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Agent-Based Transport Simulation Model of Exclusive Routing System for Disaster Response Vehicles

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Objective

- To develop an agent-based transport simulation model in determining the traffic routes exclusive for disaster response vehicles in reaching the affected area after the occurrence of disasters.

Motivation

- **Traffic Management Officers**
  Identify exclusive traffic routes for DRVs
- **DRV Operators**
  Routes known upon deployment
- **Medical, Police and Fire Protection Teams**
  Faster delivery of support services
- **Victims of Disaster**
  Faster medical attention given
  Faster recovery of lives

Motivation: Absence of Simulation Software

Table 4. Percent of Cities with Availability of Equipment and References Related to Transport Planning and Traffic Management

(%)

Equipment/Reference	Large City	Mid-sized City	Small City	All
1. Traffic Lights	72	25	13	37
2. Vehicles for Enforcers	94	90	72	87
3. Tow Trucks	50	15	4	23
4. Ambulances	69	88	84	81
5. Communication System for traffic police	76	85	75	80
6. Computers for Planning Use	69	65	80	70
7. Geographic Information System	33	38	25	33
8. Gas Analyzer (for emission test)	19	8	8	11
9. Opacimeter (for emission test)	33	2	8	13
10. Traffic Simulation Software	0	0	0	0
11. Demand Forecast Software	0	0	0	0
12. Highway Design Reference	48	42	48	46
13. Road Maintenance Reference	59	55	64	58
14. Traffic Engineering Reference	53	33	24	37
15. Transport Planning Reference	53	32	32	39
16. Land Use Planning Reference	77	88	84	84

Source: TPTM Self-assessment Survey, 2008.

Source : TPTM Self-Assessment Survey, 2008.

Absence

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Motivation: Absence of Simulation Software

"Enhancement of Capacity Building on Transport Planning and Traffic Management in the Context of Philippine Local Cities: A Needs Assessment Approach"

"traffic congestion due to improper planning and management system"

- examine the needs of cities in dealing with transport and traffic problems
- nationwide survey of 120 cities
- classify cities: large >250K; medium-sized 100K-250K; small <100K
- questionnaires and simple approach analysis
- no city: traffic simulation software & demand forecast software

absence of a system to support planning agencies
problem is widespread
scope of intervention should also be widespread

I.C. Espada, H.S. Lidasan & M.M. De Leon in 2008

Related Studies: Traffic after Major Disaster

What: "Network Capacity Reliability Analysis Considering Traffic Regulation after a Major Disaster"

"optimization problem"

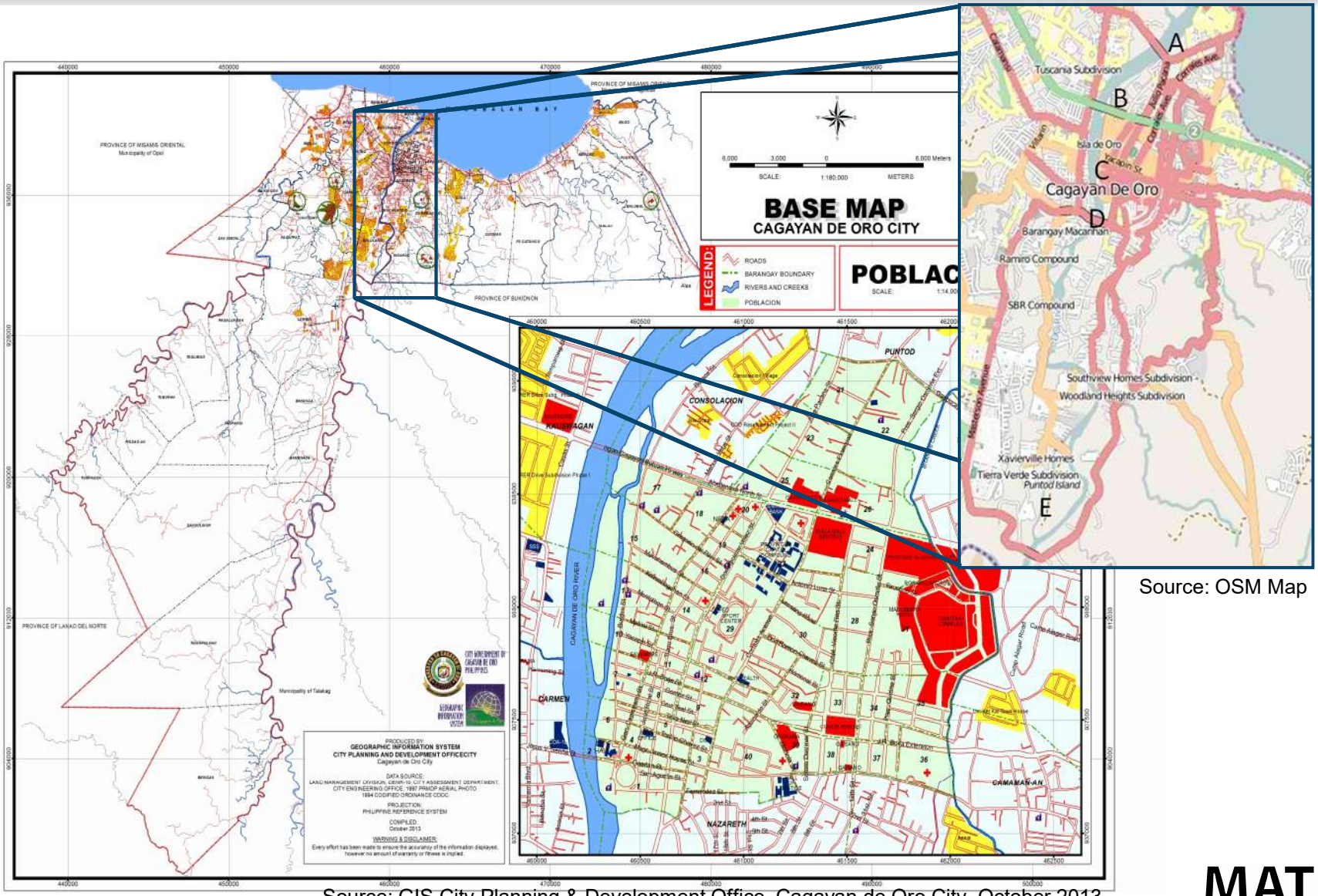
How:

- context of traffic regulation after a major disaster
- regulate volume of traffic movements
- maximize traffic volumes in the network
- optimization algorithm and implicit programming approach
- Monte-Carlo Simulation
- road network of Kobe City in Japan

evaluate performance of traffic management scheme
road network capacity reliability

Authors: A. Sumalee & F. Kurauchi in 2006 , Japan

Scope and Limitations:
Cagayan de Oro City, Misamis Oriental, Philippines



Source: OSM Map

Source: GIS City Planning & Development Office, Cagayan de Oro City, October 2013.

5 Bridges

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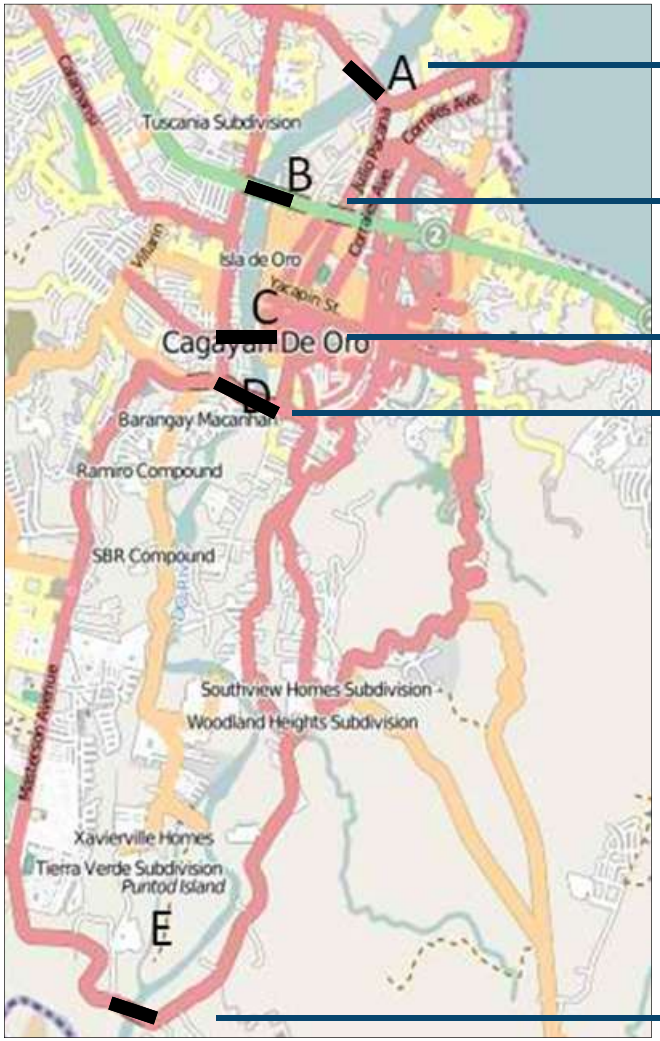
Site Coverage: Includes 5 Major Bridges



A. Kauswagan-Puntod Bridge

B. Marcos Bridge

C. Carmen Bridge

D. Rotunda Bridge

E. Pelaez Bridge

Source: OSM Map

SDLC

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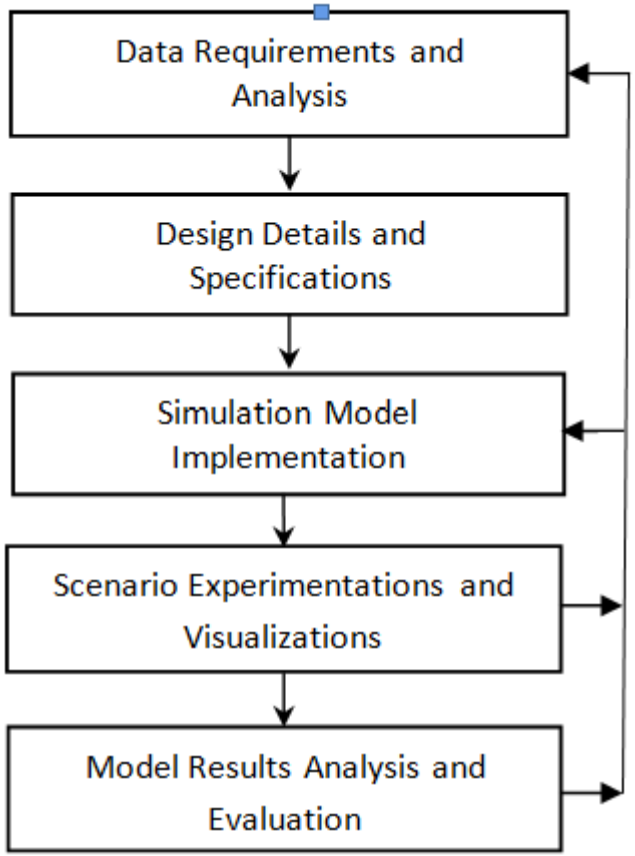
Methodology: Agent-Based Transport Simulation Development Life Cycle



Design and Programming Methods:

- Graphical Representation of Road Networks
- Conversion to XML Format
- Geographical Map Coordinates
- Simulation Modeling
- Agent-Based Modeling Paradigm
- Scenario Experimentations
- Visualization of Simulation Results

Routing Calculations

- Dijkstra's Algorithm
- Test Car Technique

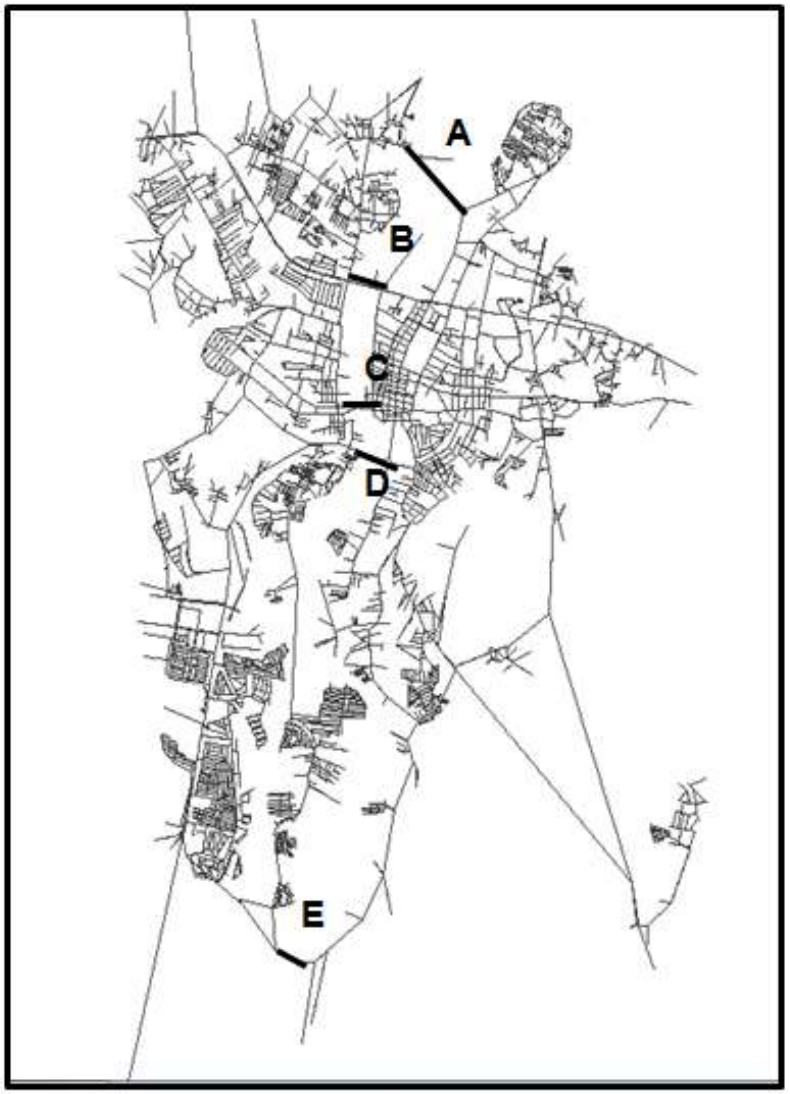
Design of Simulation Model

1. **ENVIRONMENT**
   - Road Network
   - Facilities (Hospital, BFP & PNP Stations, Evacuation Dropping Points)
2. **AGENTS**
   - Disaster Response Vehicles (Ambulances, Fire Trucks & Police Cars)
3. **INTERACTIONS**
   - Presence of Road Closures
   - Other Vehicles

Philippine: Coordinate Reference System

- EPSG:3121: PRS92 / Philippines zone 1
- EPSG:3122: PRS92 / Philippines zone 2
- EPSG:3123: PRS92 / Philippines zone 3
- EPSG:3124: PRS92 / Philippines zone 4
- EPSG:3125: PRS92 / Philippines zone 5

SCENARIO: Road Network
Cagayan de Oro City, Misamis Oriental, Philippines



Five (5) Major Bridges:

A. Kauswagan-Puntod Bridge
B. Marcos Bridge
C. Carmen Bridge
D. Rotunda Bridge
E. Pelaez Bridge

Road Network:

Nodes = 3847

Links = 9830

Road Intersection

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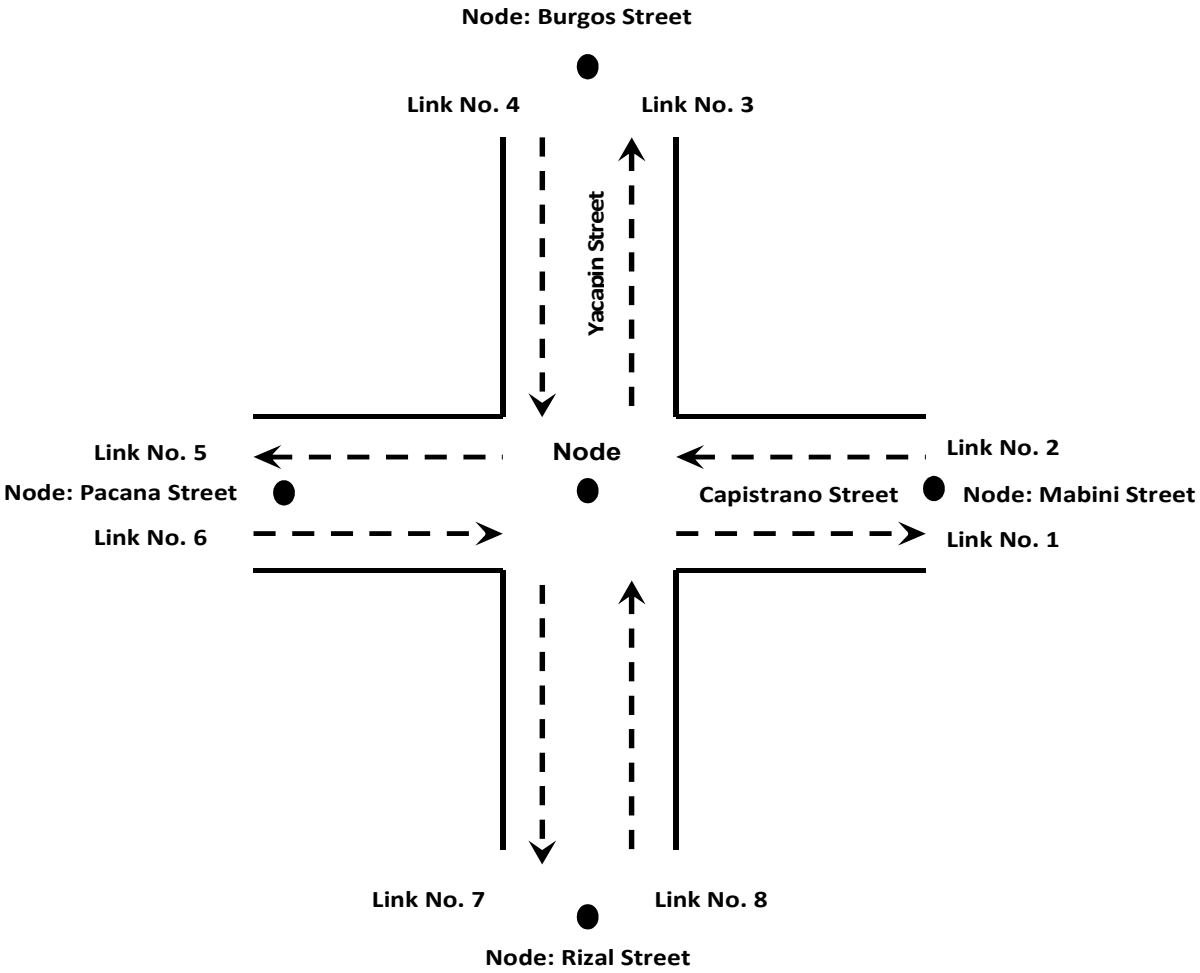
Road Intersection: represented by NODES and LINKS



Hospitals

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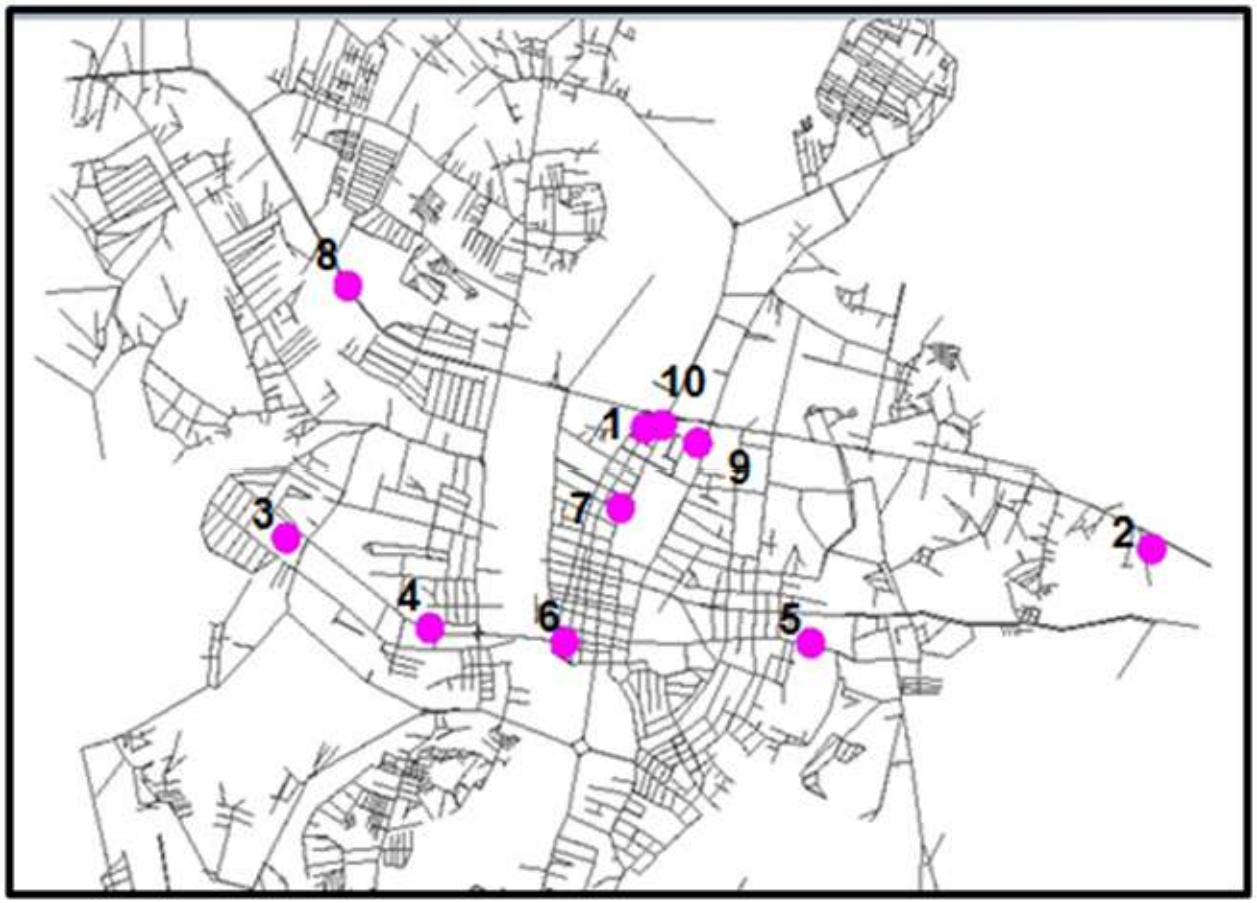
FACILITIES: Hospitals



Cagayan de Oro Hospital Locations in the Road Network: 1. Medical Center; 2. CUMC; 3. City Hospital; 4. Madonna & Child Hospital; 5. Maria Reyna Hospital; 6. Maternity Hospital; 7. Polymedic General Hospital; 8. Polymedic Medical Plaza; 9. Provincial Hospital and 10. Sabal Hospital.

FACILITIES:
Bureau of Fire Protection (BFP) Stations

Bureau of Fire Protection Station Locations in the Road Network: 1. CV Roa Fire Station 2. Aluba Fire Station and 3. Macabalan Fire Station

PNP

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FACILITIES:
Philippine National Police (PNP) Stations

Police Precinct Locations in the Road Network. A-PNP Headquarters, B-COCPO CPSC, 1-Police Precinct No.1 at Divisoria, 2-Police Precinct No.2 at Cogon Market, 3-Police Precinct No.3 at Agora, 4-Police Precinct No.4 at Carmen Market, 5-Police Precinct No.5 at Macabalan and 9-Police Precinct No.9 a Macasandig.

Road Closure IDs

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INTERACTIONS: **Road / Bridge Closures**

Table 1: Links IDs of the Five Bridges.

No.	Name of Bridges	Link IDs	
1	Sen. Aquilino Pimentel Bridge *(near Puntod)*	5785	5786
2	Maharlika Bridge *(formerly Marcos Bridge)*	9499	9500
3	Gov. Ysalina Bridge *(formerly Carmen Bridge)*	1783	1784
4	Kagay-an Bridge *(near Rotunda)*	4707	4708
5	Emmanuel Pelaez Bridge *(at Taguanao area)*	7632	7633

Simulation Model Implementation

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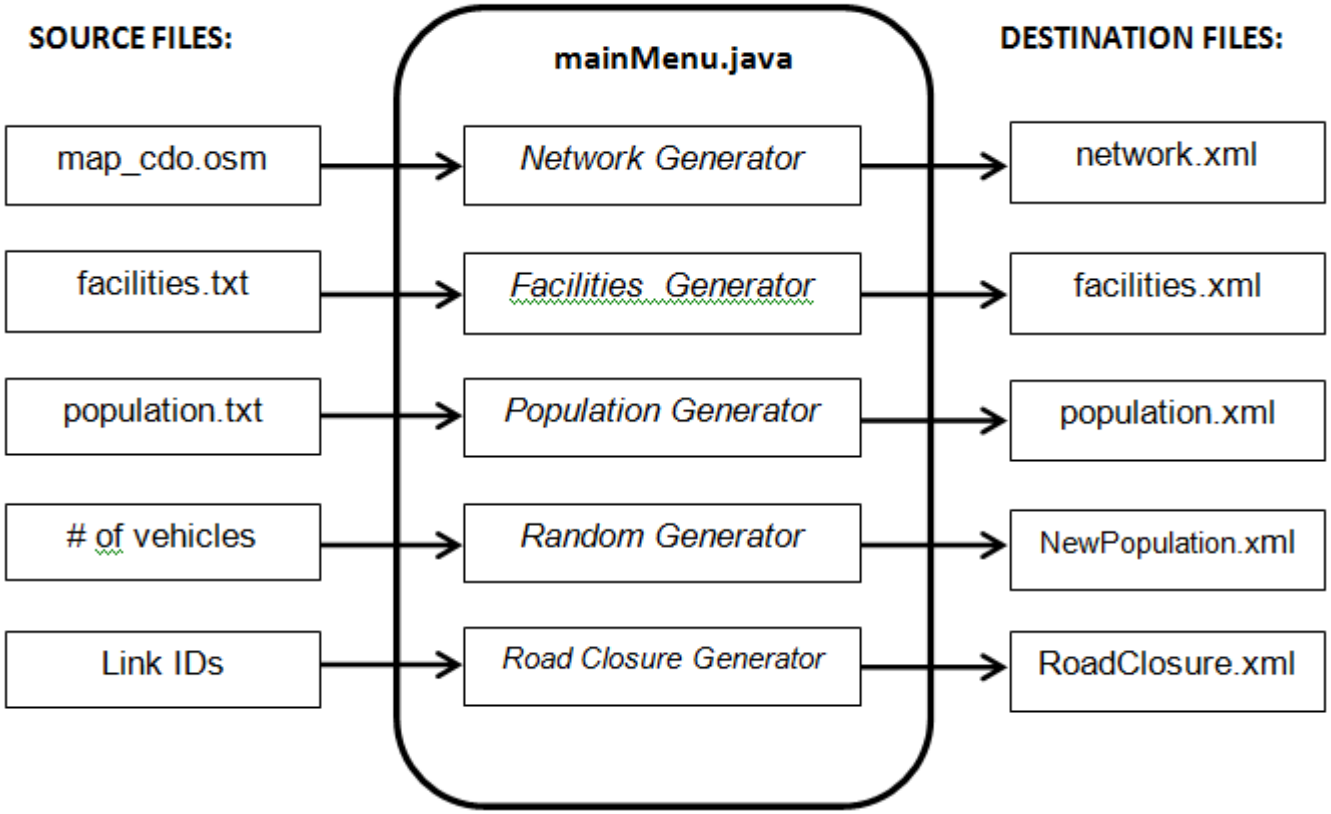
Senozon Via

Source Dest Flow

Implementation:
Source to Destination Conversion Flow Diagram



Scenario Gen Flow

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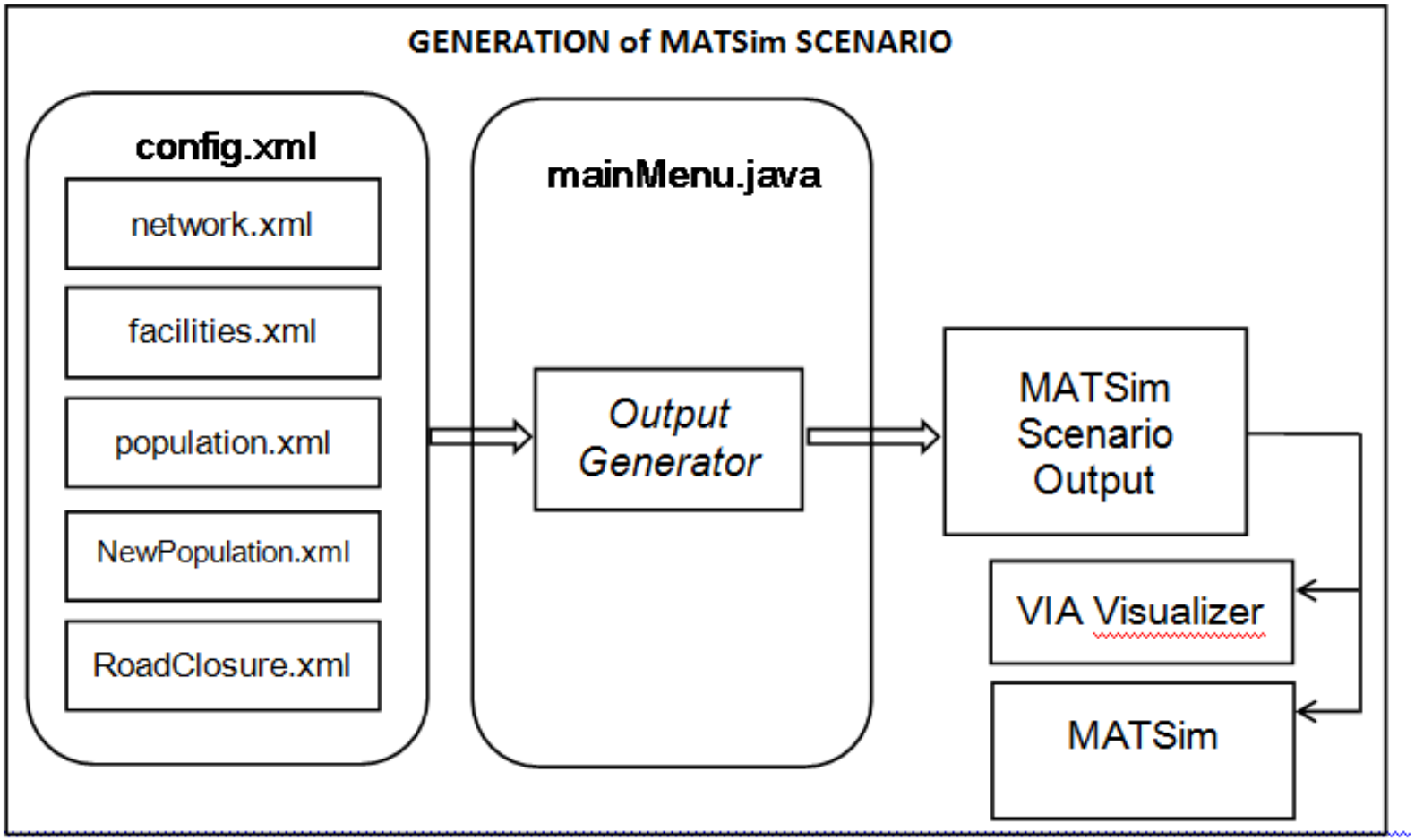
Implementation:
Scenario Generation Flow Diagram



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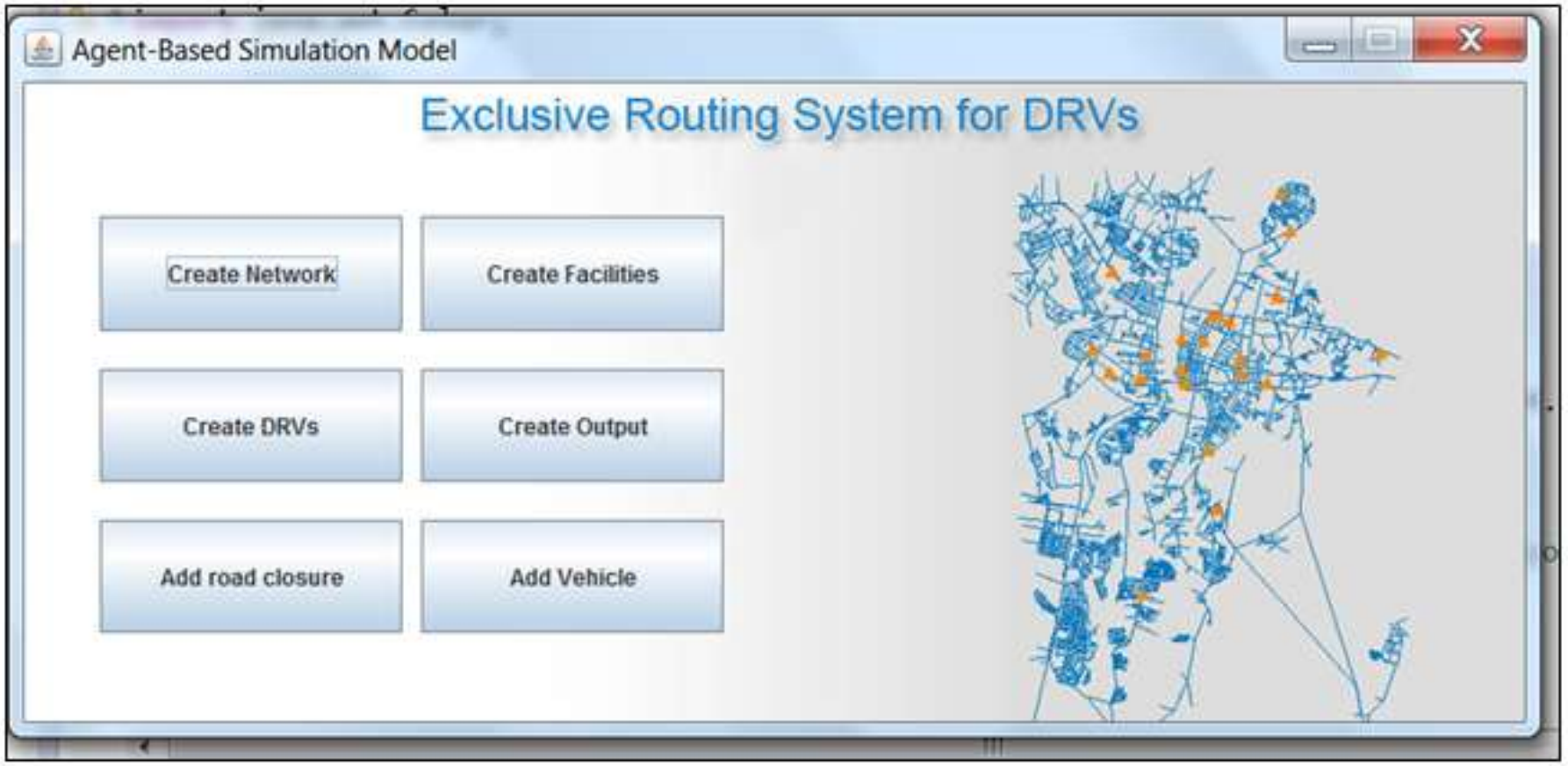
The Simulation Model: ERS Main Window



Sample Visualization

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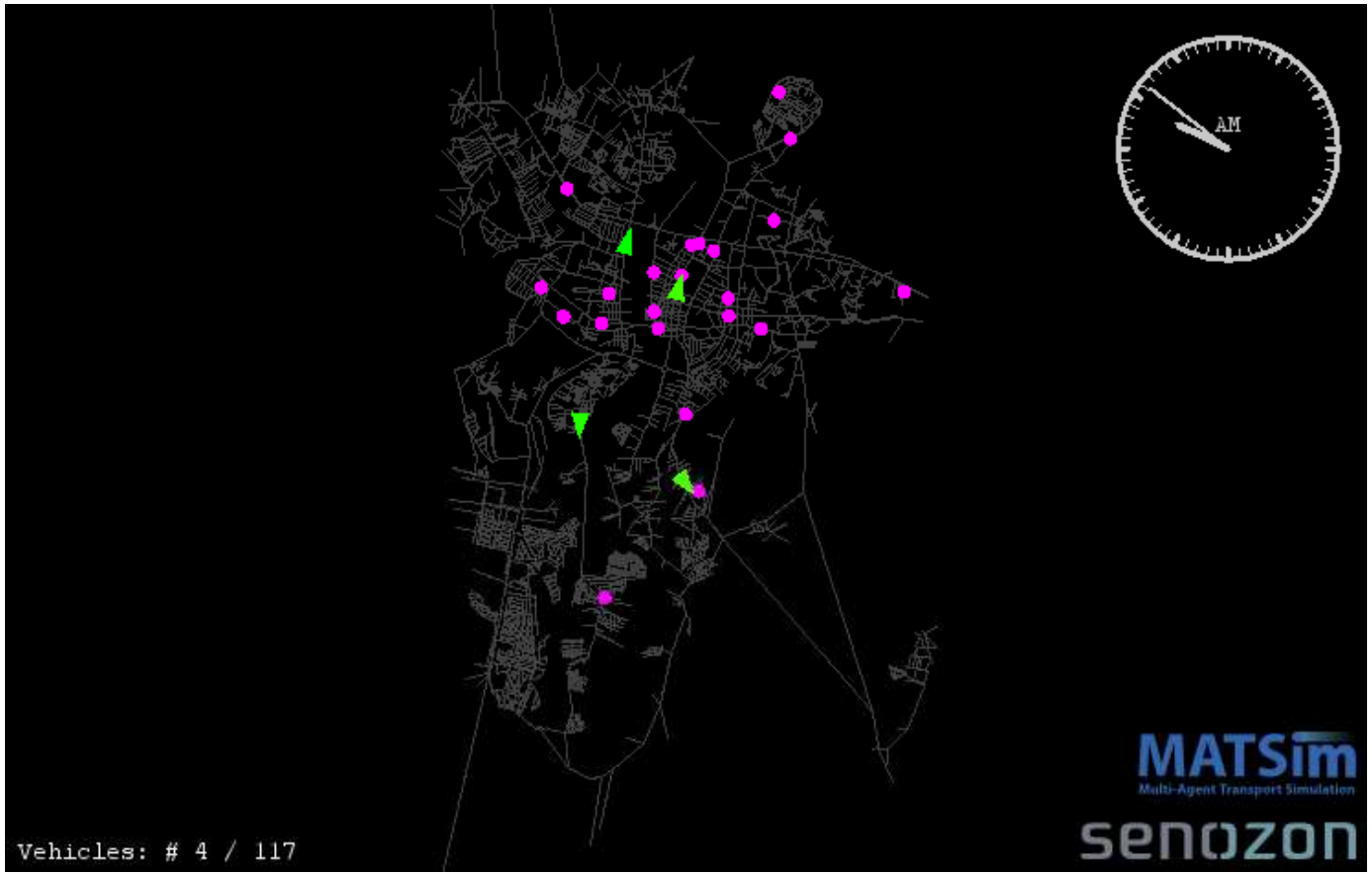
Sample Visualization Snapshot:



Green : Disaster Response Vehicles (DRVs)

Pink : Hospitals, Fire & Police Stations (Facilities)

SCENARIO EXPERIMENTS

Scenario 1: No Bridge Closures

Scenario 2: With Bridge Closures

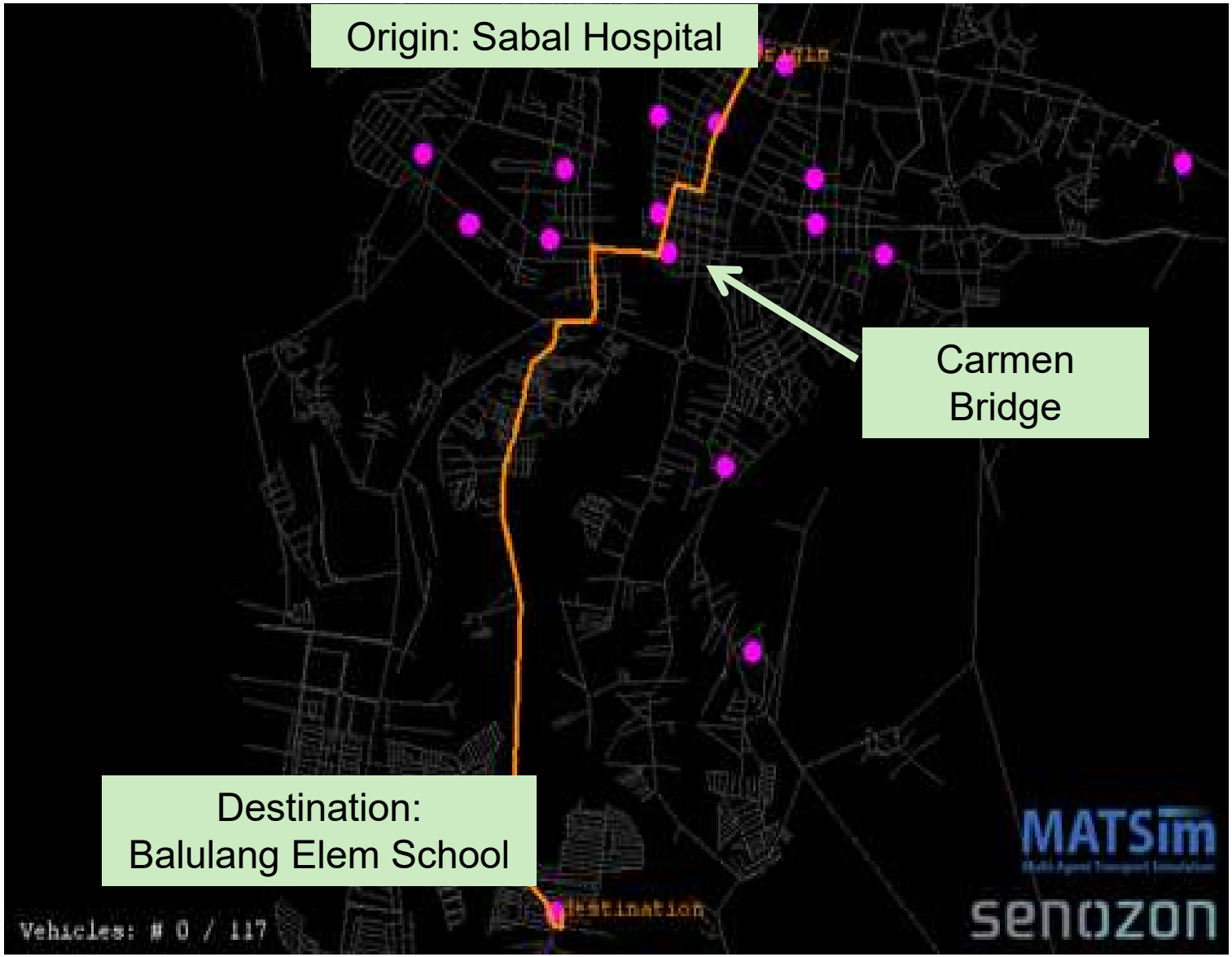
Non-passable Bridges:

- Marcos
- Carmen and
- Rotunda Bridges

Passable Bridges:

- Kauswagan-Puntod Bridge and
- Pelaez Bridge

SCENARIO 1 Snapshot – No Bridge Closure



Travel Time

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SCENARIO 1: Travel Time Record

Table 2: Travel Time Record of Scenario 1-No Bridge Closures

	A	B	C	D	E	F	G	H	I
1	DRV#	Entity Name		Route		Number of Links Traversed	Departure Time	Arrival Time	Travel Time
2		Origin (O)	Destination (D)	OD	Return		(sec)	(sec)	(sec)
41	23	CV Roa BFP	Burgos	x		19	09:00:00	09:01:21	00:01:21
42					x	16	09:15:00	09:16:30	00:01:30
43	42	Cogon PNP	Burgos	x		23	03:00:00	03:01:36	00:01:36
44					x	23	03:30:00	03:31:29	00:01:29
45	47	NMMC Hosp	Balulang	x		75	10:00:00	10:06:28	00:06:28
46					x	72	10:15:00	10:21:24	00:06:24
47	48	Sabal Hosp	Balulang	x		74	10:30:00	10:36:13	00:06:13
48					x	73	10:45:00	10:51:19	00:06:19
49	49	Polymedic Gen Hosp	Balulang	x		68	11:00:00	11:05:51	00:05:51
50					x	67	11:15:00	11:20:57	00:05:57

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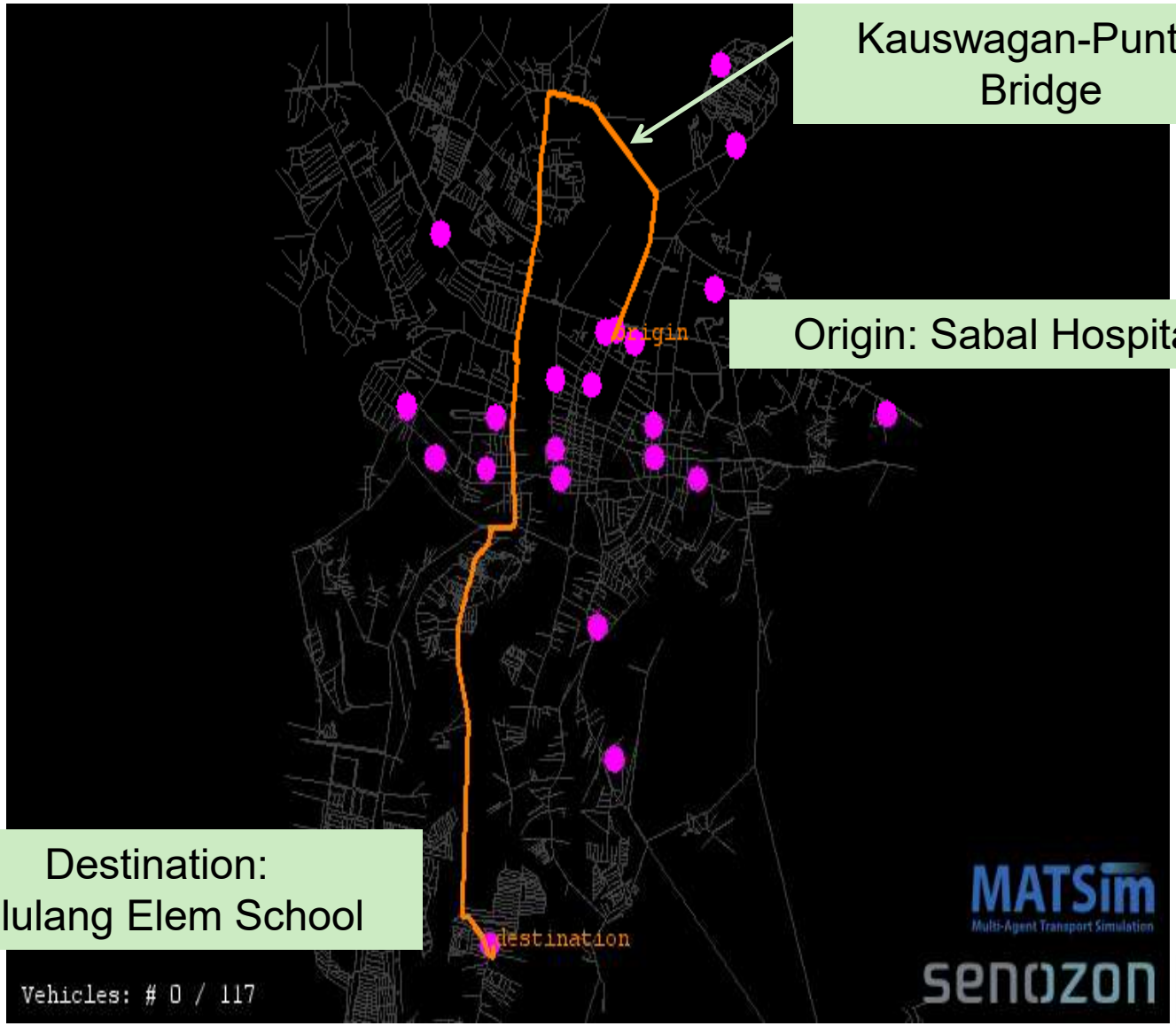
RESULTS of SCENARIO 1: (6.9% of 9630 links) 667 Links (57 Streets) for Exclusive Use of DRVs

Table 3: Scenario 1-Links for Exclusive Use of DRVs

NO.	STREET NAMES	FREQUENCY	#OF LINKS
1	highway	1524	147
2	Vamenta Boulevard	364	40
3	Gen. Capistrano St.	287	34
4	Don Apolinar Velez Street	197	45
5	JV SeriÃ±a Street	166	22
6	J.R. Borja St	139	21
7	Burgos Street	121	16
8	Tomas Saco	101	28
9	Julio Pacana	100	26
10	Cagayan-Gingoog-Butuan National Highway	98	44
11	Justo Gaerlan Street	79	10
12	Corrales Ave.	62	27
13	Mandumol-Aluba-Buena Oro Road	60	30
14	Claro M. Recto	54	22
15	Carmen Bridge	29	2

SCENARIO 2 Snapshot: With Bridge Closure



Travel Time

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SCENARIO 2: Travel Time Record

Table 4: Travel Time Record of Scenario 2-With Bridge Closures

	A	B	C	D	E	F	G	H	I
1	DRV#	Entity Name		Route		Number of Links Traversed	Departure Time	Arrival Time	Travel Time
2		Origin (O)	Destination (D)	OD	Return		(sec)	(sec)	(sec)
93	45	DVSoria PNP	Balulang	x		121	09:00:00	09:10:13	00:10:13
94					x	118	09:15:00	09:25:20	00:10:20
95	46	Maria Reyna Hosp	Balulang	x		119	09:30:00	09:40:47	00:10:47
96					x	114	09:45:00	09:55:37	00:10:37
97	47	NMMC Hosp	Balulang	x		104	10:00:00	10:09:24	00:09:24
98					x	101	10:15:00	10:24:30	00:09:30
99	48	Sabal Hosp	Balulang	x		102	10:30:00	10:39:17	00:09:17
100					x	98	10:45:00	10:54:15	00:09:15
101	49	Polymedic Gen Hosp	Balulang	x		109	11:00:00	11:09:38	00:09:38
102					x	104	11:15:00	11:24:37	00:09:37

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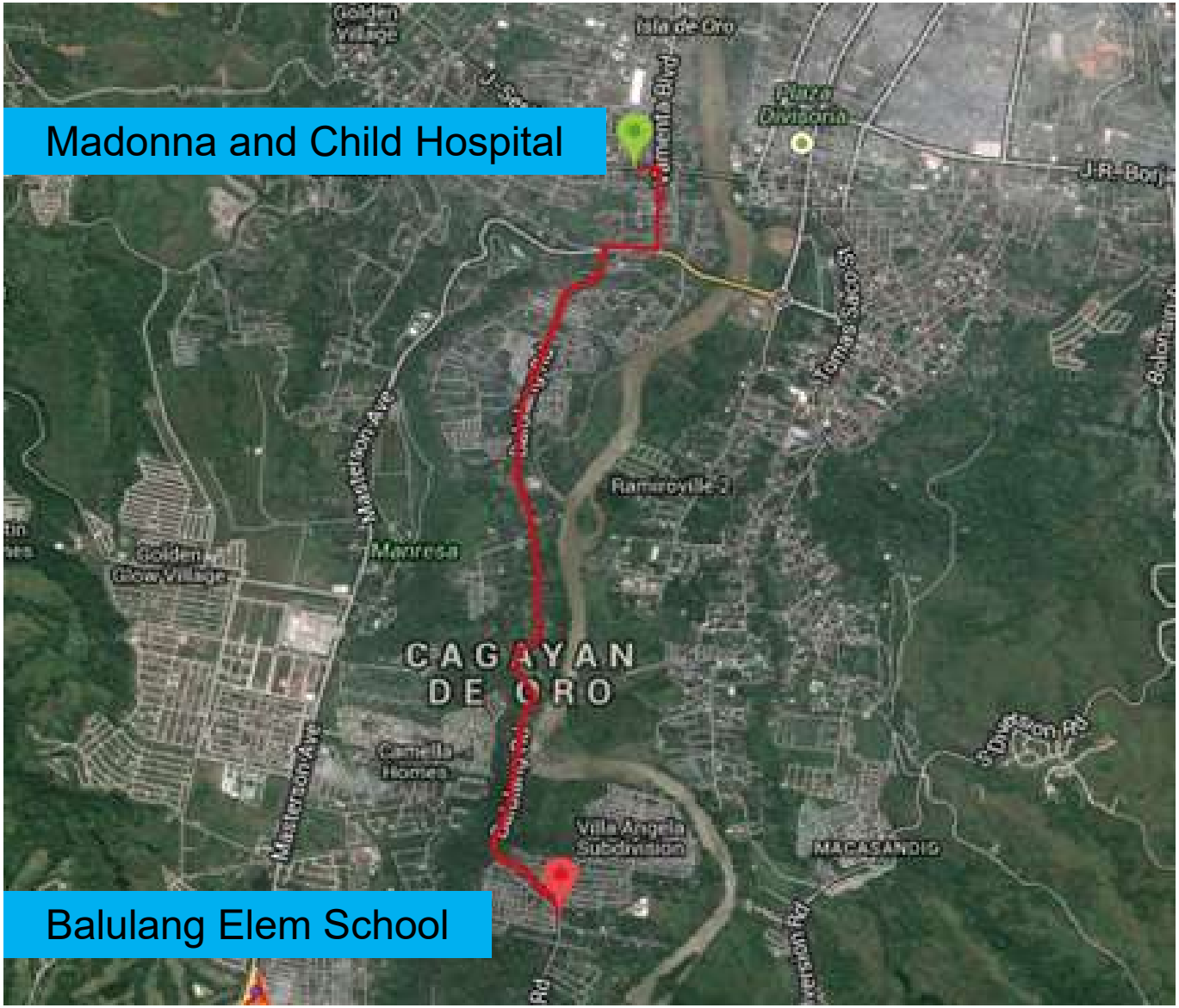
RESULTS of SCENARIO 2: (8.7% of 9630 links) 841 Links (61 Streets) for Exclusive Use of DRVs

Table 5: Scenario 2-Links for Exclusive Use of DRVs

NO.	STREET NAMES	FREQUENCY	# OF LINKS
1	highway	2141	278
2	Vamenta Boulevard	651	42
3	R. N. Pelaez Boulevard	528	32
4	Julio Pacana	224	30
5	Don Apolinar Velez Street	201	44
6	Gen. Capistrano St.	167	23
7	J.R. Borja St	110	21
8	Burgos Street	106	16
9	Mandumol-Aluba-Buena Oro Road	96	48
10	Cagayan-Gingoog-Butuan National Highway	83	44
11	Kauswagan-Puntod Bridge	83	6
12	JV Seriña Street	62	16
13	Gaabucayan St	59	19
14	Tomas Saco	58	28
15	Calamansi	34	16

VALIDATION: Using Test Car Technique

Origin: Madonna & Child Hosp Destination: Balulang Elem School



Route Model

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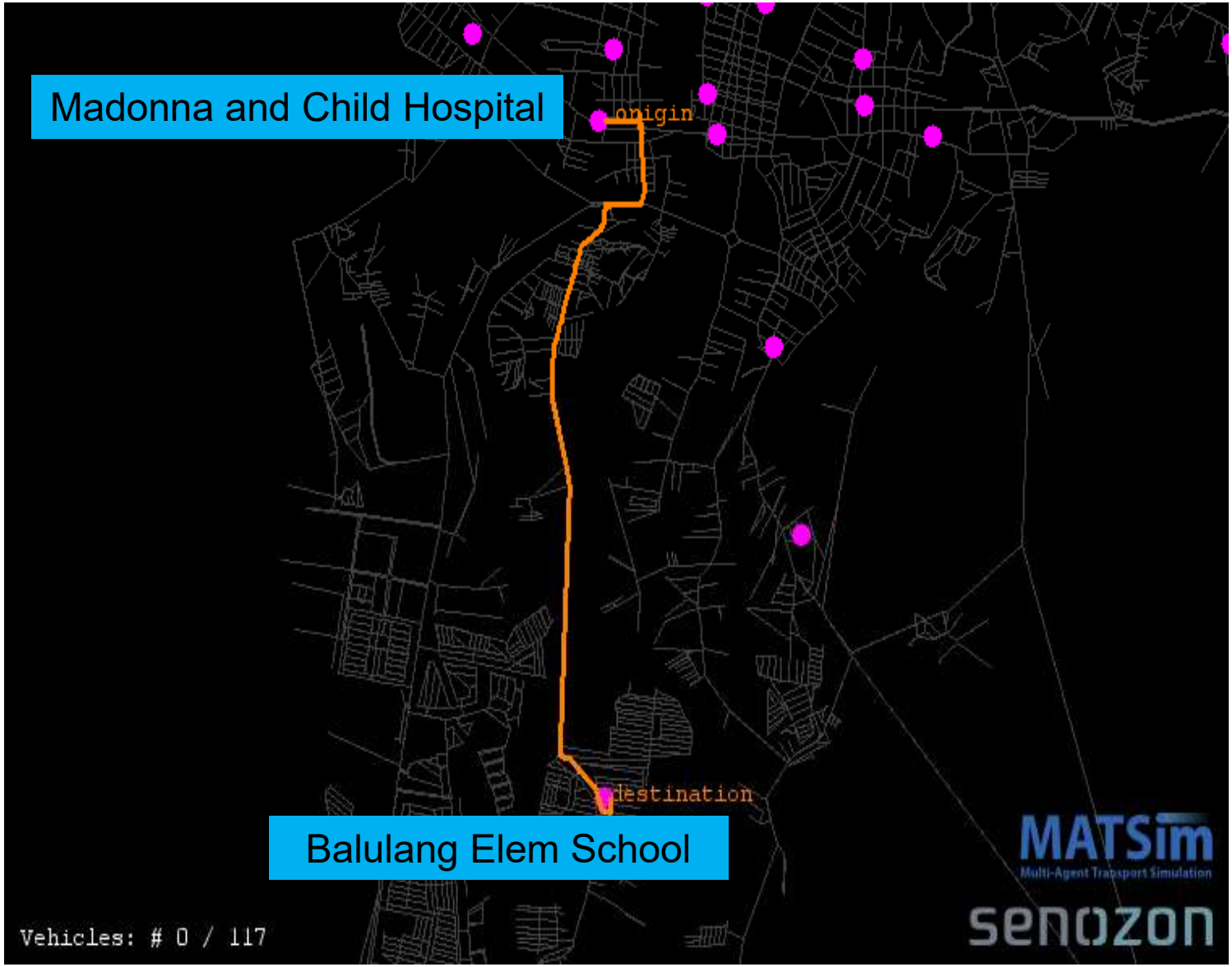
VALIDATION:
Route Generated by Simulation Model



RESULTS:
Actual Travel Time and Simulation Model

Table 6: Travel Time Validation Using Test Car Technique vs Simulation Model

Route: From Madonna & Child Hospital To Balulang Elementary School (Total distance = 4.4km)	
A. Actual Measurement Using Test Car Technique	
Total travel time	00:22:04
Total delay	00:14:04
Total Running Time	00:07:59
Speed Ranges	11.95km/hr to 35.75 km/hr *(Source: MyTracks)*
B. Travel Time Using Simulation Model	
Total travel time	00:05:08
Total delay	none
Total Running Time	00:05:08
Speed Ranges	14.4 km/hr to 79.2 km/hr

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EVALUATION of Simulation Model: By 4 Domain Experts

Four (**4**) Domain Experts:

1) **Traffic engineering**
   - *Transportation Eng'g & Built Environment Specialist*

2) Computing
   - *Computing Scientist*

3) **Management**
   - *Technical Supervisor, Road & Traffic Admin Office*

4) **Planning**
   - *Coordinator of CDO City Planning Office*

Conclusion

- proves the concept of exclusive routing system
- helps traffic management agencies
- determines road traffic routes
- exclusive use of disaster response vehicles

Thanks

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Thanks for your attention!

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The following people contributed to the work presented in this talk:

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- Dr. Anabel Abuzo - Civil Eng'g Dept., XU

and from the MATSim community

- Prof. Dr. Kai Nagel
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- Dr. Alex Erath