UNIVERSITY OF MICHIGAN

2019 NOCoE Transportation Technology Tournament

Corridor Management in I-75/I-696 Influence Area

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MDOT Michigan Department of Transportation

AADT Annual Average Daily Traffic

CCTV Closed-circuit Television

DMS Dynamic Message Sign

TMC Traffic Management Center

SMART Suburban Mobility Authority for Regional Transportation

1 Overview

This document is prepared for the '2019 Transportation Technology Tournament' hosted by the National Operations Center of Excellence and the U.S. DOT ITS JOP PCB program. This document presents the operational concepts of a proposed solution to the recurring congestion at the corridor segment around I-75/I-696 interchange, a problem presented by the Michigan Department of Transportation (MDOT). The University of Michigan team has summarized the current situation of the influence area, analyzed the potential solutions as well as identified the final solutions, both targeted the problem from the supply and demand perspectives.

1.1 Current Situation

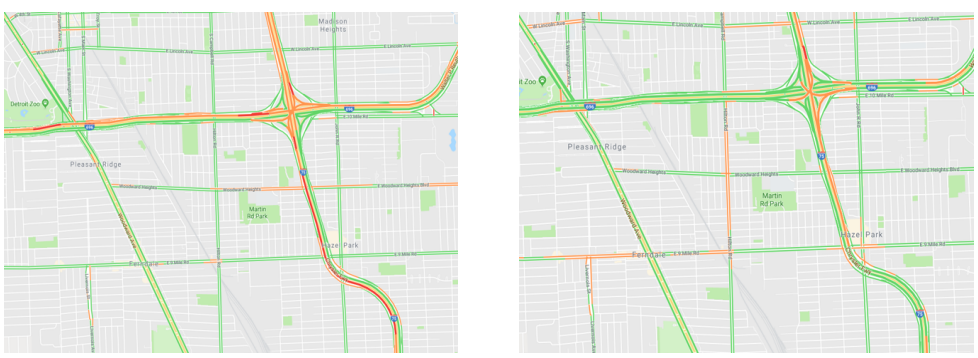
The south-north Interstate Highway 75 (I-75) and west-east Interstate Highway 696 (I-696) cross over the central of southeast Michigan, which serve the bypass traffic across as well as the local traffic in this area. The two highways are connected by a four-layer stack interchange, which is located at the middle of the Detroit Metropolitan Area, closely connects three counties: Wayne County, Oakland County and Macomb County.

Table 1: AADT on freeways

	N I-75	S I-75	E I-696	W I-696
Interchange Upstream	94,500	56,700	102,900	71,100
Interchange Downstream	72,800	68,300	102,900	71,100

Table 2: AADT from I-75 to I-696 and from I-696 to I-75

	E I-696	W I-696		N I-75	S I-75
N I-75	27,900	14,200	E I-696	21,000	11,600
S I-75	18,900	28,500	W I-696	16,800	28,500



(a) Morning **(b)** Evening

Figure 1: Typical traffic conditions at peak periods

Both I-75 and I-696 are high capacity highways, possessing six and eight lanes respectively. Traffic count data (Table 1, [1]) suggests that the two highways in the study area are heavily used: the northbound of I-75 and the eastbound of I-696 generate relatively high demand. The data (Table 5) also suggests that the two highways are closely interacting with each other, with a large amount of merge and diverge traffic. Meanwhile, preliminary analysis founds that directional congestion patterns are presented during morning and evening peak-hours (Figure 1). The morning peak usually lasts from 7:00 am to 9:00 am, during which the I-75 southbound is the most congested. The congestion starts from downstream of the interchange and then propagates upstream, which easily blocks both the eastbound and westbound on-ramps from of I-696. The evening peak usually lasts from 4:00 pm to 7:00 pm, during which the I-75 northbound is the most congested. Specifically, traffic merging from the westbound I-696 to northbound I-75 usually experiences chaotic lane changes and queues.

1.2 Influence Area

The recurring congestion is mostly induced by commuting traffic. As introduced previously, the highways connect residential areas and business area in southeast Michigan. We pin down the most affected area to the one shown in Figure 2, which covers area north to Troy, south to Detroit Downtown, east to Southfield and west to Warren. Other highways and major arterials in this area include north-south Michigan Highway 1 (M-1), Michigan Highway 53 (M-53), and east-west I-94, 8 mile road, 12 mile road. Together with I-75/I-696, these major roads compose into a connected traffic network where traffic can be routed from one to another.

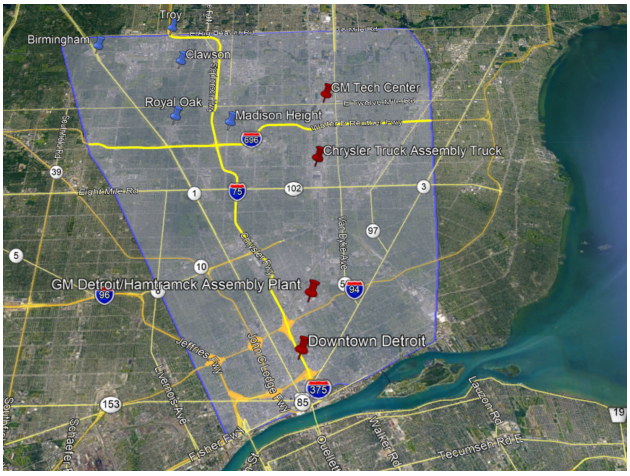


Figure 2: Influence area

The most dense residential areas are located in the north. Madison Heights, Royal Oak and Birmingham, for instance, hold population density of more than 4,000/sq mi. Jobs are primarily located in the south and the east. In addition to Downtown Detroit which possess a considerable number of jobs, big companies such as GM Tech Center, Chrysler Truck Assembly Plant, GM Detroit/Hamtramck Assembly Plant are also important traffic attractions. Therefore, the primary routes for a majority of commuters are on I-75 and I-696, which cause recurring congestion. The data on commuting pattern in southeast Michigan also supports the result. Here, we analyzed the inflows and outflows of four 'boundary' cities. The results (see Appendix) show that Detroit is all other cities' largest outflows destination, with Southfield contributing the largest inflows to Detroit, Warren the fourth largest and Troy the fifth. Needless to say, the commuting among these cities generates a large amount of transportation demand on I-75/I-696.

1.3 Existing Management

Both I-75 and I-696 are operated and maintained by MDOT. Freeway Courtesy Patrol service is deployed on highways to assist motorists by detecting, responding and removing traffic incidents. Other ITS deployments include dynamic message signs, CCTV cameras and other detection equipment. Major arterials in the influence area are mostly signalized, with a relatively low speed limit. For example, M-1, which is parallel to I-75, has a 35 mph speed limit.

Local arterial roads are owned by different levels of transport agencies, from state to county and to city. Similarly, the arterial signals are also owned by different agencies, which result in the consequence that multiple traffic signal systems are used in the study area. Therefore, to utilize the whole traffic network for mitigating recurring congestion, the involvement of different stakeholders, the negotiation and collaboration between various agencies are important.

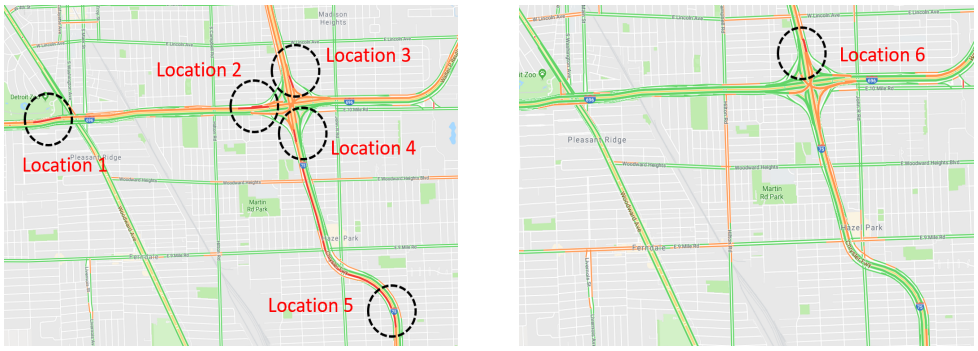
2 Solution Statement

Our team first identified two solutions that can be implemented in the study area. We distinguish the solutions by how it directly affect the transportation system, either from the demand side or the supply side.

2.1 Supply-Focused Solution

2.1.1 Analysis

The congestion on I-696 and I-75 has a clear recurrent pattern. Figure 3 shows the historical peak-hour traffic patterns given by Google Maps. In general, the morning peak-hour traffic is more congested, with five segments of very slow traffic (in red). In the evening, the congestion is moderate, with only one segment of slow traffic.



(a) Morning peak-hour traffic **(b)** Evening peak-hour traffic

Figure 3: Congestion locations

One of the primary reasons for congestion on I-696 and I-75 is merging and weaving sections. This includes both the merging of local traffic and freeway traffic, and the merging of freeway traffic and freeway traffic. Picture 4 shows the details of the most congested road segments on I-696 and I-75. At location 1 and 5, the congestion is resulted from the merging of local traffic and freeway traffic. At location 2, 3, 4, and 6, the congestion is caused by the merging of freeway traffic from different directions.

2.1.2 Solution

The analysis above suggests a combination of the following technologies to mitigate the congestion.

- Adaptive ramp metering
- Dynamic junction control
- Dynamic merge control
- Arterial green-wave signal control

For location 1 and 5, where the merging of local traffic and freeway traffic causes congestion, ramp meters could dynamically control the rate vehicles enter I-696 and I-75 from local roads. Dynamic ramp metering controls the traffic density on the freeways, allowing for efficient use of the existing freeway capacity [2]. According to the real-time and anticipated traffic conditions, collected from fixed-location sensors such as loop detectors, the ramp metering rates can be adjusted dynamically. Ramp metering by itself, however, may simply cause backups and congestion on local roads instead of the highway. For example, if the highway is congested, ramp metering will force the amount of entering flow to be very small, potentially causing a backup at the on ramp that may overflow to arterial roads. Thus, it is important to also adjust arterial signal control to manage arterial flow. In scenarios where traffic is highly congested on the highway, due to a crash or lane closure, dynamic message signs along the highway can reroute the vehicles to local arterials. Again, integrated arterial signal control is important to maintain traffic flow. Green-wave signal control allows the traffic to flow smoothly without stops over several intersections in one main direction. Since the traffic in the interested area is primarily directional during peak hours, green-wave signal control could significantly reduce the delays the travelers endure.

For location 2, 3, 4, and 6 shown in Figure 3, dynamic junction control can dynamically allocate lane access in the interchange areas. This might be implemented as an extended use of a shoulder lane as an acceleration lane for a two-lane entrance ramp. Dynamic merge control could manage the entry of vehicles into merge areas. This can be implemented by a series of portable dynamic message signs approaching the merge point that prepare travelers for an upcoming merge. The dynamic message signs could encourage consistent merging behaviors, create safe merging gaps, and thus reduce shockwaves and mitigate congestion at merge points.

(a) Location 1 **(b)** Location 2 **(c)** Location 3

(d) Location 4 **(e)** Location 5 **(f)** Location 6

Figure 4: Traffic congestion caused merging

2.1.3 Con-ops

2.1.3.1 Functional Architecture

The functional architecture addresses the analysis of abstract functional elements and their logical interactions [3].

Table 3: Functional architecture for the supply-focused solution

Physical Object	Functional Object	Description
ITS Roadway Equipment	Roadway Basic Surveillance	Monitors traffic conditions using fixed equipment such as loop detectors and CCTV cameras.
	Roadway Traffic Information Dissemination	Includes field elements that provide information to drivers, including dynamic message signs and highway advisory radios.
	Roadway Signal Control	Includes the field elements that monitor and control signalized intersections.
	Roadway Field Management Station Operation	Supports direct communications between field management stations and the local field equipment under their control.
	Roadway Traffic Metering	Includes the field equipment used to meter traffic on ramps, through interchanges, and on the mainline roadway.
Traffic Management Center	TMC Basic Surveillance	Remotely monitors and controls traffic sensor systems and surveillance (e.g., CCTV) equipment, and collects, processes and stores the collected traffic data.
	TMC Roadway Equipment Monitoring	Monitors the operational status of field equipment and detects failures.
	TMC Traffic Information Dissemination	Disseminates traffic and road conditions, closure and detour information, incident information, driver advisories, and other traffic-related data to other centers, the media, and driver information systems.
	TMC Traffic Metering	Provides center monitoring and control of traffic metering systems including on ramps, through interchanges, and on the mainline roadway.
	TMC Signal Control	Provides the capability for traffic managers to monitor and manage the traffic flow at signalized intersections

2.1.3.2 Physical Architecture

The physical architecture of the system leverages existing ITS deployments in the study area, including CCTV, loop detector, DMS and traffic signal. What's more, ramp meter, a new physical object, is introduced to the system to enable the operation of the proposed solution method. The physical architecture of our solution is adopted from the service packages of TM03 and TM05 (The National ITS Reference Architecture).

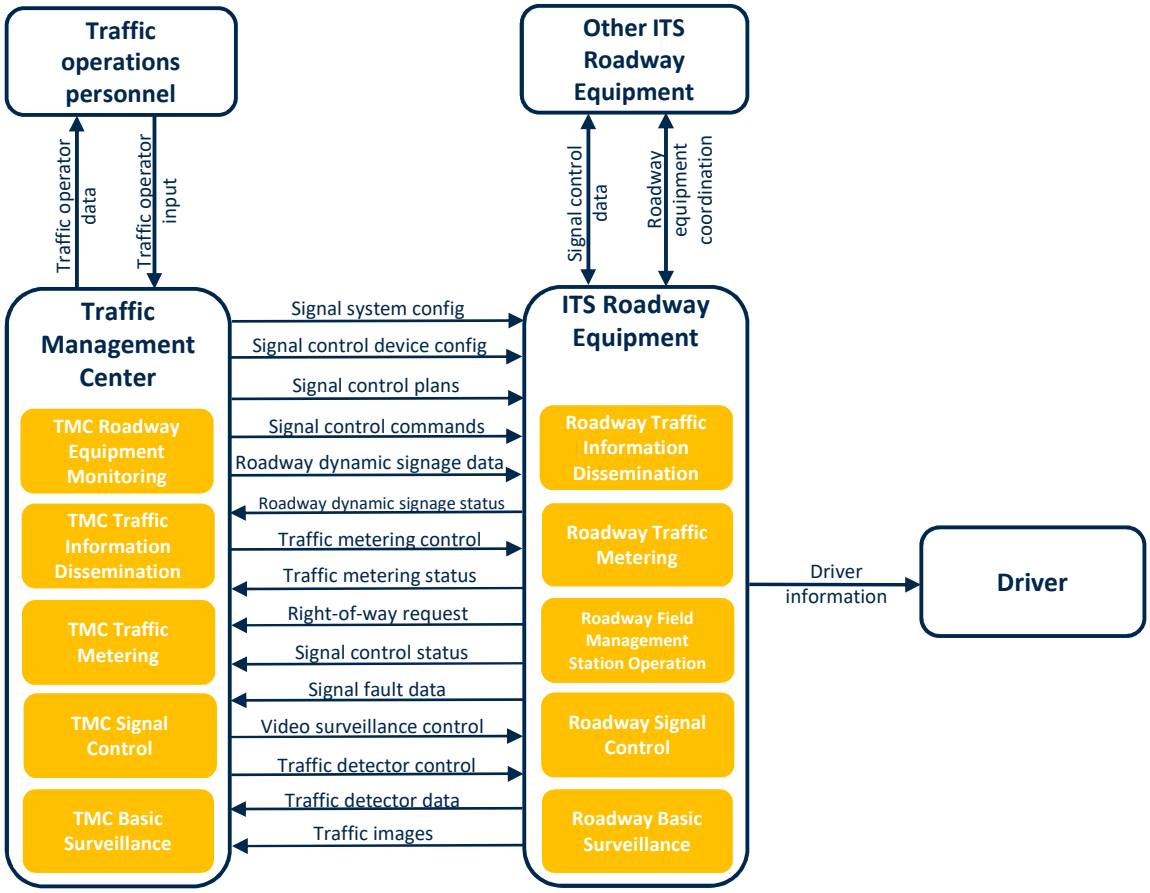


Figure 5: Physical architecture for the supply-focused solution

2.1.3.3 Enterprise Architecture

Physical objects and functional objects are also depicted as resources in the enterprise view, which describes the organizations that are involved and the roles they play in installing, operating, maintaining, and certifying all of the components of the architecture. The enterprise architecture of the demand-focused solution is presented in Figure 6.

2.1.4 Cost Breakdown and Timeline

Table 4: Cost breakdown for the supply-focused solution [4]

	Description	Quantity	Unit Price	Subtotal
1	Ramp meter	20	$ 4,000	$800,000
2	Portable Dynamic Message Sign	10	$ 5,000	$ 50,000
3	Traffic Signal Retiming	~20	$ 3,000	$ 60,000
				$910,000

Table 5: Timeline for the supply-focused solution

Task	Time Estimate
Ramp Meter Installation	3 months
Portable Dynamic Message Sign	1 month
Traffic Signal Retiming	1 month

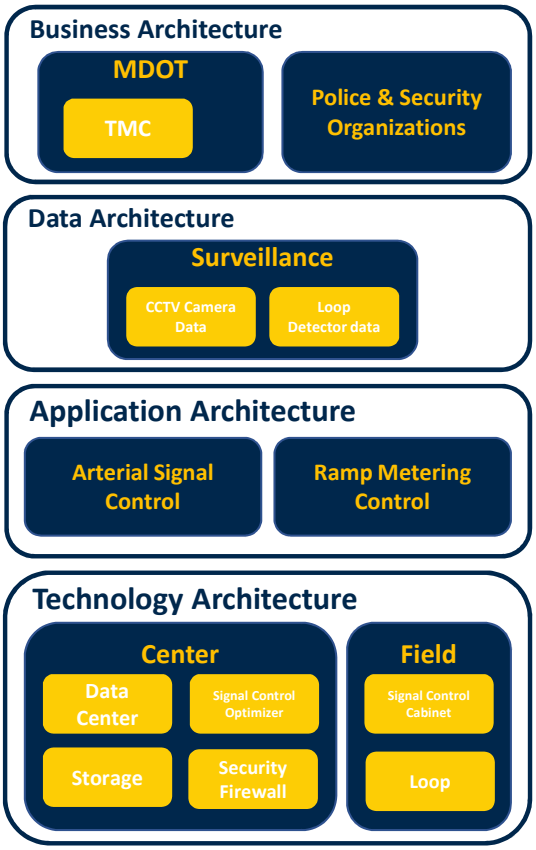


Figure 6: Enterprise architecture for the supply-focused solution

2.2 Demand-Focused Solution

2.2.1 Solution

As mentioned earlier, our preliminary analysis of the influence area reveals that commuting trips play a major role in the congestion of the corridor. Therefore, devising an effective plan to manage such trips will considerably alleviate the congestion. Toward this end, we propose an on-demand flex-route transit system provided by MDOT that offers services to only the employees of these companies. This system can be readily incorporated in the commuter benefits of employees in these companies. In recent years, many national companies including but not limited to Google, Apple, and Facebook have introduced successful instances of carpooling programs to their employees. The studies suggest that such programs can benefit employees in many ways such as increasing annual savings and avoiding stressful bumper-to-bumper traffic lasting for hours.

Although every incorporation in the influence area can individually practice similar programs, we propose an integrated system that collaborates with all companies to optimize the overall benefits. However in order to succeed, this program requires high rates of participation. As a viable action, we would suggest companies to incentives their employees to participate by rising the price of on-campus parking.

Study of existing transit programs in the influence area suggests that they already have a transit provider called SMART that offers flex-route shuttles. However, these routes are open to public and mostly require phone call arrangements. In contrary, we propose a program that only serves the employees, and shuttles are deployed proactively en-route between the high-demand stations to increase the level of service. According to the 2000 U.S. Census Journey to Work survey, less than 2 percent of commuters used transit as their primary choice of transportation in the Detroit region due to low density of land use in the I-75 corridor. As a result, we propose a multi-modal transit system where these flex-route, short-range shuttles work in conjunction with the fixed-route transit to accommodate long commuting trips.

2.2.2 Con-ops

2.2.2.1 Functional Architecture

Due to the similarities between our proposed solution and the "Vehicle Trip Planning and Route Guidance" in the National ITS Reference Architecture, we closely adopt the functional and physical architecture of the service packages TI04.

Table 6: Functional architecture for the demand-focused solution

Physical Object	Functional Object	Description
Personal Information Device	Personal Trip Planning and Route Guidance	Provides a personalized trip plan to the traveler
Transit Management Center	Transit Center Connection Protection	Manages the coordination of transit transfers between routes within a single transit agency, between routes of different transit agencies, or between different modes
Transportation Information Center	TIC Data Collection	Collects transportation-related data from other centers, performs data quality checks on the collected data and then consolidates, verifies, and refines the data and makes it available in a consistent format to applications.
	TIC Trip Planning	Provides pre-trip and en-route trip planning services for travelers
Traveler Support Equipment	Traveler Trip Planning	Provides a personalized trip plan to the traveler
Vehicle OBE	Vehicle Trip Planning and Route Guidance	Includes the in-vehicle system that coordinates with a traveler information center to provide a personalized trip plan to the driver

2.2.2.2 Physical Architecture

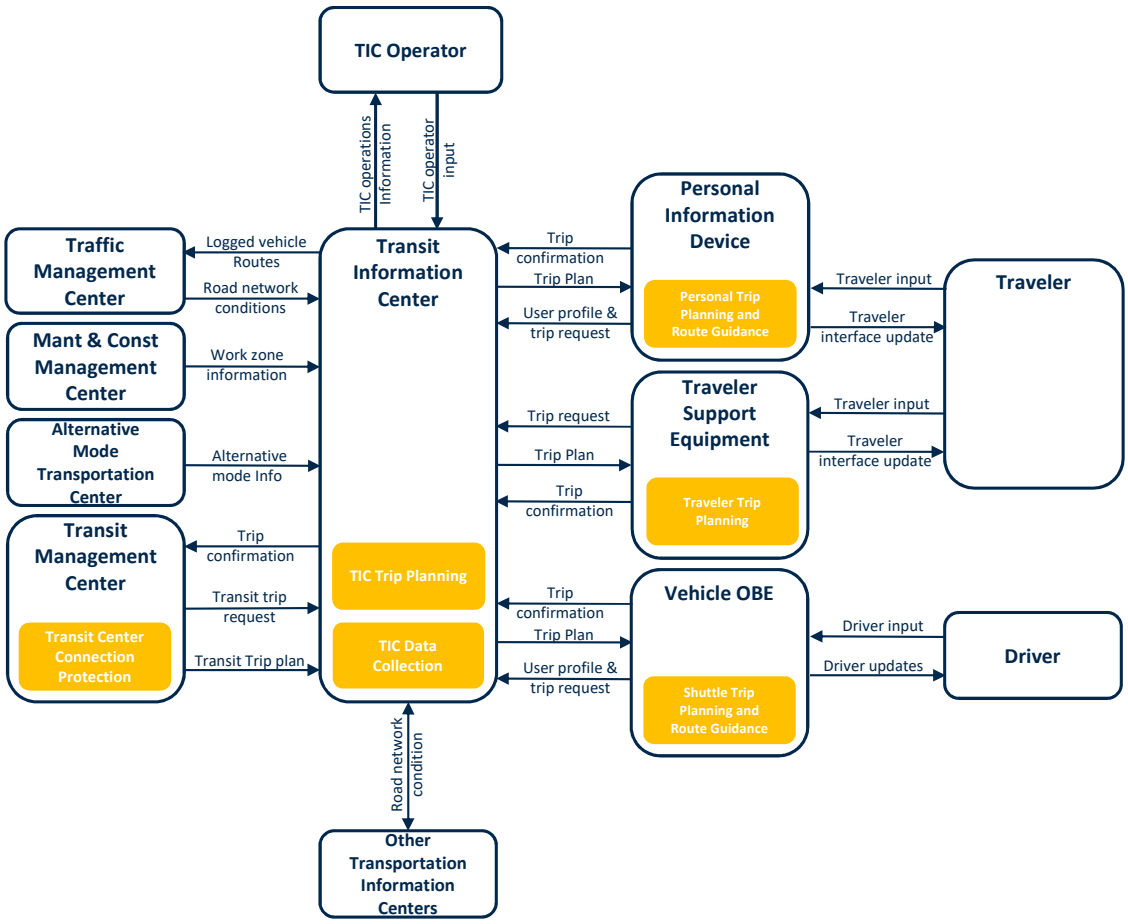


Figure 7: Physical architecture for the demand-focused solution

2.2.2.3 Enterprise Architecture

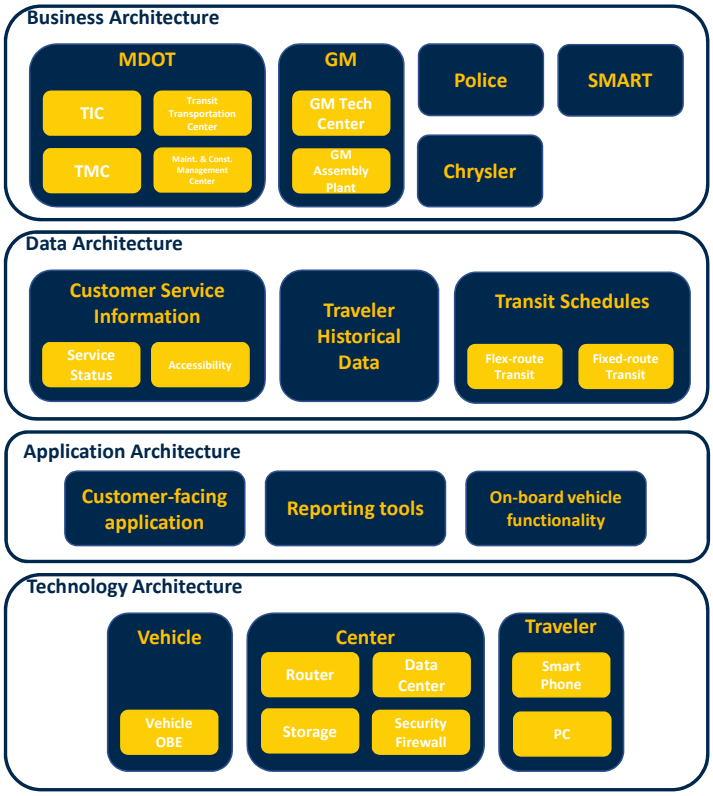


Figure 8: Enterprise architecture for the demand-focused solution

2.2.3 Cost Breakdown and Timeline

We make an estimation that the TMCs will purchase 10 hybrid buses for the flex route transit system. Each bus has a life-cycle of 12 years. The buses operate only on peak-hours, that is 7:00 am to 9:00 am and 4:30 pm to 7:30 pm every workday.

Table 7: Cost breakdown for the demand-focused solution [5, 6]

	Description	Unit Price	Subtotal
1	Hybrid Bus	$ 59,500	$ 595,000
2	Operation Cost	$ 102,000	$ 1,020,000
3	Fuel/Electricity Cost	$ 15,200	$ 152,000
			$ 1,767,000

Table 8: Timeline for the demand-focused solution

Task	Time Estimate
Stakeholder Meetings	1 month
Public Hearing	3 months
Bus Schedule Determination	1 month
Trial Operation	2 month

3 Anticipated Outcome

3.1 Benefits

3.1.1 Operational Benefits

The supply-focused solution requires the enhancement of the existing ITS system on corridor. This provides TMCs more accurate real-time data to analyze and predict the traffic conditions. The deployment of ramp-metering and other control systems allows TMCs to perform proactive strategies to better manage the traffic flows.

3.1.2 Mobility Improvement

One of the essential benefits is the mobility improvement. With the reduction of the traffic demand on the corridor, the recurring congestion will be mitigated. Meanwhile, the availability of flex-route transit service will decrease the total number of vehicle trips during the peak periods for the whole study area. As a consequence, the total travel time will be reduced.

3.1.3 Safety Improvement

By the enhancement of the ITS sytem, TMC will have a better detection of incidents. Meanwhile, the highway patrol will have a quicker reaction to the incidents that have been occurred due to the overall reduced travel time on corridor. Using ramp-metering and dynamic message signs to re-route the potential demand also help clean site of accidents faster.

3.1.4 Environmental Benefits

The possible environmental benefits include the reduction of fuel consumption, emissions and noises. These benefits are contributed by three key factors. Firstly, the mobility improvement results in the reduction of stop-and-go in traffic flows, which can significantly reduce the fuel consumption and emissions. Secondly, the deployment of flex-route transit system will potentially decrease the total number of vehicle trips. Thirdly, SMART bus service in Detroit area is increasing the number of hybrid electric buses to its fleet, which will bring further emission reduction.

3.1.5 Economic Benefits

On one hand, the proposed solutions do not involve with the roadway construction and attempt to utilize the currently available management tools and services to the largest degree. From this perspective, the solutions are cost-effective for the transportation agencies. On the other hand, the flex-route transit service provides an economic but still efficient travel mode for commuters. In addition, the fuel cost is reduced because of better mobility.

3.1.6 Cooperation

The implementation of these solutions will bring closer inter-agency collaborations, which will boost the area's transportation industry in a long term.

3.2 Impacts and challenges

Nevertheless, we also anticipate some possible impacts and challenges due to the implementation of the solutions. For example, the ramp-metering and re-routing information may lead to an increase of traffic demand on local arterial roads, which may not be welcomed by the local residents, the pedestrian and non-motorized road users. In addition, during the period of the installation of control devices, the normal traffic pattern may be significantly influenced. Thirdly, to implement the solutions successfully, the negotiation of all stakeholders is crucial, and early outreach is necessary.

4 Conclusion

In this document, we have presented a concept-of-operations for a two-sided solution to mitigate congestion in the I-75/I-696 influence area around Detroit, Michigan.

The supply-focused solution aims to make better use of the existing road infrastructure. In order to do so, an integrated dynamic ramp metering and arterial signal control plan is proposed for local on ramps to reduce highway slowdowns and shockwaves occurring from merging. Additionally for highway to highway merges from I-696 to I-75, a dynamic lane access is proposed to incorporate a shoulder lane for additional merge capacity.

On the other hand, there are physical limitations to the roadway network and with the population growing in Detroit and the surrounding areas, a solution is also needed that reduces congestion by reducing car use. The second part of the solution is demand-focused, aimed at providing commuters with viable transit alternatives to commuting by car. A flex-route bus transit system is proposed to transport commuters from high demand areas to large employers in the area, giving commuters a way to avoid congestion and save money, and reduce the number of vehicles causing congestion at peak hours.

In conclusion, recurring peak congestion in a high traffic corridor is a problem experienced in many metro areas across the country and has a number of potential solutions. This document has proposed a multi-pronged solution that we believe will help mitigate congestion not only in the short-term, but also in the long run in this growing metropolitan area.

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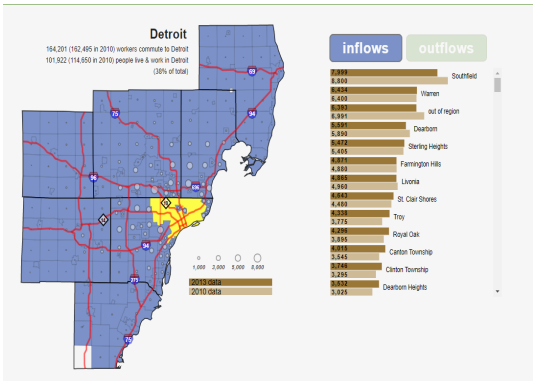
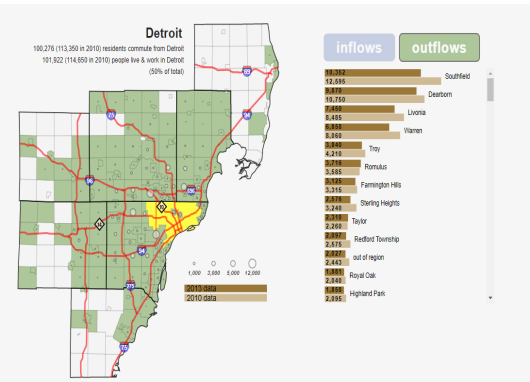
A Inflows and Outflows

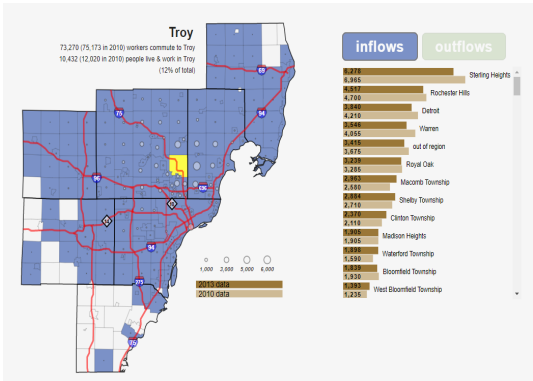


(a) *Inflow*



(b) *Outflow*

Figure A.1: Inflows and Outflows of Detroit



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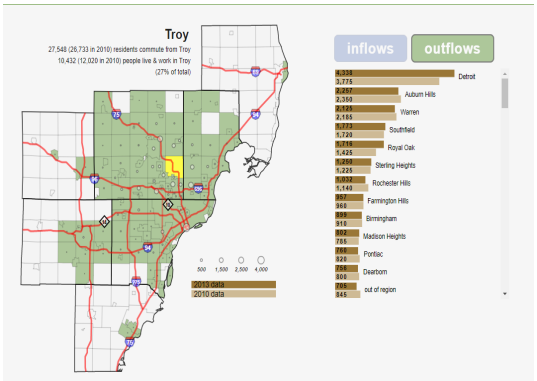
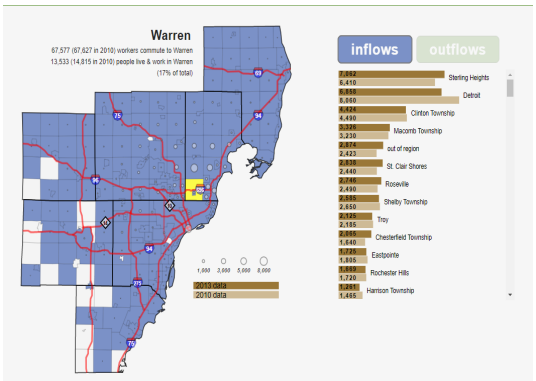


(b) *Outflow*

Figure A.2: Inflows and Outflows of Troy



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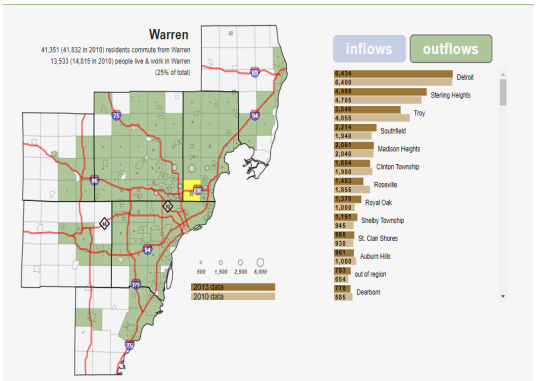
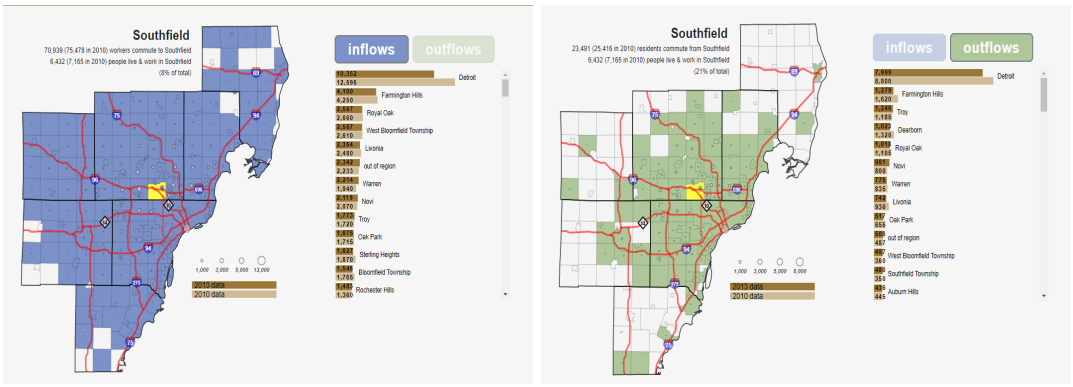


(b) *Outflow*

Figure A.3: Inflows and Outflows of Warren



(a) *Inflow* **(b)** *Outflow*

Figure A.4: Inflows and Outflows of Southfield