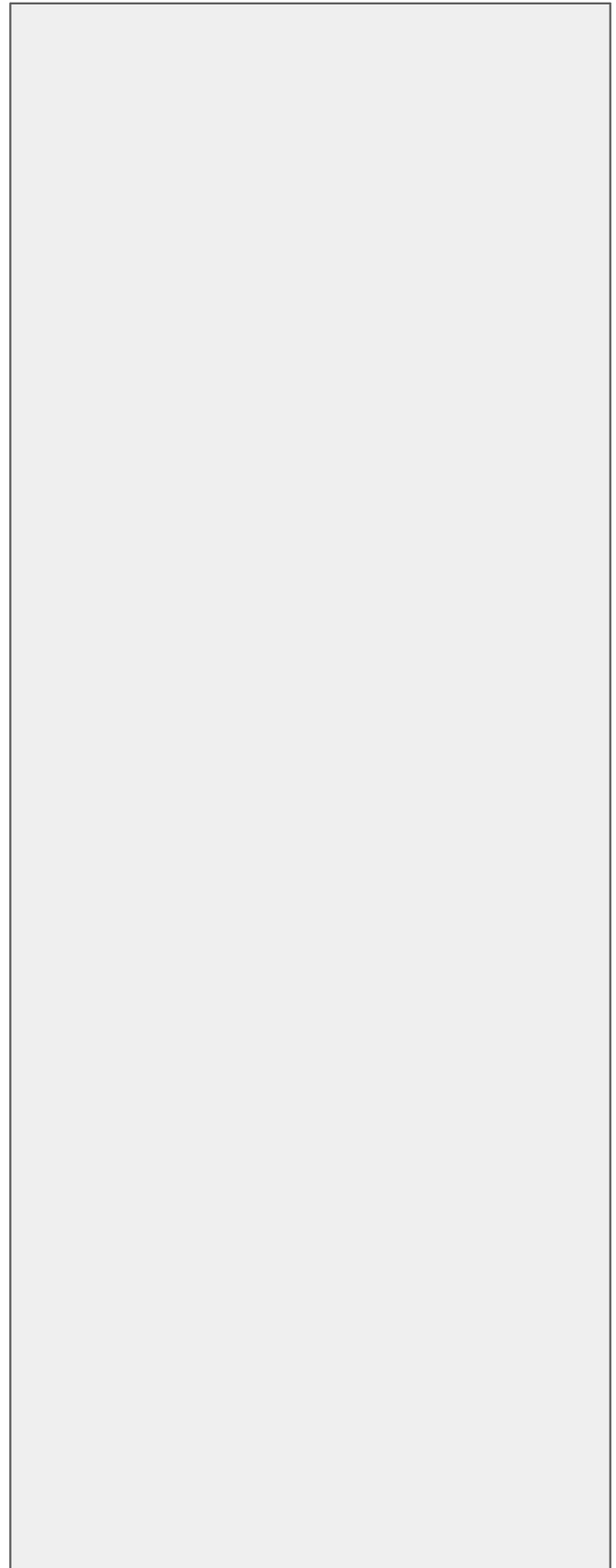
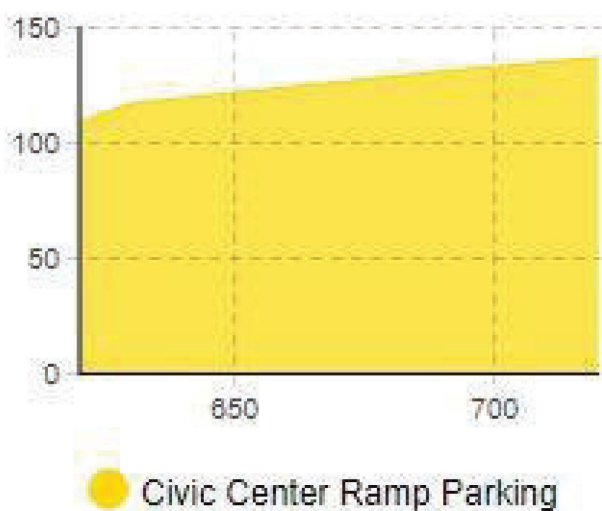
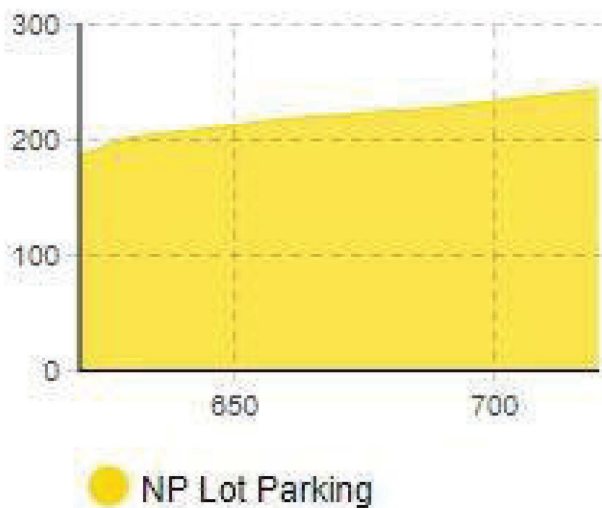
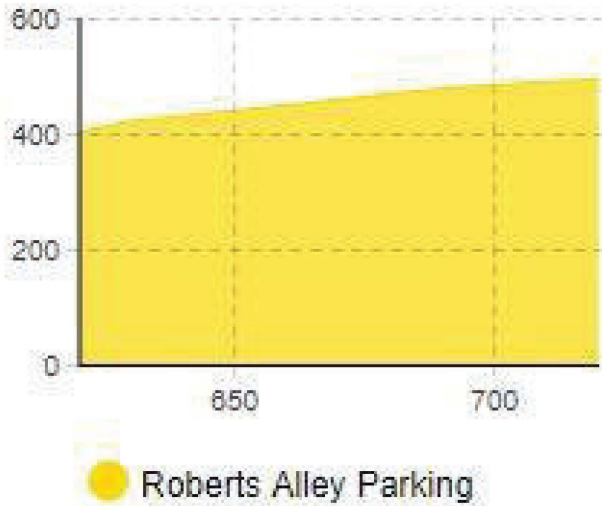
# III. RESULTS - MODEL PERFORMANCE

## Bike Traffic Model



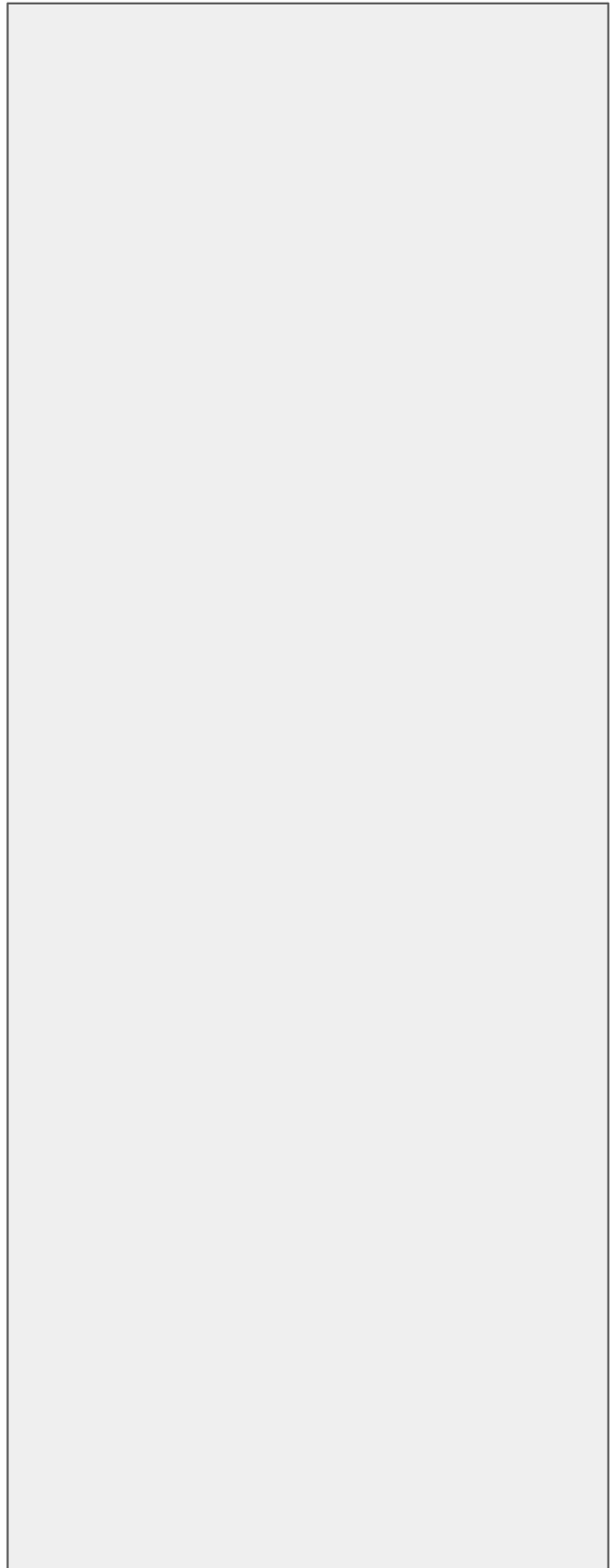
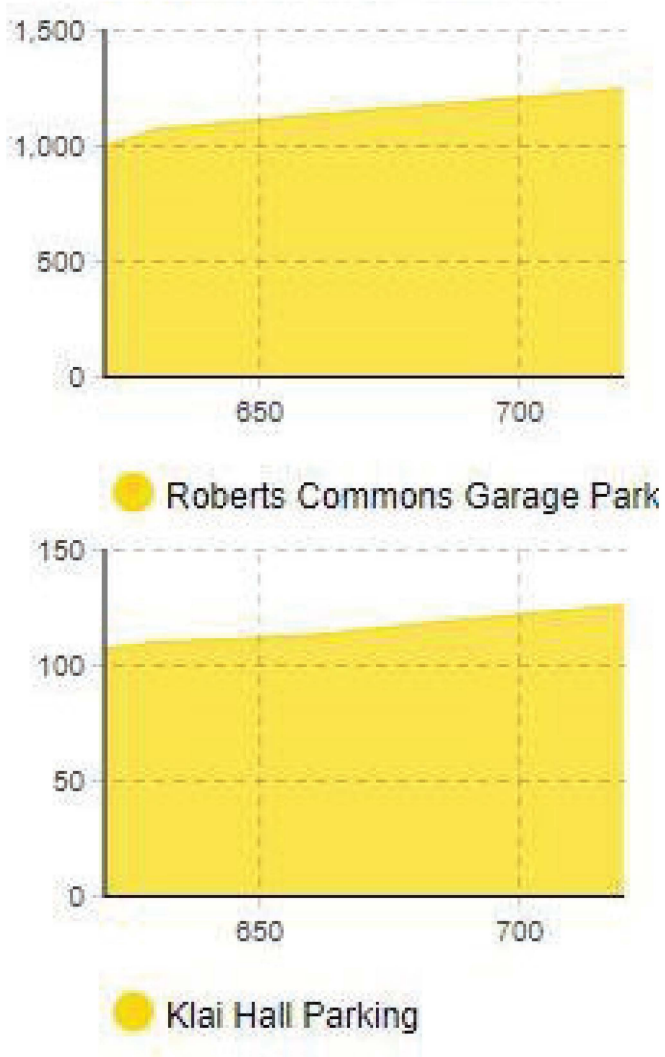
# III. RESULTS - SPATIAL ANALYSIS

## Hierarchical Model



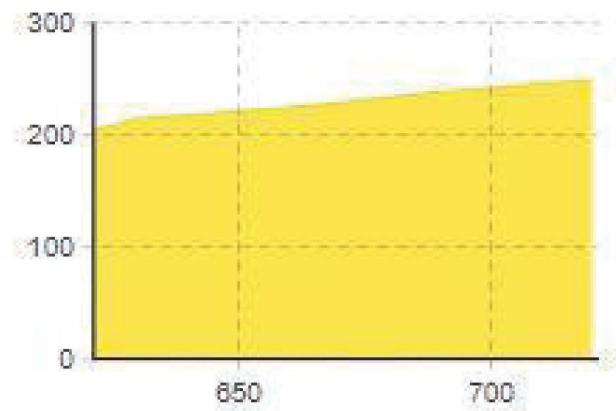
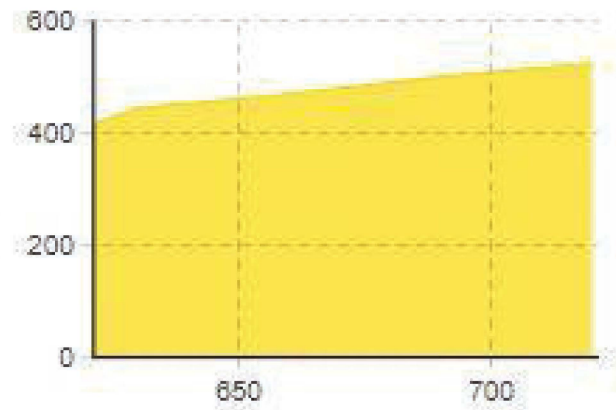
# III. RESULTS - SPATIAL ANALYSIS

## Hierarchical Model

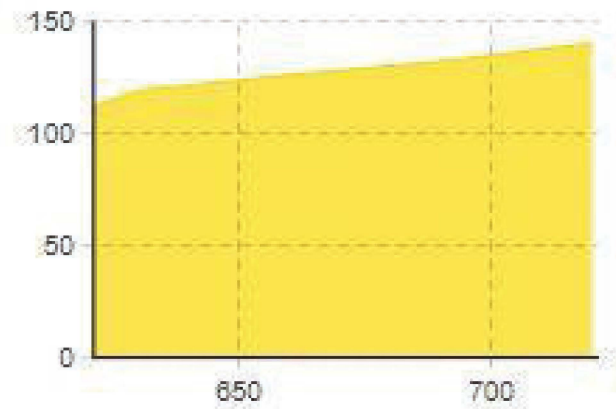


# III. RESULTS - SPATIAL ANALYSIS

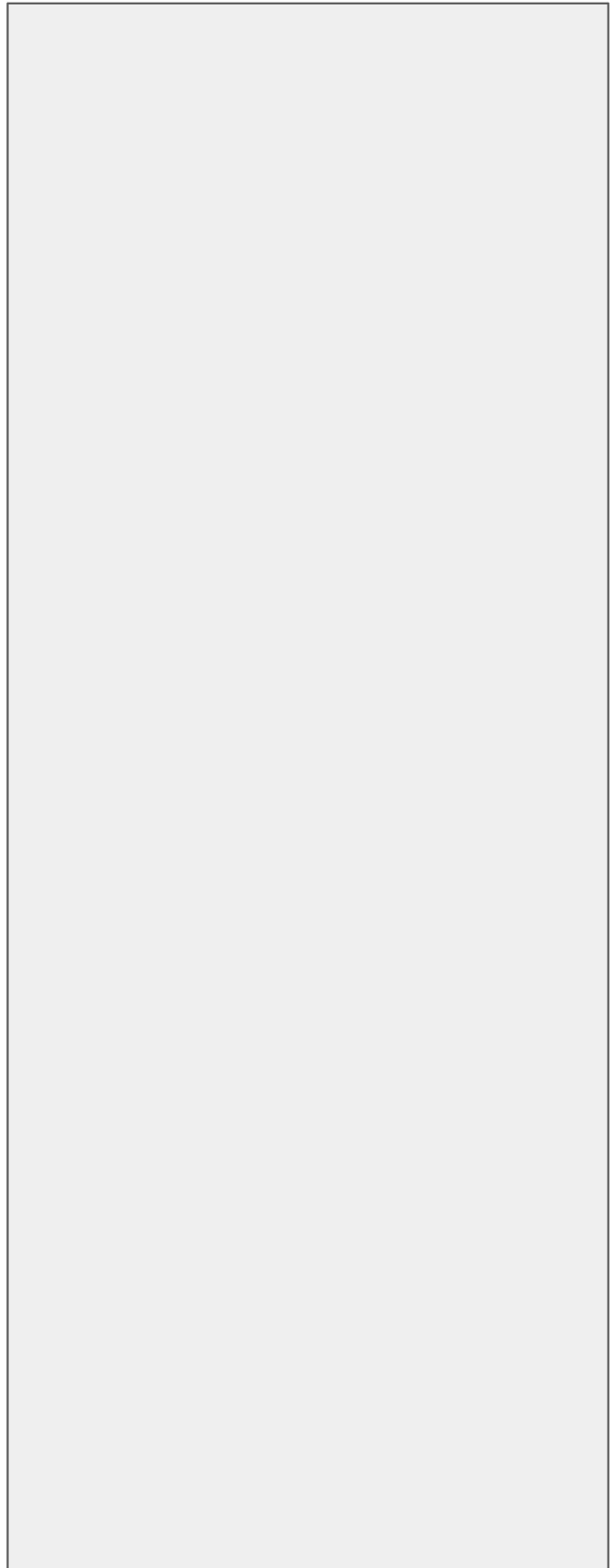
## Distributed Model



● NP Lot Parking

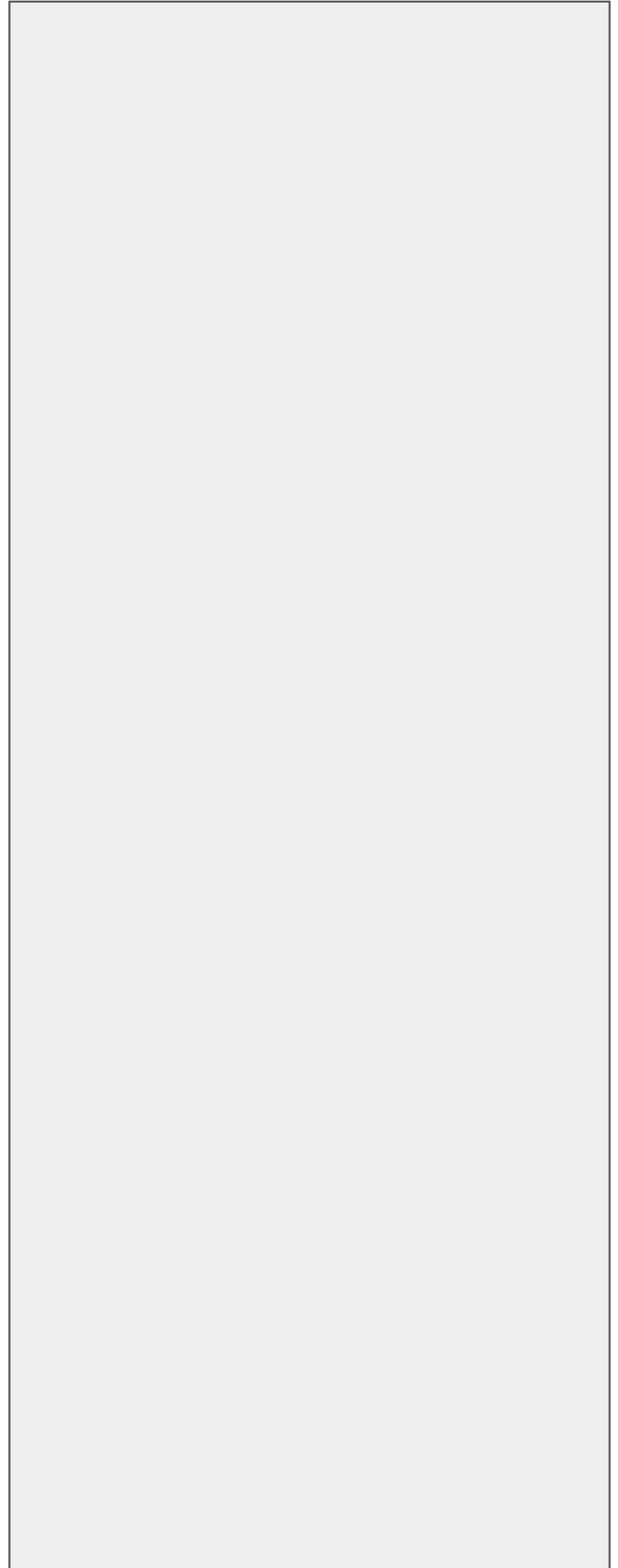
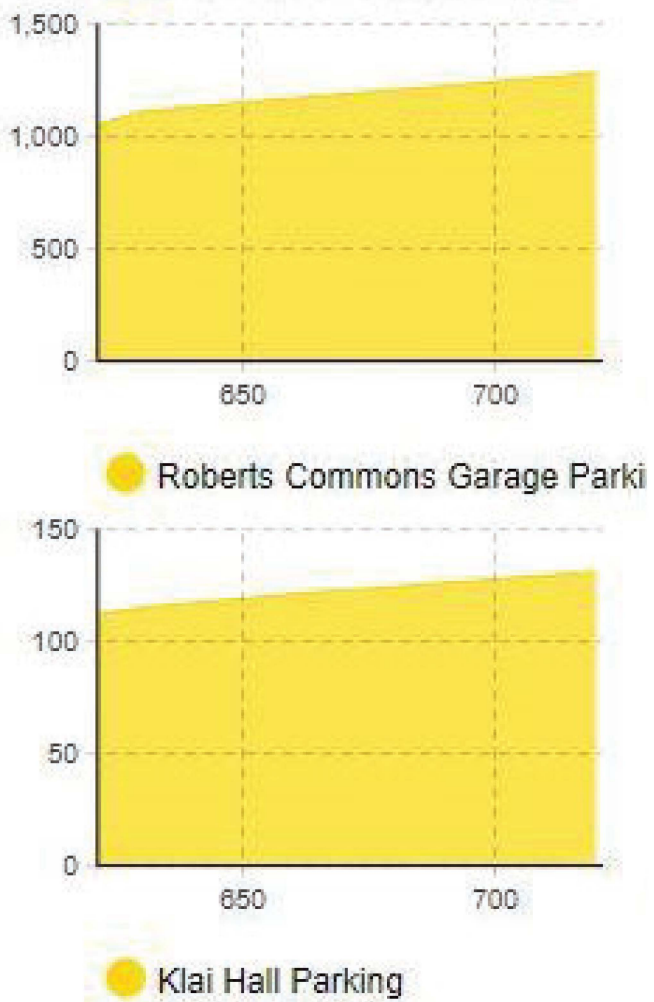


● Civic Center Ramp Parking



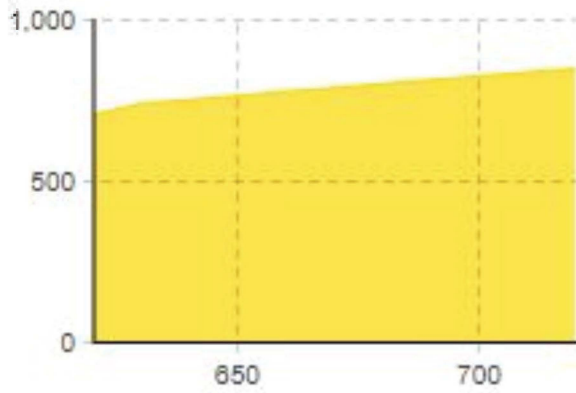
# III. RESULTS - SPATIAL ANALYSIS

## Distributed Model

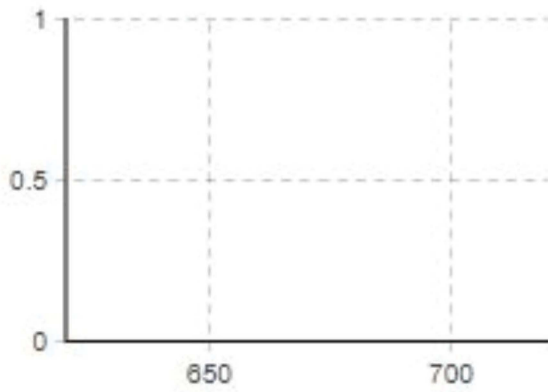


# III. RESULTS - SPATIAL ANALYSIS

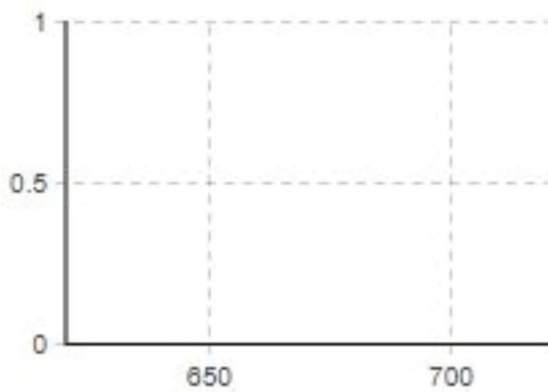
## Intersectional Parking Model



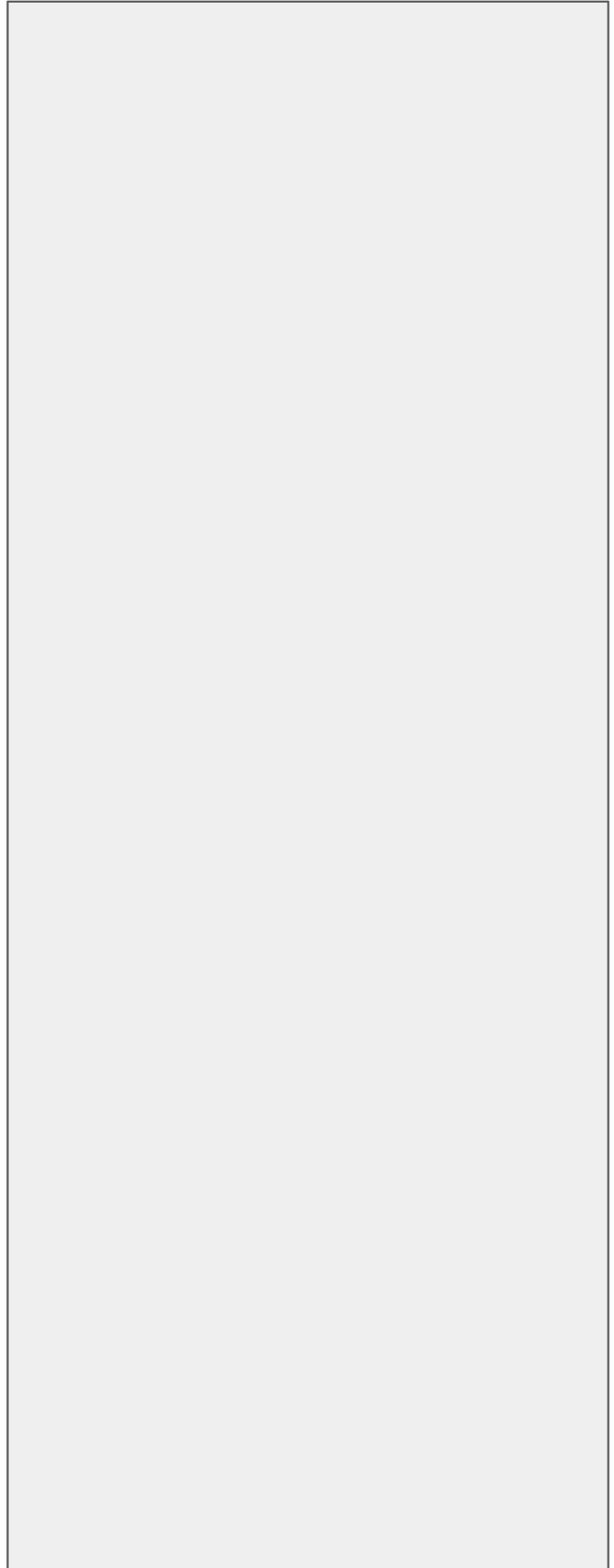
● Roberts Alley Parking



● NP Lot Parking

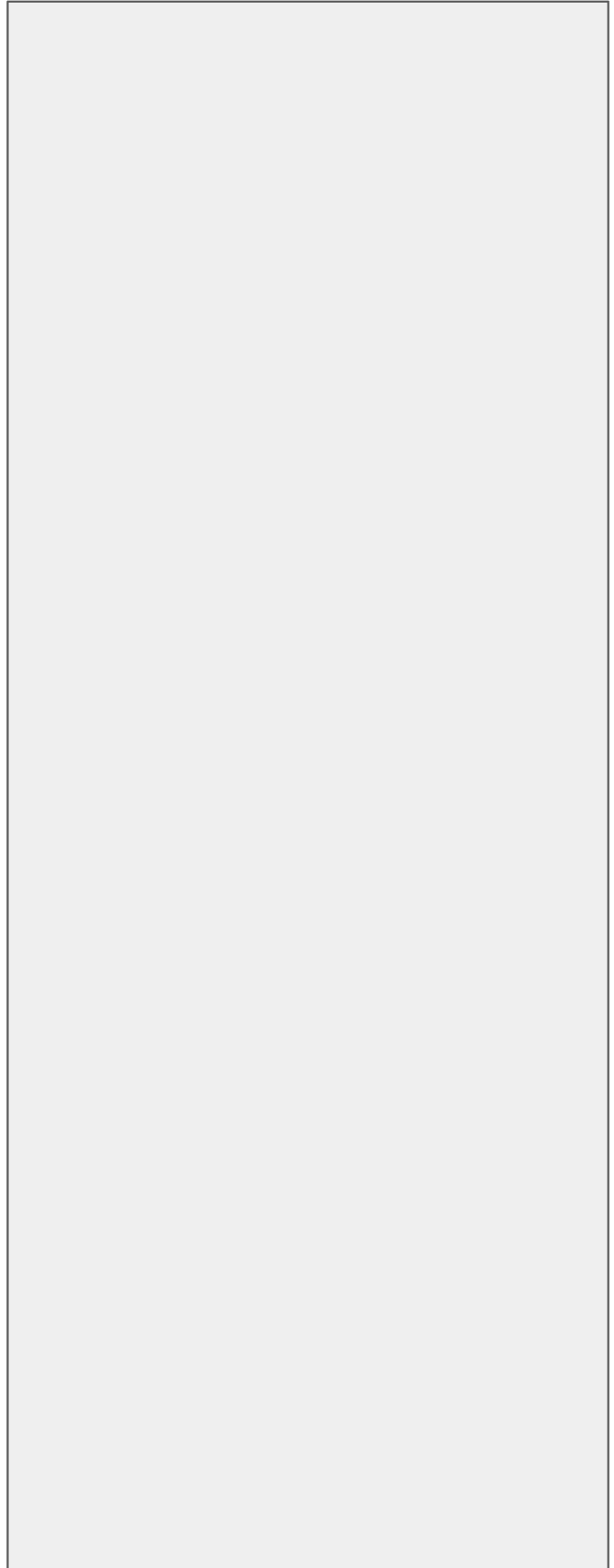
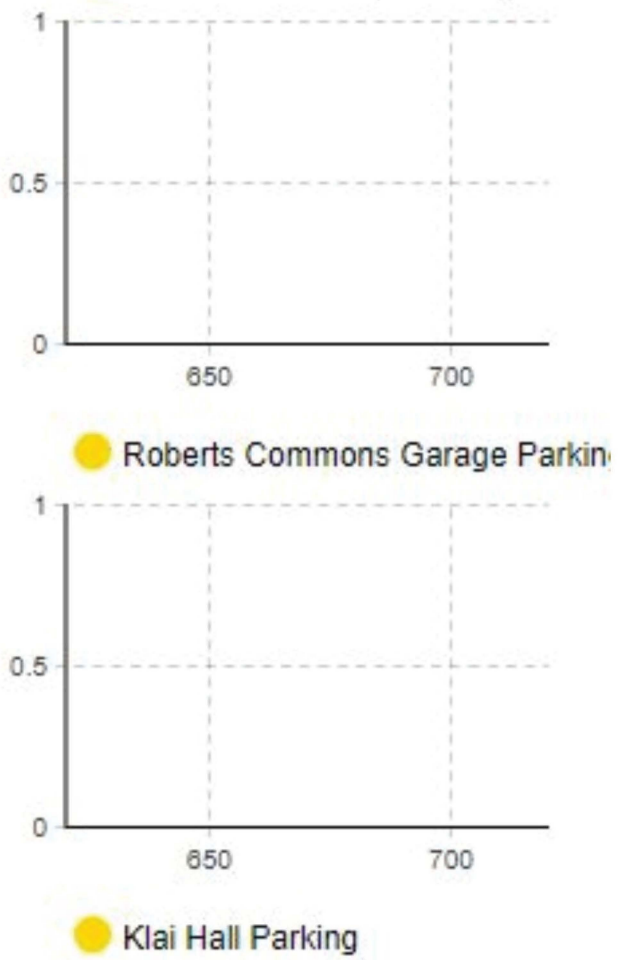


● Civic Center Ramp Parking



# III. RESULTS - SPATIAL ANALYSIS

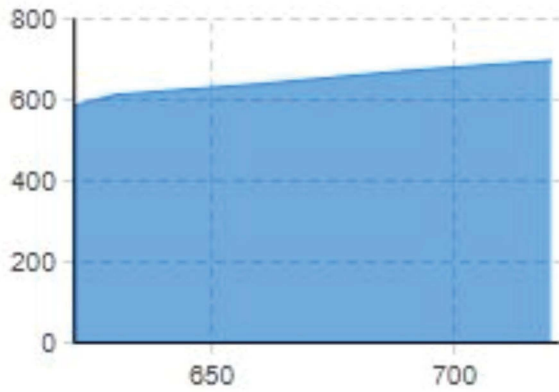
## Intersectional Parking Model



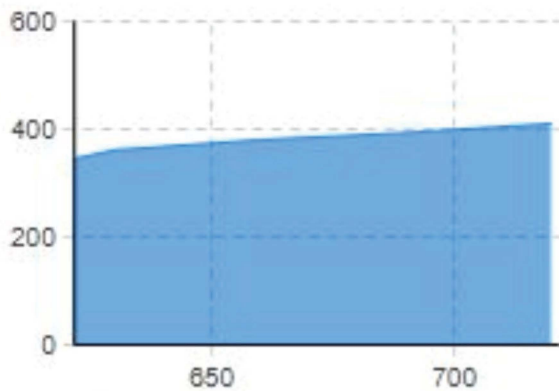


# III. RESULTS - SPATIAL ANALYSIS

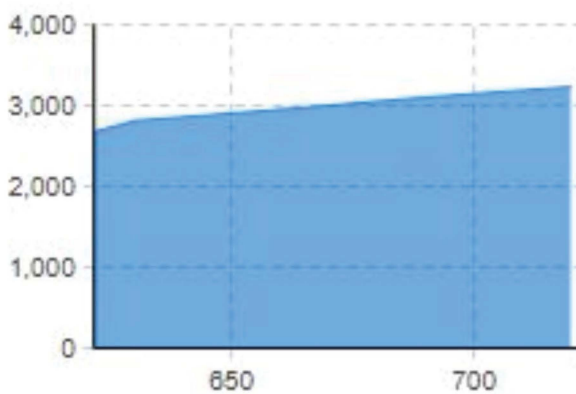
## Centralized Parking Model



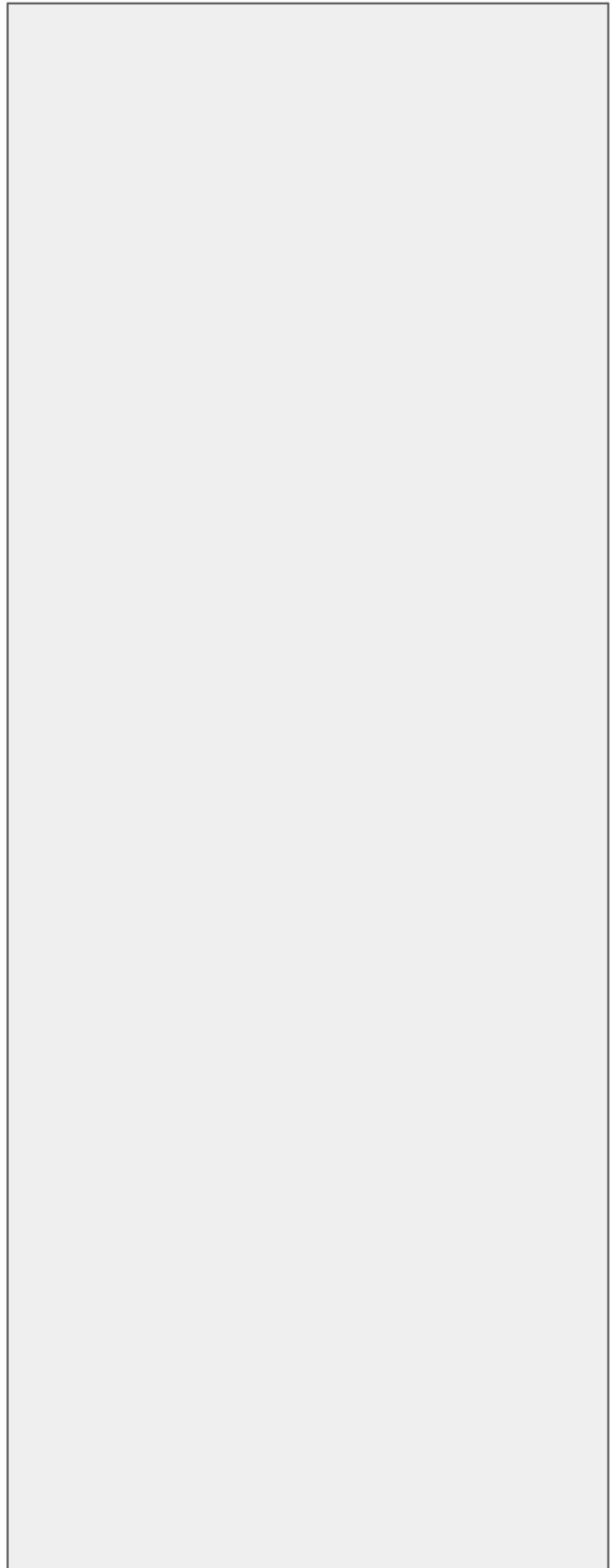
● 4th St N Bus Stop



● 6th Ave N Bus Stop

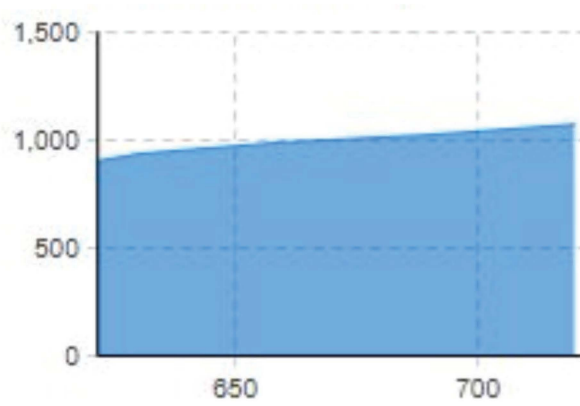


● Broadway Bus Stop

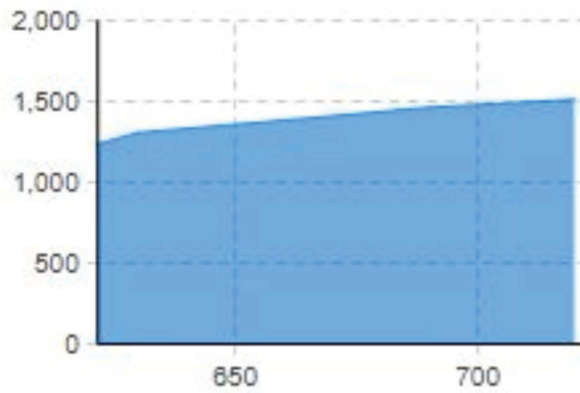


# III. RESULTS - SPATIAL ANALYSIS

## Centralized Parking Model



● 2nd Ave N Bus Stop



● NP Ave Bus Stop



# III. RESULTS - TEMPORAL ANALYSIS

## Hierarchical Model

block_type	block	activity_type	mean (seconds)	total (seconds)	min (seconds)	max (seconds)
MoveTo	destination46NorthPints	MOVE	297.5417721	80931.362	100.687	738.711
MoveTo	destinationBarryHall	MOVE	420.9085148	113645.299	19.138	785.268
MoveTo	destinationBeerAndFishCompany	MOVE	289.120364	78640.739	4.465	707.876
MoveTo	destinationBernBaums	MOVE	318.4108971	77373.848	30.03	825.212
MoveTo	destinationBismarckTavern	MOVE	436.4889793	105630.333	35.763	957.324
MoveTo	destinationBlackBirdWoodFirePizza	MOVE	264.9847107	74195.719	17.512	801
MoveTo	destinationBlackCoffeeAndWaffleBar	MOVE	565.7107647	153873.328	8.716	1161.479
MoveTo	destinationBossPizzaAndChicken	MOVE	309.5659216	94727.172	6.751	719.05
MoveTo	destinationChubsPub	MOVE	796.4397574	216631.614	200.025	1186.227
MoveTo	destinationCowboyJacks	MOVE	379.8855667	102569.103	35.763	921.561
MoveTo	destinationDempseys	MOVE	275.6015285	72483.202	5.21	712.299
MoveTo	destinationDistrict64	MOVE	346.5014167	83160.34	31.118	923.767
MoveTo	destinationDrunkenNoodle	MOVE	346.5342227	88712.761	3.508	857.422
MoveTo	destinationEmpireTavern	MOVE	340.02925	88407.605	1.422	874.166
MoveTo	destinationFargoCivicCenter	MOVE	418.129412	111640.553	199.94	1010.397
MoveTo	destinationFargoTheatre	MOVE	323.5175146	88643.799	17.139	768.1
MoveTo	destinationFirstLutheranChurch	MOVE	608.2205365	141715.385	9.531	1144.5
MoveTo	destinationFortNoks	MOVE	364.4290077	94751.542	13.663	1016.956
MoveTo	destinationHavocHouse	MOVE	295.9765394	75178.041	4.465	712.341
MoveTo	destinationKlaiHall	MOVE	372.168354	101974.129	40.57	682.674
MoveTo	destinationLittleBrother	MOVE	597.5844415	158359.877	0.598	1186.227
MoveTo	destinationMezzaluna	MOVE	297.9132992	75669.978	17.139	750.961
MoveTo	destinationNoBullSmokehouse	MOVE	362.2146846	101057.897	19.815	979.267
MoveTo	destinationOldBroadway	MOVE	379.2595692	98607.488	13.684	1006.214
MoveTo	destinationParadoxEventCenter	MOVE	448.2753077	116551.58	112.201	838.899
MoveTo	destinationPhoDLicious	MOVE	387.1195986	113813.162	19.816	959.451
MoveTo	destinationPixedBrewing	MOVE	637.0976681	145895.366	15.12	1088.997
MoveTo	destinationPlainsArtMuseum	MOVE	368.0887796	90181.751	91.76	772.193
MoveTo	destinationPokeBowl	MOVE	590.9709158	168426.711	8.716	1170.196
MoveTo	destinationPounds	MOVE	434.2408962	112902.633	12.395	1084.935
MoveTo	destinationProofArtisanDistillers	MOVE	288.7442459	70453.596	16.717	766.77
MoveTo	destinationRenaissanceHall	MOVE	416.4233745	104522.267	123.741	888.286
MoveTo	destinationRootersBar	MOVE	292.3111786	73662.417	59.215	885.111
MoveTo	destinationRoughCutSocial	MOVE	611.5793295	161456.943	15.12	1073.877
MoveTo	destinationSanctuaryEventsCenter	MOVE	379.5882069	99072.522	172.452	711.813
MoveTo	destinationSidestreetBarAndGrill	MOVE	396.4210579	102673.054	8.608	964.972
MoveTo	destinationSonsOfNorway	MOVE	385.5069756	94834.716	19.83	723.243
MoveTo	destinationSpicyPie	MOVE	314.5451978	87443.565	30.03	828.389
MoveTo	destinationSportsBar	MOVE	330.4140696	75995.236	31.118	906.355
MoveTo	destinationStoneEventCenter	MOVE	294.6526708	71600.599	38.836	838.576
MoveTo	destinationTacoShop	MOVE	581.8738444	149541.578	12.492	1186.227
MoveTo	destinationTeddysEateryAndParlor	MOVE	290.1278594	72241.837	16.717	783.487
MoveTo	destinationTheBoilerRoom	MOVE	283.4964484	79662.502	38.309	750.651
MoveTo	destinationTheFourAndFour	MOVE	420.4683425	106798.959	8.608	973.581
MoveTo	destinationTheNorthernGentlemansClub	MOVE	490.4702878	132917.448	38.77	863.799
MoveTo	destinationTheToastedFrog	MOVE	289.5797333	73842.832	9.331	787.939
MoveTo	destinationVFW	MOVE	258.8772448	62389.416	15.685	798.051
MoveTo	destinationVinylTaco	MOVE	318.9891227	88359.987	59.215	944.327
MoveTo	destinationWildTerraCider	MOVE	660.7049813	177068.935	78.943	1144.5
MoveTo	destinationWurstBierHall	MOVE	337.6336757	87447.122	38.835	877.41

# III. RESULTS - TEMPORAL ANALYSIS

## Hierarchical Model

n_agents	mean (minutes)	total (minutes)	min (minutes)	max (minutes)
270	0:04:58	22:28:51	0:01:41	0:12:19
267	0:07:01	31:34:05	0:00:19	0:13:05
271	0:04:49	21:50:41	0:00:04	0:11:48
240	0:05:18	21:29:34	0:00:30	0:13:45
236	0:07:16	29:20:30	0:00:36	0:15:57
276	0:04:25	20:36:36	0:00:18	0:13:21
270	0:09:26	42:44:33	0:00:09	0:19:21
303	0:05:10	26:18:47	0:00:07	0:11:59
271	0:13:16	60:10:32	0:03:20	0:19:46
267	0:06:20	28:29:29	0:00:36	0:15:22
261	0:04:36	20:08:03	0:00:05	0:11:52
239	0:05:47	23:06:00	0:00:31	0:15:24
253	0:05:47	24:38:33	0:00:04	0:14:17
260	0:05:40	24:33:28	0:00:01	0:14:34
264	0:06:58	31:00:41	0:03:20	0:16:50
270	0:05:24	24:37:24	0:00:17	0:12:48
232	0:10:08	39:21:55	0:00:10	0:19:05
259	0:06:04	26:19:12	0:00:14	0:16:57
251	0:04:56	20:52:58	0:00:04	0:11:52
269	0:06:12	28:19:34	0:00:41	0:11:23
265	0:09:58	43:59:20	0:00:01	0:19:46
252	0:04:58	21:01:10	0:00:17	0:12:31
277	0:06:02	28:04:18	0:00:20	0:16:19
258	0:06:19	27:23:27	0:00:14	0:16:46
259	0:07:28	32:22:32	0:01:52	0:13:59
291	0:06:27	31:36:53	0:00:20	0:15:59
229	0:10:37	40:31:35	0:00:15	0:18:09
242	0:06:08	25:03:02	0:01:32	0:12:52
284	0:09:51	46:47:07	0:00:09	0:19:30
259	0:07:14	31:21:43	0:00:12	0:18:05
242	0:04:49	19:34:14	0:00:17	0:12:47
250	0:06:56	29:02:02	0:02:04	0:14:48
250	0:04:52	20:27:42	0:00:59	0:14:45
260	0:10:12	44:50:57	0:00:15	0:17:54
256	0:06:20	27:31:13	0:02:52	0:11:52
256	0:06:36	28:31:13	0:00:09	0:16:05
246	0:06:26	26:20:35	0:00:20	0:12:03
275	0:05:15	24:17:24	0:00:30	0:13:48
229	0:05:30	21:06:35	0:00:31	0:15:06
241	0:04:55	19:53:21	0:00:39	0:13:59
256	0:09:42	41:32:22	0:00:12	0:19:46
247	0:04:50	20:04:02	0:00:17	0:13:03
279	0:04:43	22:07:43	0:00:38	0:12:31
251	0:07:00	29:39:59	0:00:09	0:16:14
268	0:08:10	36:55:17	0:00:39	0:14:24
252	0:04:50	20:30:43	0:00:09	0:13:08
239	0:04:19	17:19:49	0:00:16	0:13:18
275	0:05:19	24:32:40	0:00:59	0:15:44
266	0:11:01	49:11:09	0:01:19	0:19:05
254	0:05:38	24:17:27	0:00:39	0:14:37

# III. RESULTS - TEMPORAL ANALYSIS

## Distributed Model

block_type	block	activity_type	mean (seconds)	total (seconds)	min (seconds)	max (seconds)
MoveTo	destination46NorthPints	MOVE	131.5287336	30120.08	100.687	165.552
MoveTo	destinationBarryHall	MOVE	167.7798768	35401.554	102.594	276.938
MoveTo	destinationBeerAndFishCompany	MOVE	49.50198333	11880.476	4.465	171.758
MoveTo	destinationBernBaums	MOVE	75.30973636	16568.142	30.03	110.041
MoveTo	destinationBismarckTavern	MOVE	109.9269327	22864.802	35.763	221.943
MoveTo	destinationBlackBirdWoodFirePizza	MOVE	80.29126471	16379.418	17.512	148.04
MoveTo	destinationBlackCoffeeAndWaffleBar	MOVE	226.1117214	45448.456	8.716	359.631
MoveTo	destinationBossPizzaAndChicken	MOVE	52.58664352	11358.715	6.751	183.719
MoveTo	destinationChubsPub	MOVE	520.0352098	116487.887	322.428	607.376
MoveTo	destinationCowboyJacks	MOVE	93.7794901	18943.457	35.763	257.706
MoveTo	destinationDempseys	MOVE	46.93623853	10232.1	5.209	176.968
MoveTo	destinationDistrict64	MOVE	90.93590871	21915.554	31.118	134.567
MoveTo	destinationDrunkenNoodle	MOVE	116.8180221	26400.873	16.743	321.845
MoveTo	destinationEmpireTavern	MOVE	120.999379	26498.864	16.743	305.101
MoveTo	destinationFargoCivicCenter	MOVE	207.0845799	45351.523	199.94	215.54
MoveTo	destinationFargoTheatre	MOVE	83.79044976	17512.204	17.139	141.798
MoveTo	destinationFirstLutheranChurch	MOVE	276.3427281	59966.372	221.942	321.845
MoveTo	destinationFortNoks	MOVE	96.32476623	22251.021	40.631	137.431
MoveTo	destinationHavocHouse	MOVE	47.69737383	10207.238	4.465	167.293
MoveTo	destinationKlaiHall	MOVE	113.4612511	26663.394	40.57	174.344
MoveTo	destinationLittleBrother	MOVE	525.4494578	87224.61	484.605	562.041
MoveTo	destinationMezzaluna	MOVE	97.98695455	21557.13	17.139	158.937
MoveTo	destinationNoBullSmokehouse	MOVE	125.079657	30269.277	40.631	178.063
MoveTo	destinationOldBroadway	MOVE	151.549608	30158.372	46.762	289.891
MoveTo	destinationParadoxEventCenter	MOVE	272.1477917	52252.376	171.962	397.843
MoveTo	destinationPhoDLicious	MOVE	141.3803211	26862.261	46.762	243.129
MoveTo	destinationPixedBrewing	MOVE	298.7729686	66626.372	15.12	598.95
MoveTo	destinationPlainsArtMuseum	MOVE	171.5644974	33455.077	91.759	306.673
MoveTo	destinationPokeBowl	MOVE	246.1937903	61056.06	8.716	368.348
MoveTo	destinationPounds	MOVE	218.3096221	47373.188	107.953	397.843
MoveTo	destinationProofArtisanDistillers	MOVE	174.9816283	39545.848	167.292	183.719
MoveTo	destinationRenaissanceHall	MOVE	173.2403143	36380.466	126.629	240.618
MoveTo	destinationRootersBar	MOVE	285.3479028	61635.147	78.761	484.606
MoveTo	destinationRoughCutSocial	MOVE	278.2902454	60110.693	15.12	607.376
MoveTo	destinationSanctuaryEventsCenter	MOVE	238.4113767	51258.446	174.343	306.673
MoveTo	destinationSidestreetBarAndGrill	MOVE	243.7979778	54854.545	8.608	368.348
MoveTo	destinationSonsOfNorway	MOVE	108.1000846	21728.117	40.57	214.913
MoveTo	destinationSpicyPie	MOVE	70.97478505	15188.604	30.03	113.219
MoveTo	destinationSportsBar	MOVE	115.2405556	26966.29	31.118	165.685
MoveTo	destinationStoneEventCenter	MOVE	287.0056887	60845.206	38.835	524.667
MoveTo	destinationTacoShop	MOVE	522.1213846	74663.358	484.605	562.041
MoveTo	destinationTeddysEateryAndParlor	MOVE	88.69741558	20489.103	17.512	165.552
MoveTo	destinationTheBoilerRoom	MOVE	90.95609048	19100.779	47.4	112.266
MoveTo	destinationTheFourAndFour	MOVE	230.9032747	53800.463	8.608	359.739
MoveTo	destinationTheNorthernGentlemansClub	MOVE	477.6596364	105085.12	322.428	537.389
MoveTo	destinationTheToastedFrog	MOVE	108.6904554	24346.662	45.717	158.937
MoveTo	destinationVFW	MOVE	65.31787665	14827.158	47.352	100.688
MoveTo	destinationVinylTaco	MOVE	138.6062949	30077.566	104.558	178.063
MoveTo	destinationWildTerraCider	MOVE	344.3388263	73344.17	78.943	537.389
MoveTo	destinationWurstBierHall	MOVE	307.4290087	71016.101	38.835	562.041

# III. RESULTS - TEMPORAL ANALYSIS

## Distributed Model

n_agents	mean (minutes)	total (minutes)	min (minutes)	max (minutes)
210	0:02:12	8:22:00	0:01:41	0:02:46
203	0:02:48	9:50:02	0:01:43	0:04:37
219	0:00:50	3:18:00	0:00:04	0:02:52
215	0:01:15	4:36:08	0:00:30	0:01:50
193	0:01:50	6:21:05	0:00:36	0:03:42
192	0:01:20	4:32:59	0:00:18	0:02:28
192	0:03:46	12:37:28	0:00:09	0:06:00
204	0:00:53	3:09:19	0:00:07	0:03:04
209	0:08:40	32:21:28	0:05:22	0:10:07
187	0:01:34	5:15:43	0:00:36	0:04:18
209	0:00:47	2:50:32	0:00:05	0:02:57
220	0:01:31	6:05:16	0:00:31	0:02:15
214	0:01:57	7:20:01	0:00:17	0:05:22
203	0:02:01	7:21:39	0:00:17	0:05:05
206	0:03:27	12:35:52	0:03:20	0:03:36
198	0:01:24	4:51:52	0:00:17	0:02:22
200	0:04:36	16:39:26	0:03:42	0:05:22
215	0:01:36	6:10:51	0:00:41	0:02:17
196	0:00:48	2:50:07	0:00:04	0:02:47
221	0:01:53	7:24:23	0:00:41	0:02:54
160	0:08:45	24:13:45	0:08:05	0:09:22
211	0:01:38	5:59:17	0:00:17	0:02:39
225	0:02:05	8:24:29	0:00:41	0:02:58
188	0:02:32	8:22:38	0:00:47	0:04:50
184	0:04:32	14:30:52	0:02:52	0:06:38
180	0:02:21	7:27:42	0:00:47	0:04:03
210	0:04:59	18:30:26	0:00:15	0:09:59
187	0:02:52	9:17:35	0:01:32	0:05:07
229	0:04:06	16:57:36	0:00:09	0:06:08
205	0:03:38	13:09:33	0:01:48	0:06:38
212	0:02:55	10:59:06	0:02:47	0:03:04
197	0:02:53	10:06:20	0:02:07	0:04:01
194	0:04:45	17:07:15	0:01:19	0:08:05
205	0:04:38	16:41:51	0:00:15	0:10:07
200	0:03:58	14:14:18	0:02:54	0:05:07
209	0:04:04	15:14:15	0:00:09	0:06:08
188	0:01:48	6:02:08	0:00:41	0:03:35
202	0:01:11	4:13:09	0:00:30	0:01:53
215	0:01:55	7:29:26	0:00:31	0:02:46
197	0:04:47	16:54:05	0:00:39	0:08:45
134	0:08:42	20:44:23	0:08:05	0:09:22
210	0:01:29	5:41:29	0:00:18	0:02:46
193	0:01:31	5:18:21	0:00:47	0:01:52
214	0:03:51	14:56:40	0:00:09	0:06:00
210	0:07:58	29:11:25	0:05:22	0:08:57
208	0:01:49	6:45:47	0:00:46	0:02:39
210	0:01:05	4:07:07	0:00:47	0:01:41
201	0:02:19	8:21:18	0:01:45	0:02:58
205	0:05:44	20:22:24	0:01:19	0:08:57
218	0:05:07	19:43:36	0:00:39	0:09:22

# III. RESULTS - TEMPORAL ANALYSIS

## Bike Traffic Model

block_type	block	activity_type	mean (seconds)	total (seconds)	min (seconds)	max (seconds)
MoveTo	destination46NorthPints	MOVE	93.9243	939.243	25.172	231.179
MoveTo	destinationBarryHall	MOVE	149.096	1490.96	70.303	313.309
MoveTo	destinationBeerAndFishCompany	MOVE	103.5818889	932.237	46.531	193.326
MoveTo	destinationBernBaums	MOVE	68.91875	275.675	12.239	94.77
MoveTo	destinationBismarckTavern	MOVE	99.7534	997.534	8.941	289.812
MoveTo	destinationBlackBirdWoodFirePizza	MOVE	137.873	413.619	110.731	162.035
MoveTo	destinationBlackCoffeeAndWaffleBar	MOVE	192.5755	1540.604	113.237	281.26
MoveTo	destinationBossPizzaAndChicken	MOVE	77.82433333	466.946	7.978	124.346
MoveTo	destinationChubsPub	MOVE	232.0741429	1624.519	130.483	338.193
MoveTo	destinationCowboyJacks	MOVE	78.1357	781.357	8.941	195.492
MoveTo	destinationDempseys	MOVE	127.5396	637.698	40.062	221.985
MoveTo	destinationDistrict64	MOVE	114.565	343.695	98.791	122.452
MoveTo	destinationDrunkenNoodle	MOVE	96.91466667	581.488	24.975	176.802
MoveTo	destinationEmpireTavern	MOVE	135.8625556	1222.763	47.727	260.139
MoveTo	destinationFargoCivicCenter	MOVE	158.334	791.67	75.466	233.3
MoveTo	destinationFargoTheatre	MOVE	107.7135833	1292.563	24.02	314.14
MoveTo	destinationFirstLutheranChurch	MOVE	95.83742857	670.862	13.001	247.378
MoveTo	destinationFortNoks	MOVE	163.15325	652.613	94.77	255.499
MoveTo	destinationHavocHouse	MOVE	116.5005	699.003	80.069	154.212
MoveTo	destinationKlaiHall	MOVE	118.1248333	708.749	10.142	210.829
MoveTo	destinationLittleBrother	MOVE	193.6495	1161.897	119.424	297.183
MoveTo	destinationMezzaluna	MOVE	136.0145	816.087	4.284	231.651
MoveTo	destinationNoBullSmokehouse	MOVE	123.813	495.252	18.103	246.405
MoveTo	destinationOldBroadway	MOVE	129.7666	648.833	80.069	160.282
MoveTo	destinationParadoxEventCenter	MOVE	153.81075	1230.486	61.133	263.678
MoveTo	destinationPhoDLicious	MOVE	93.02716667	558.163	31.658	162.706
MoveTo	destinationPxeledBrewing	MOVE	151.01825	604.073	82.372	219.129
MoveTo	destinationPlainsArtMuseum	MOVE	189.6235	379.247	148.166	231.081
MoveTo	destinationPokeBowl	MOVE	206.7261667	1240.357	127.159	272.514
MoveTo	destinationPounds	MOVE	115.1851667	691.111	89.784	166.973
MoveTo	destinationProofArtisanDistillers	MOVE	116.6883333	1050.195	40.277	251.284
MoveTo	destinationRenaissanceHall	MOVE	162.0322222	1458.29	70.359	251.816
MoveTo	destinationRootersBar	MOVE	151.6463333	1364.817	57.412	254.085
MoveTo	destinationRoughCutSocial	MOVE	124.989	374.967	39.574	253.327
MoveTo	destinationSanctuaryEventsCenter	MOVE	142.3746667	427.124	120.087	170.679
MoveTo	destinationSidestreetBarAndGrill	MOVE	115.122	460.488	11.83	177.142
MoveTo	destinationSonsOfNorway	MOVE	160.33475	1282.678	75.584	286.773
MoveTo	destinationSpicyPie	MOVE	102.9084	1029.084	40.536	299.623
MoveTo	destinationSportsBar	MOVE	107.4441111	966.997	55.34	172.057
MoveTo	destinationStoneEventCenter	MOVE	116.822625	934.581	23.751	270.913
MoveTo	destinationTacoShop	MOVE	225.2961667	1351.777	169.107	291.463
MoveTo	destinationTeddysEateryAndParlor	MOVE	104.0712	520.356	25.406	193.727
MoveTo	destinationTheBoilerRoom	MOVE	88.7785	177.557	79.319	98.238
MoveTo	destinationTheFourAndFour	MOVE	167.6106	838.053	81.584	266.34
MoveTo	destinationTheNorthernGentlemansClub	MOVE	150.9948333	905.969	49.961	298.849
MoveTo	destinationTheToastedFrog	MOVE	117.87575	471.503	51.966	198.613
MoveTo	destinationVFW	MOVE	59.41233333	178.237	25.171	107.953
MoveTo	destinationVinylTaco	MOVE	107.5174286	752.622	37.779	177.382
MoveTo	destinationWildTerraCider	MOVE	216.9794444	1952.815	121.294	293.977
MoveTo	destinationWurstBierHall	MOVE	124.4113333	373.234	41.268	221.972

# III. RESULTS - TEMPORAL ANALYSIS

## Bike Traffic Model

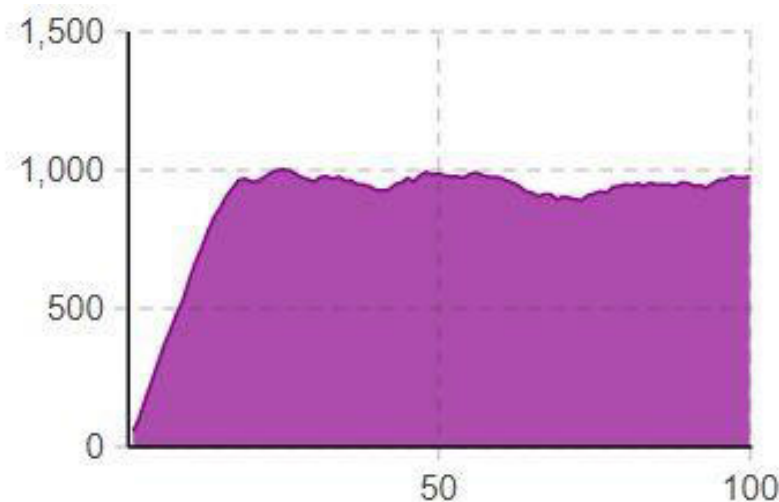
n_agents	mean (minutes)	total (minutes)	min (minutes)	max (minutes)
9	0:01:34	0:15:39	0:00:25	0:03:51
10	0:02:29	0:24:51	0:01:10	0:05:13
9	0:01:44	0:15:32	0:00:47	0:03:13
4	0:01:09	0:04:36	0:00:12	0:01:35
10	0:01:40	0:16:38	0:00:09	0:04:50
3	0:02:18	0:06:54	0:01:51	0:02:42
8	0:03:13	0:25:41	0:01:53	0:04:41
6	0:01:18	0:07:47	0:00:08	0:02:04
7	0:03:52	0:27:05	0:02:10	0:05:38
10	0:01:18	0:13:01	0:00:09	0:03:15
5	0:02:08	0:10:38	0:00:40	0:03:42
3	0:01:55	0:05:44	0:01:39	0:02:02
6	0:01:37	0:09:41	0:00:25	0:02:57
9	0:02:16	0:20:23	0:00:48	0:04:20
5	0:02:38	0:13:12	0:01:15	0:03:53
11	0:01:48	0:21:33	0:00:24	0:05:14
7	0:01:36	0:11:11	0:00:13	0:04:07
4	0:02:43	0:10:53	0:01:35	0:04:15
6	0:01:57	0:11:39	0:01:20	0:02:34
6	0:01:58	0:11:49	0:00:10	0:03:31
6	0:03:14	0:19:22	0:01:59	0:04:57
6	0:02:16	0:13:36	0:00:04	0:03:52
4	0:02:04	0:08:15	0:00:18	0:04:06
5	0:02:10	0:10:49	0:01:20	0:02:40
8	0:02:34	0:20:30	0:01:01	0:04:24
6	0:01:33	0:09:18	0:00:32	0:02:43
4	0:02:31	0:10:04	0:01:22	0:03:39
2	0:03:10	0:06:19	0:02:28	0:03:51
6	0:03:27	0:20:40	0:02:07	0:04:33
6	0:01:55	0:11:31	0:01:30	0:02:47
8	0:01:57	0:17:30	0:00:40	0:04:11
9	0:02:42	0:24:18	0:01:10	0:04:12
9	0:02:32	0:22:45	0:00:57	0:04:14
3	0:02:05	0:06:15	0:00:40	0:04:13
3	0:02:22	0:07:07	0:02:00	0:02:51
4	0:01:55	0:07:40	0:00:12	0:02:57
8	0:02:40	0:21:23	0:01:16	0:04:47
10	0:01:43	0:17:09	0:00:41	0:05:00
9	0:01:47	0:16:07	0:00:55	0:02:52
8	0:01:57	0:15:35	0:00:24	0:04:31
6	0:03:45	0:22:32	0:02:49	0:04:51
5	0:01:44	0:08:40	0:00:25	0:03:14
2	0:01:29	0:02:58	0:01:19	0:01:38
5	0:02:48	0:13:58	0:01:22	0:04:26
6	0:02:31	0:15:06	0:00:50	0:04:59
4	0:01:58	0:07:52	0:00:52	0:03:19
3	0:00:59	0:02:58	0:00:25	0:01:48
7	0:01:48	0:12:33	0:00:38	0:02:57
8	0:03:37	0:32:33	0:02:01	0:04:54
3	0:02:04	0:06:13	0:00:41	0:03:42



# III. RESULTS - IMPACT ASSESSMENT

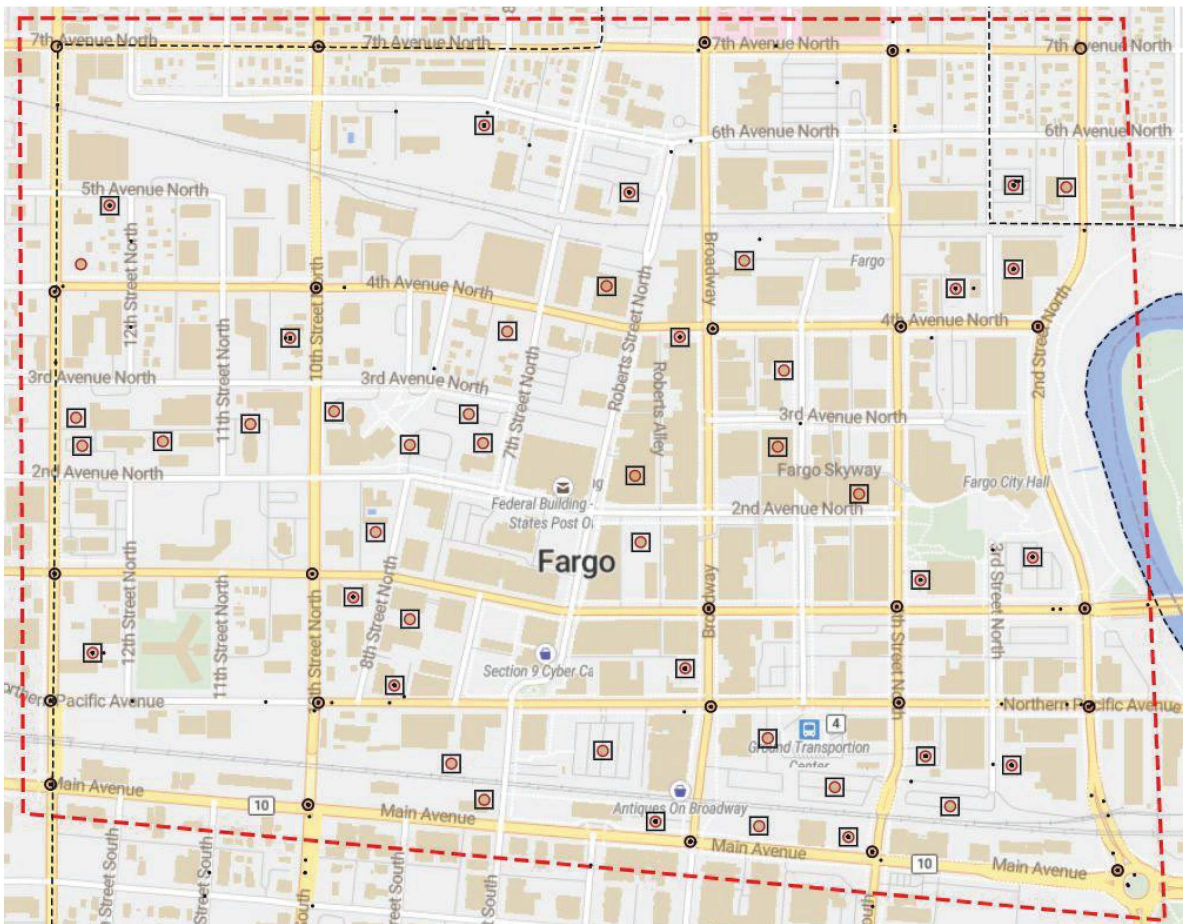
The final results provide just an example of what information can be accessed from a smart city simulation. This includes the time it takes to move between points and the amount of pedestrian moved in this way. Varying information from the graph sections are resulted from the "MoveToNearest" line of code which redirects the pedestrian's path of travel. For example, if a pedestrian wants to go the nearest parking, the pedestrian will not choose one the furthest away. This is reason why some graphs are left blank from the Intersectional Parking Model.

The amount of time is takes from one point to another can show if the downtown area is "walkable" or accessible by foot traffic. If the parking locations are farther away, The data would result in a longer time and distance traveled. In this way, urban planners can use this information to find areas of issue and perhaps adjust the urban area to accommodate pedestrians.



# IV. CONCLUSIONS - FUTURE DIRECTIONS

Future simulations could perhaps become more advanced and simulate if new adjustments to the urban environment are more efficient. This model only shows public assembly buildings within downtown, and does not include residential buildings and private buildings. With a more advanced model could provide different datasets that can provide additional information. For example, advanced models could calculate the time it takes to go to specific buildings of occupation, such as how far a grocery store is from a residential building or how far a parking spot is from a workplace. Different scenarios could alter design choices and provide multiple design considerations in the urban environment.



# IV. CONCLUSIONS - CHALLENGES

## **Time to produce**

Further Advanced models could result in taking a vast amount of time to produce. For comparison, this model only has 50 buildings and 45 parking spaces. If the advanced models include residential buildings and private buildings, more time could be needed.

## **Computational limitations**

Modeling a specific zone is more feasible compared to the entirety of the city. However, it may be possible with efficient resources.

## **Multiple departments are needed for information**

The collaborative effort of universities, city departments, historical preservation, and private businesses is needed to require accurate information of occupancy and other additional information. In Fargo's case, private buildings and older/historical buildings must be individually accessed. This can vary from city to city depending on if the information is archived. Overall, this may take a large amount of time and money.

## **Zoning**

In the case of mixed-use buildings, the contrasting use of spaces between private and public areas can prove to be difficult to access necessary information.

# IV. CONCLUSIONS - CLOSING REMARKS

This exploration of smart city simulating and modeling shows the feasibility and practicality of the models. Real world uses such as showing the distance to necessary or common building types are important show the walkability of urban environments. While the models only simulate the downtown Fargo area, future models could perhaps simulate an entire city. This would result in a more advanced and accurate model.

Using GIS integration with AnyLogic provided an accurate location and distances which helped with overall organization and efficiency. However, new city designs can still use this workflow, but sidewalks, roads, and buildings would have to be modeled from the ground up.

While the challenges of smart city modeling are proven to be difficult to overcome, benefits such as designing for efficiency to benefit the health and wellness of the pedestrian outweigh these difficulties.

This research mostly focused on the efficiency of downtown Fargo vacancy. However, with future improvements and accessible information, future models can become more advanced and provide numerous benefits regarding the urban environment.

