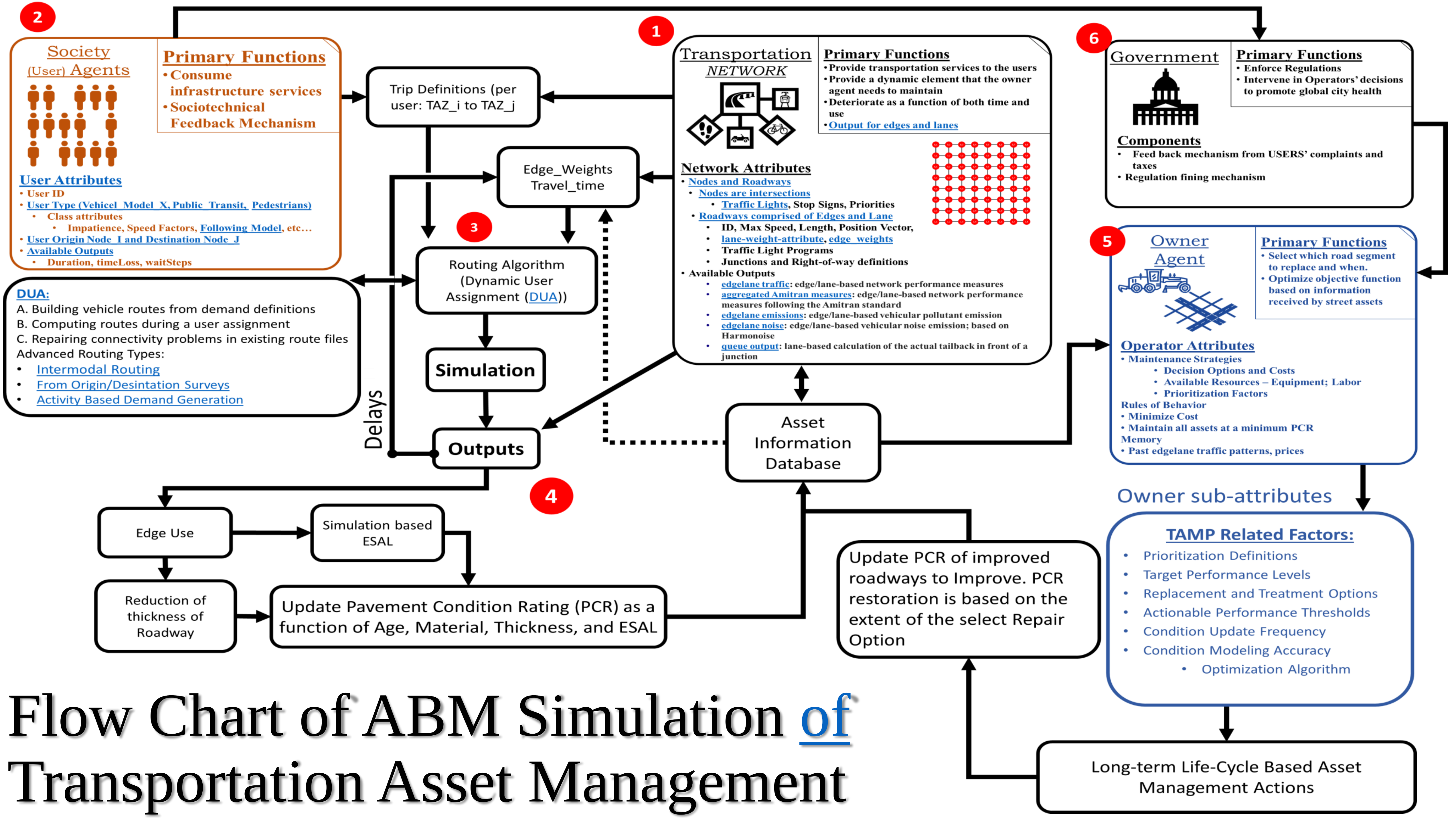
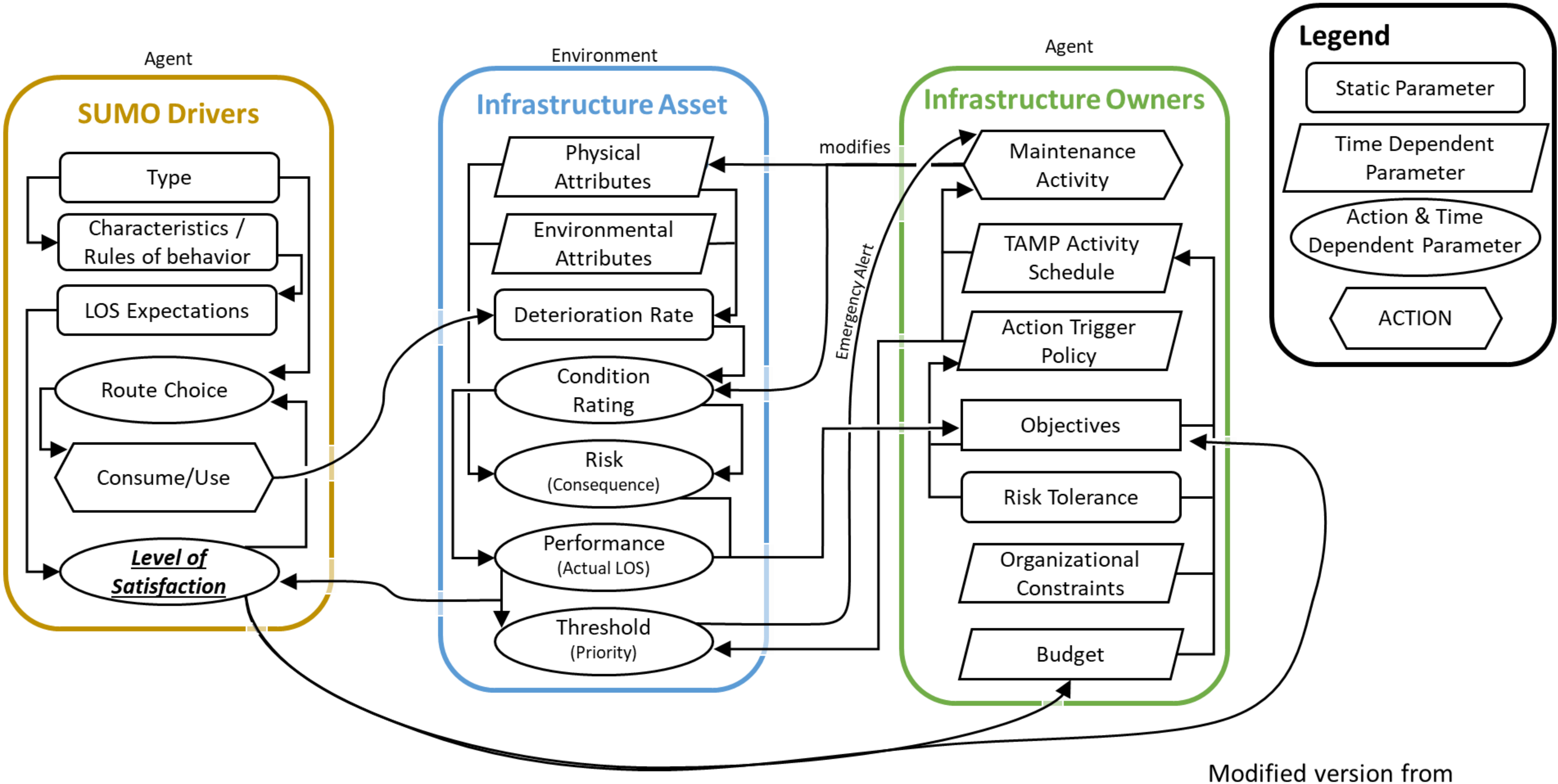
PhD Final Model

2/14/2018

Ben Cohen



Flow Chart of ABM Simulation of Transportation Asset Management

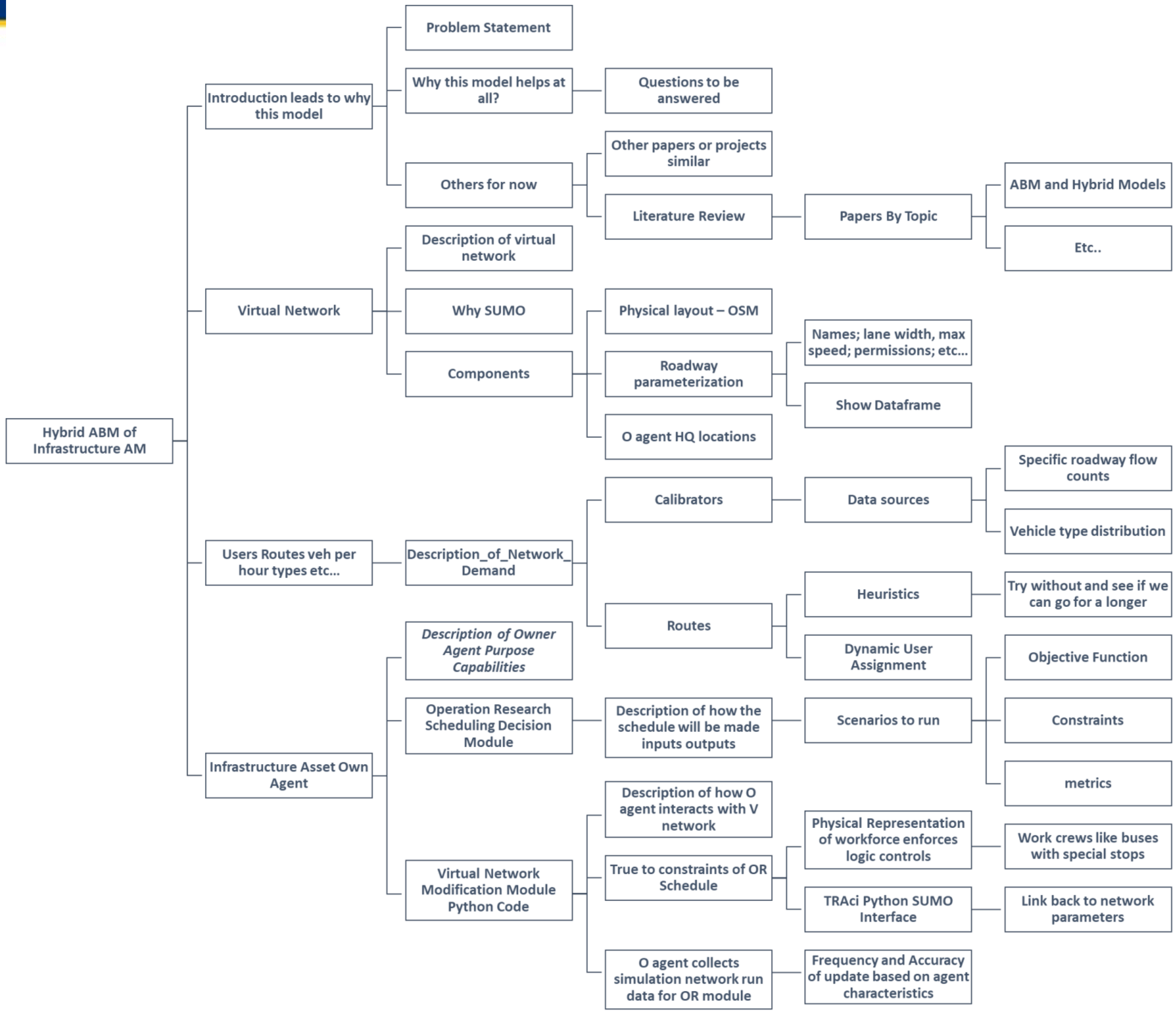


Modified version from

H. Osman / Automation in Construction 28 (2012) 45–57

Root Tree Structure

- Introduction leads to why this model
    - Problem Statement
    - Why this model helps at all?
        - Questions to be answered
    - Others for now
        - Other papers or projects similar
        - Literature Review
            - Papers By Topic
                - ABM and Hybrid Models
                - Etc..
- Virtual Network
    - Description of virtual network
    - Why SUMO
    - Components
        - Physical layout – OSM
        - Roadway parameterization
            - Names; lane width, max speed; permissions; etc…


Hybrid ABM of Infrastructure AM
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Show Dataframe
O agent HQ locations
Users Routes veh per hour types etc...
Description_of_Network_Demand
Calibrators
Data sources
Specific roadway flow counts
Vehicle type distribution
Routes
Heuristics
Try without and see if we can go for a longer
Dynamic User Assignment
Infrastructure Asset Own Agent
Description of Owner Agent Purpose Capabilities
Operation Research Scheduling Decision Module
Description of how the schedule will be made inputs outputs
Scenarios to run
Objective Function
Constraints
metrics
Virtual Network Modification Module Python Code
Description of how O agent interacts with V network
True to constraints of OR Schedule
Physical Representation of workforce enforces logic controls
Work crews like buses with special stops
TRAci Python SUMO Interface
Link back to network parameters
O agent collects simulation network run data for OR module
Frequency and Accuracy of update based on agent characteristics

INTRO

- Problem statement

Can we model the current state of TAM at the Local Municipalities (at the City Ownership Level) [via a Hybrid ABM] to Examine Potential Performance Gains Through A Multi-objective Sociotechnical Optimization

…

Surface Transportation Funding Bills - MAP-21 and the FAST Acts

Transportation Planning [1201 & 1202]

- MAP-21 made a number of reforms to the metropolitan and statewide transportation planning processes, including incorporating performance goals, measures, and targets into the process of identifying needed transportation improvements and project selection. The FAST Act includes provisions to support and enhance these reforms. Public involvement remains a hallmark of the planning process.

National Highway Performance Program [1106]

- The FAST Act provides an estimated average of $23.3 billion per year for the NHPP, which will **support** the **condition** and **performance** of the National Highway System (NHS)
- Enable the construction of new facilities on the NHS
- E**nsure** that investments of Federal-aid funds in highway construction are directed to support progress toward achieving performance targets established in a State's **asset management plan** for the NHS.
    - The FAST Act also makes the following changes to NHPP eligibilities:
        - It allows States to use NHPP funds for reconstruction, resurfacing, restoration, rehabilitation, or preservation of a non-NHS bridge if the bridge is on a Federal-aid highway.
        - At a State's request, the Secretary now may use a State's NHPP apportionment to pay the subsidy and administrative costs for TIFIA credit assistance for an eligible project.
        - It provides specific NHPP eligibility for vehicle-to-infrastructure (V2I) communication equipment.

Recap – Current State of Affairs of in Transportation Asset Management

1. While the **current** transportation infrastructure asset management plans analyze **assets as part of an inventory**, they **fall short in providing adequate** overall network level performance.
2. The **limited available transportation funds** are used to address critical short term concerns, while long-term cost savings and performance enhancement measures are push aside.
3. The **"worst first"** prioritization methodology can lead to unintended changes and greater future expenditures:
4. The transportation network has many links **(interdependencies**) with other engineered and "natural" systems. This creates a **high level of complexity** within the network that is difficult to predict its future state.
5. Natural and man-made events, such as flooding or new development, can create **additional stresses** to the system. There is a demand that is not currently being met, at the local level, to be able to simulate these events and develop strategies to mitigate their effects.
6. States are likely to begin to put pressure on local municipalities to **comply** with the data collection and reporting standards required under MAP-21 and the FAST act. It is important to explore how these new requirements can be beneficial to the old way of business for the cash strapped local DOTs.

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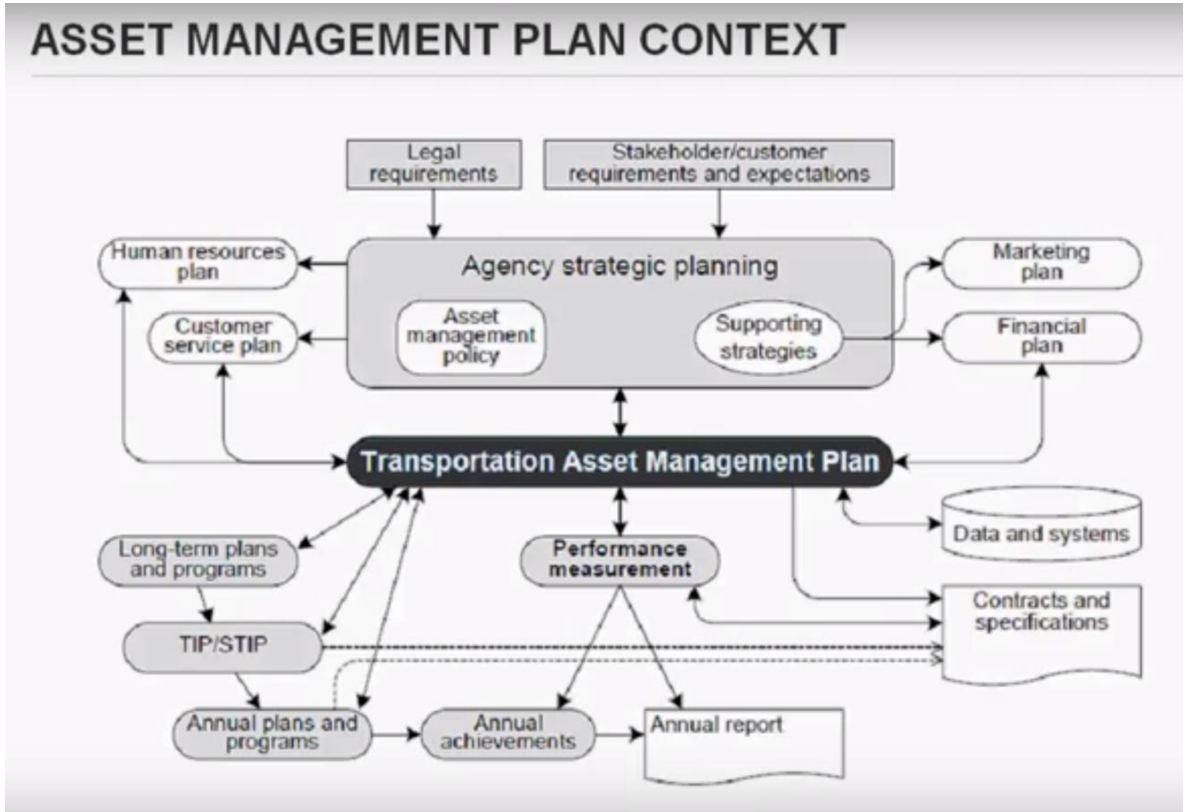
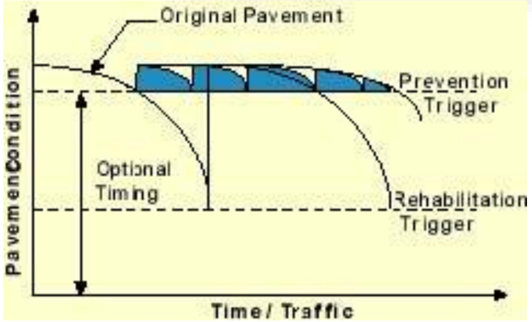
Asset Management – FHWA Style





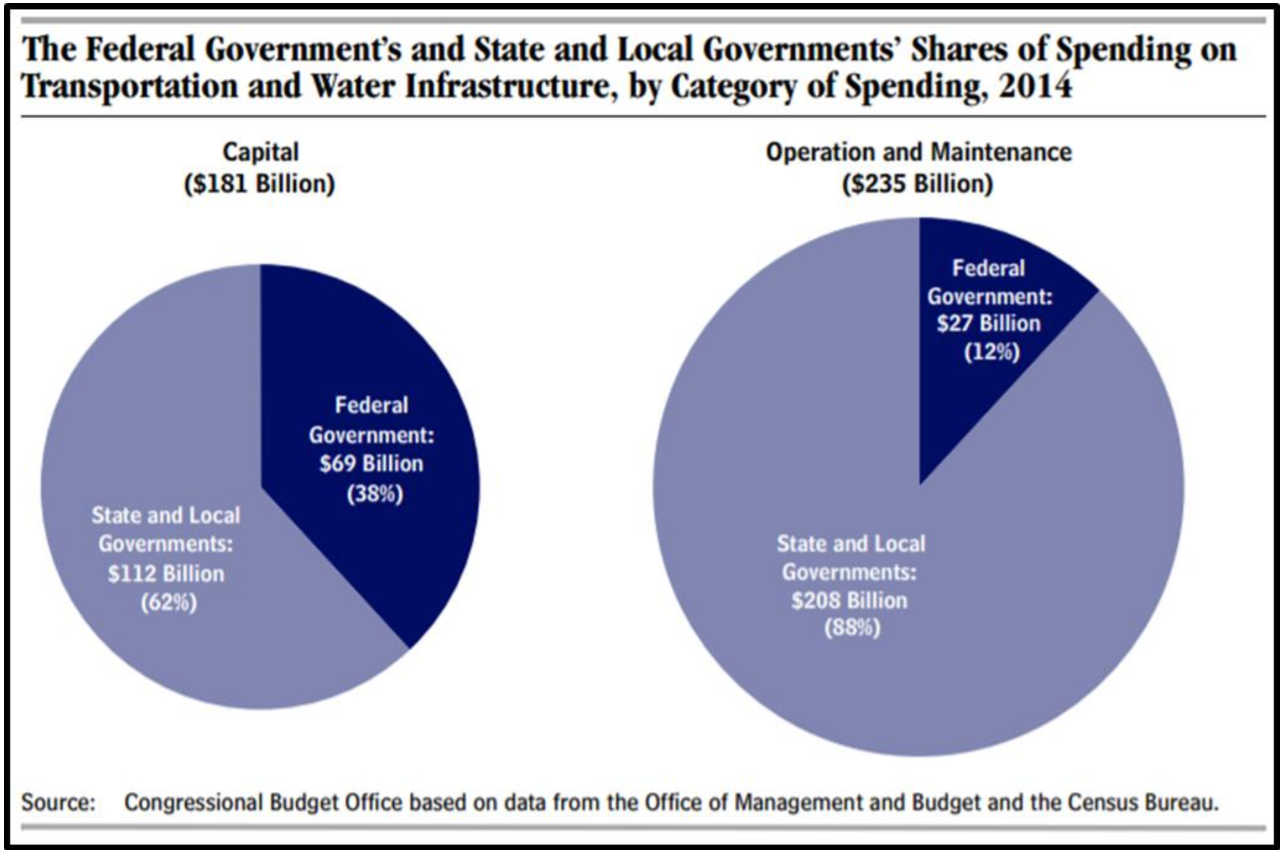
"The goal of infrastructure asset management is to meet a required level of service, in the most cost effective manner, through the management of assets for present and future customers." - NAMS

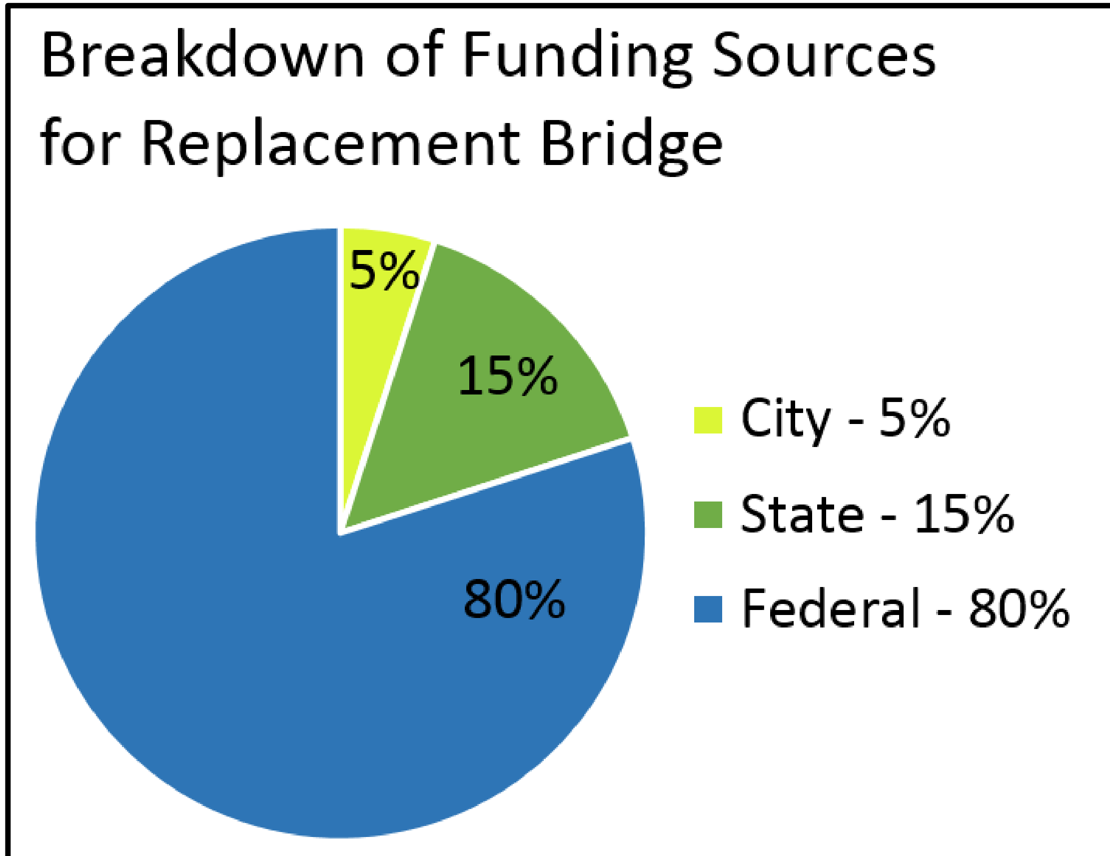
The systematic approach to the integrated management of the highway infrastructure to deliver agreed service levels at minimum whole-life value

Recognize that the revenue available for asset management is a significant constraint!

Challenge: Fed Government Does Not Encourage Maintenance

- Operations and Maintenance responsibility is assigned to State and Local Gov's - ***unless emergency retrofit or renewal is required.***
- The Federal Government has been changing the language included in Federal Transportation Bills since the 1980's, but unfortunately there is still a wide gap in how funds are allocated between new vs preservation (FHWA 2015; PEW, 2015)



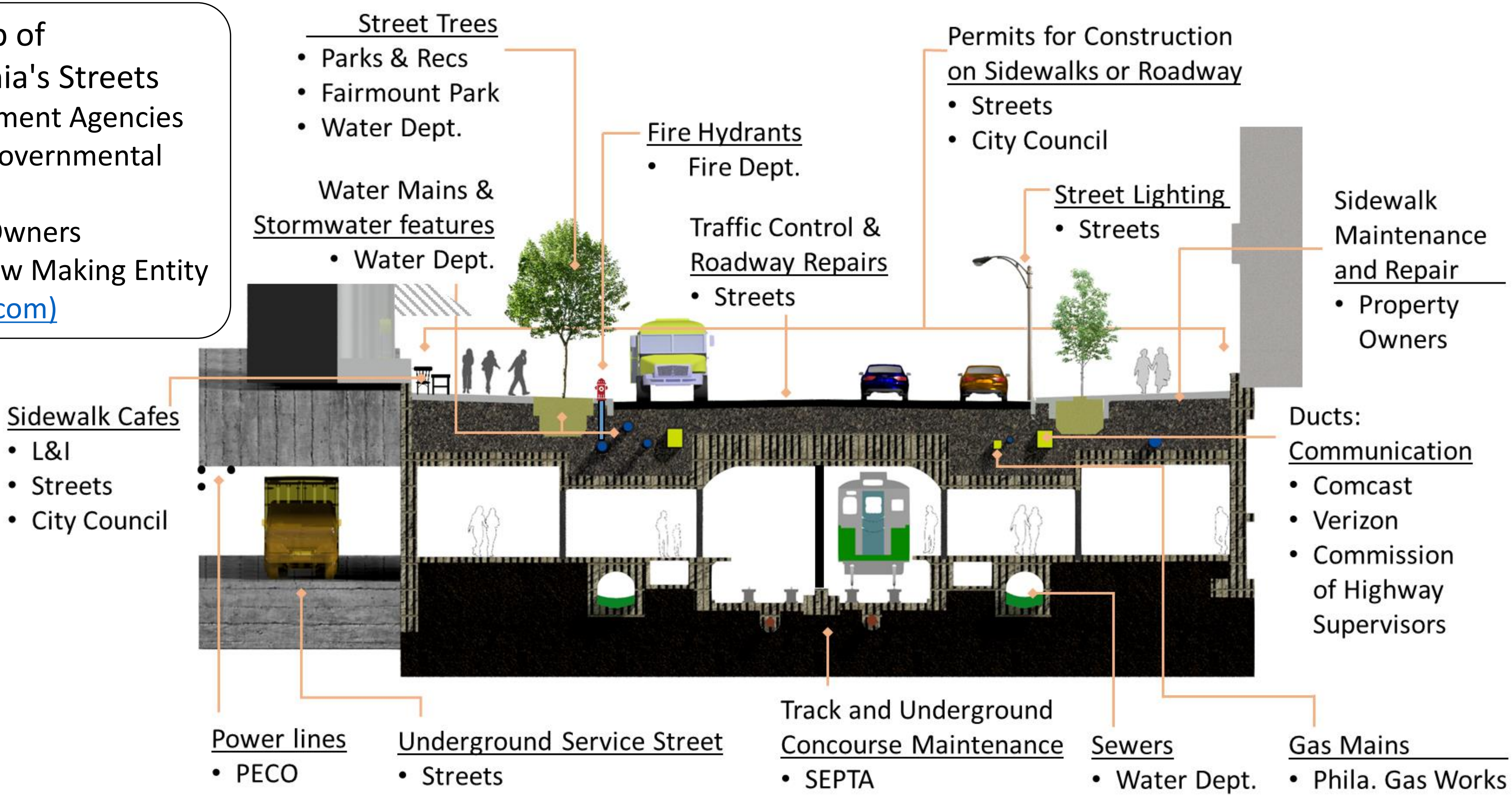


Different Ownership Across the Spring Garden Street Viaduct – Restored 2015

Challenge: Complete Care of a City Street

Cross-section of East Market Street with Assets and Responsible Steward

Ownership of Philadelphia's Streets
7 – Government Agencies
2 - Quasi-governmental agencies
4- Private Owners
1 – Local Law Making Entity
(PlanPhilly.com)



The Way Forward

- Data driven policies and actions
  - Pros:
    - Transparency
    - Lower Life Cycle Costs
    - Performance Driven Outcomes
    - …
  - Cons:
    - Large Initial Investments
    - Agency Resistance to Change
    - Sociotechnical Concerns
      - Socially connected issues never have an optimal solution for everyone.
        - How are priorities established?
        - How do the trade-offs effect the multi-domain metrics?
      - Political Election Cycles << Asset Life-Span

TAMP SUB_TREE

Life-Cycle Phases

Key Element #1: The whole-life/life cycle of an asset is considered

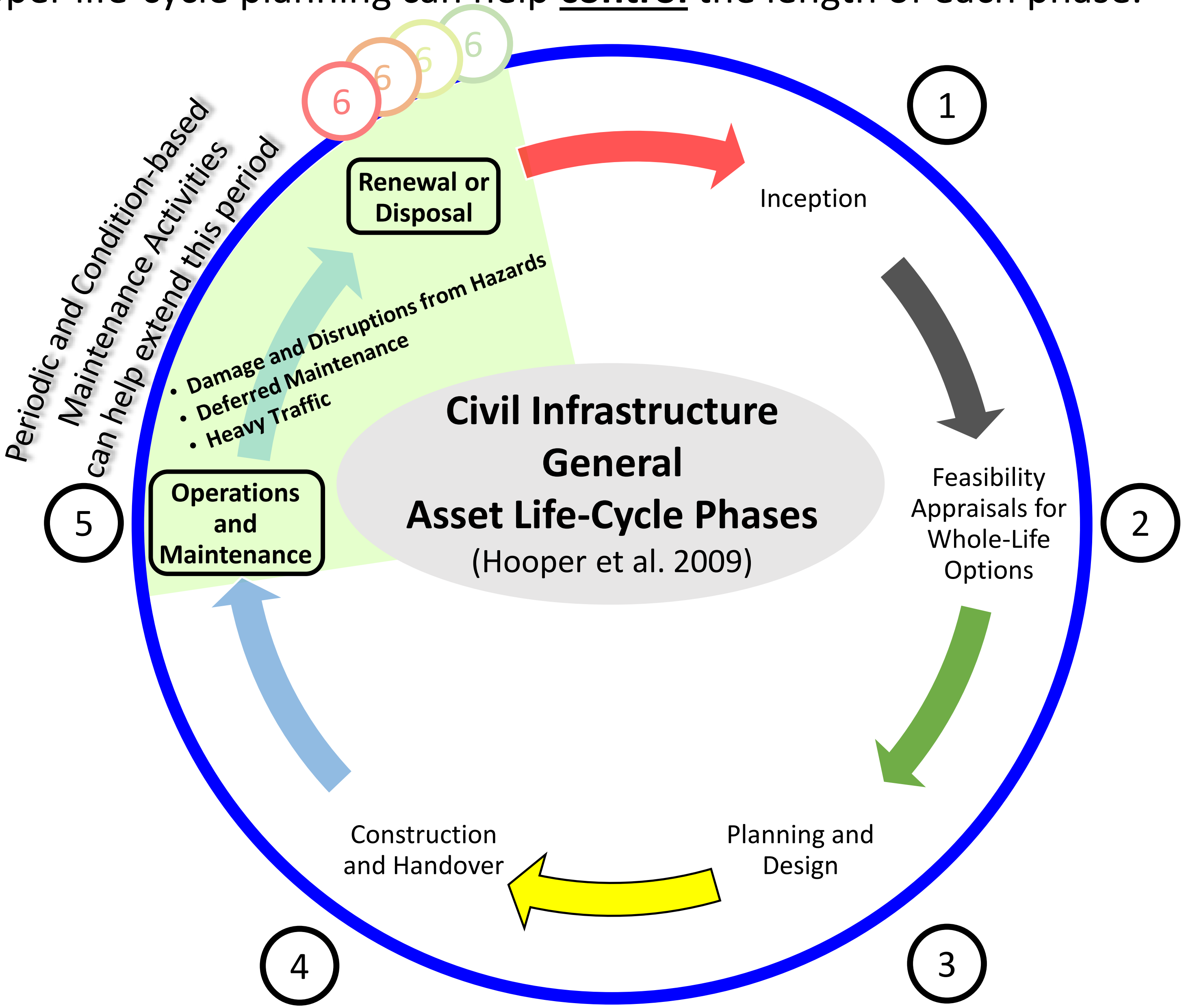
The goal of AM is to maximize the utility of an asset:

- Requires longer initial phases to ensure that the foreseeable future needs asset are not negatively impacted by an initial short term cost minimization approach
- This can result in a significant increase in the length of the operations and maintenance phase

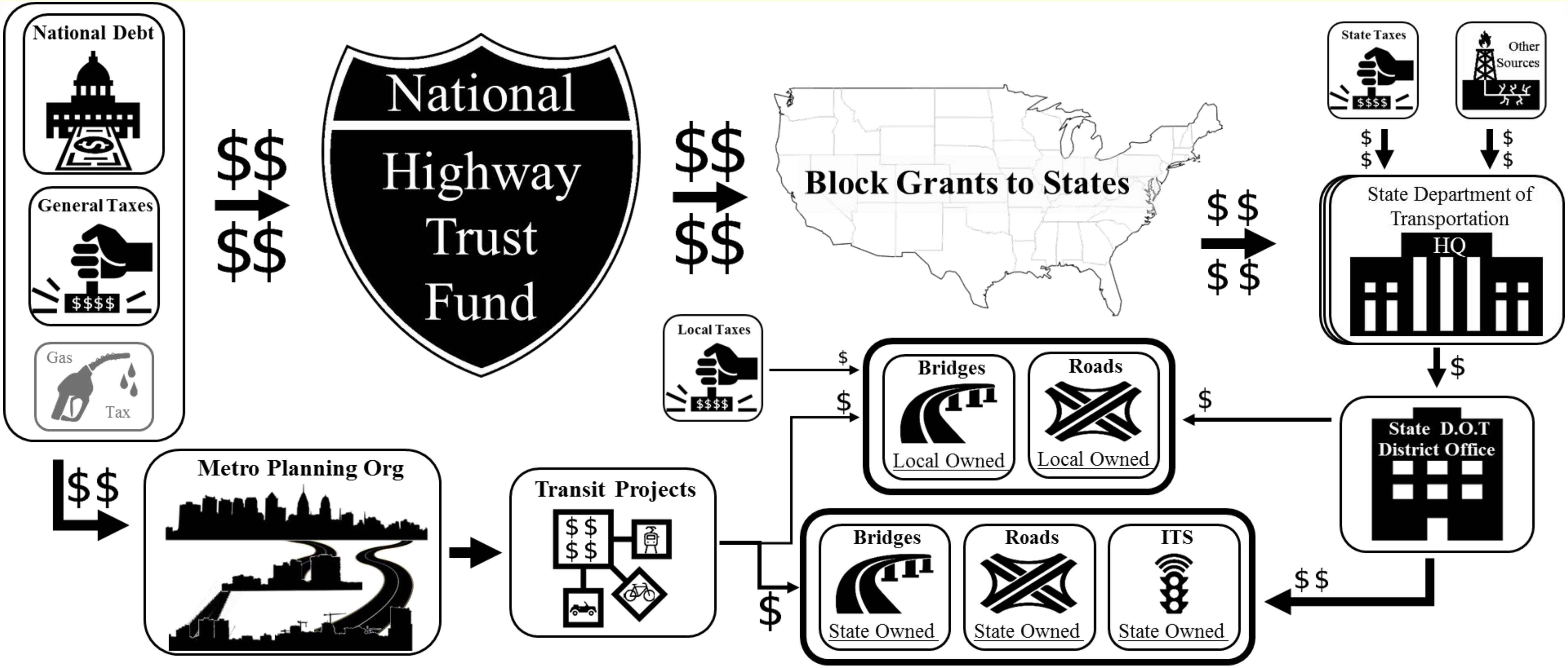
Ad-hoc planning and maintenance leaves owners without a clear understanding of the future resources that each asset might require

- Under this management style:
  - Proper funds can not be allocated beforehand, because the owner is not aware of the asset's potential needs
  - Assets deteriorate at a higher rate, because funds are typically not available or willing to be spent of *preventative maintenance* activities, which can elongate an asset's life-span and save on costly large repairs and renewal activities.

Proper life-cycle planning can help **control** the length of each phase.

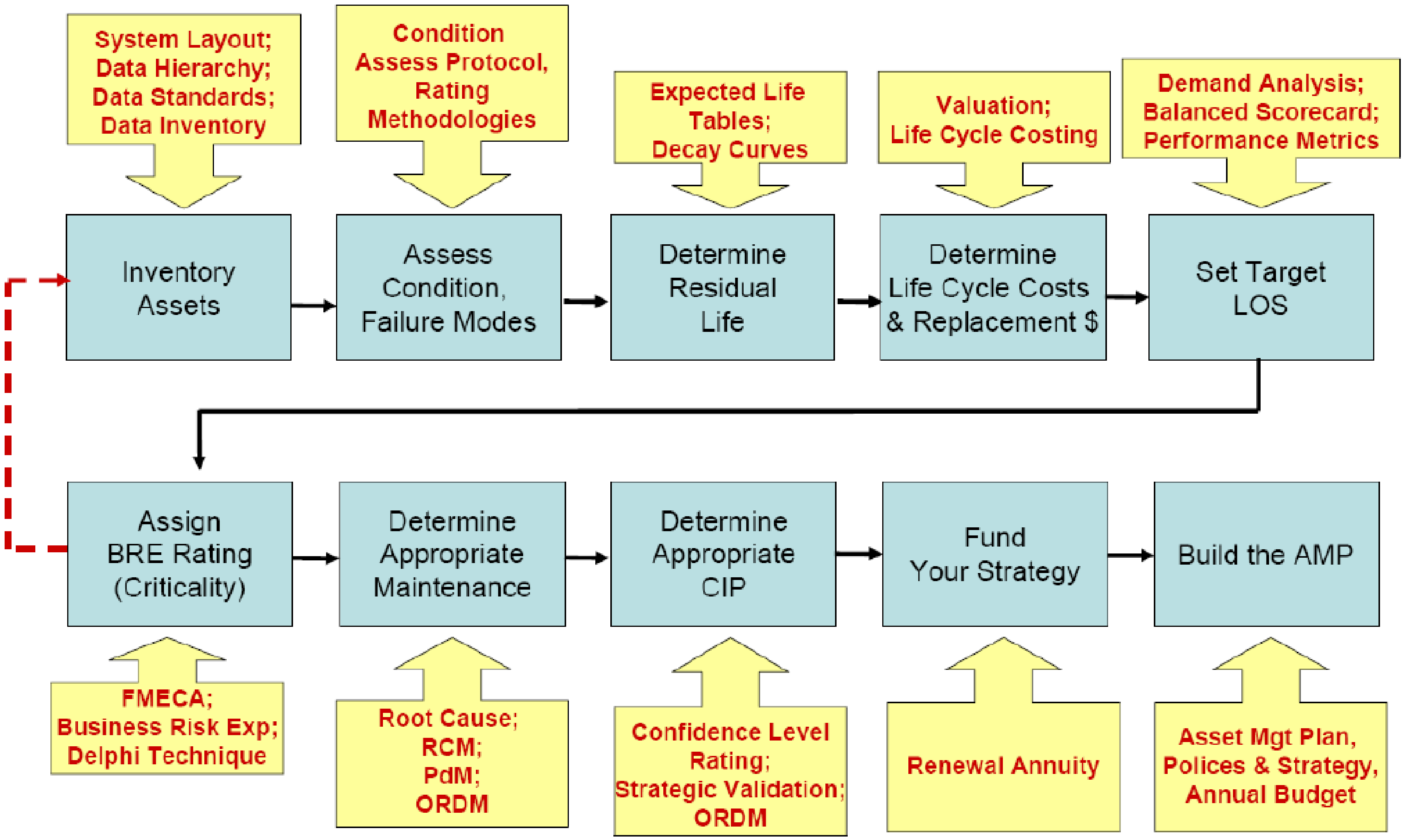


How Does the Money Flow into State and Local Bridges?

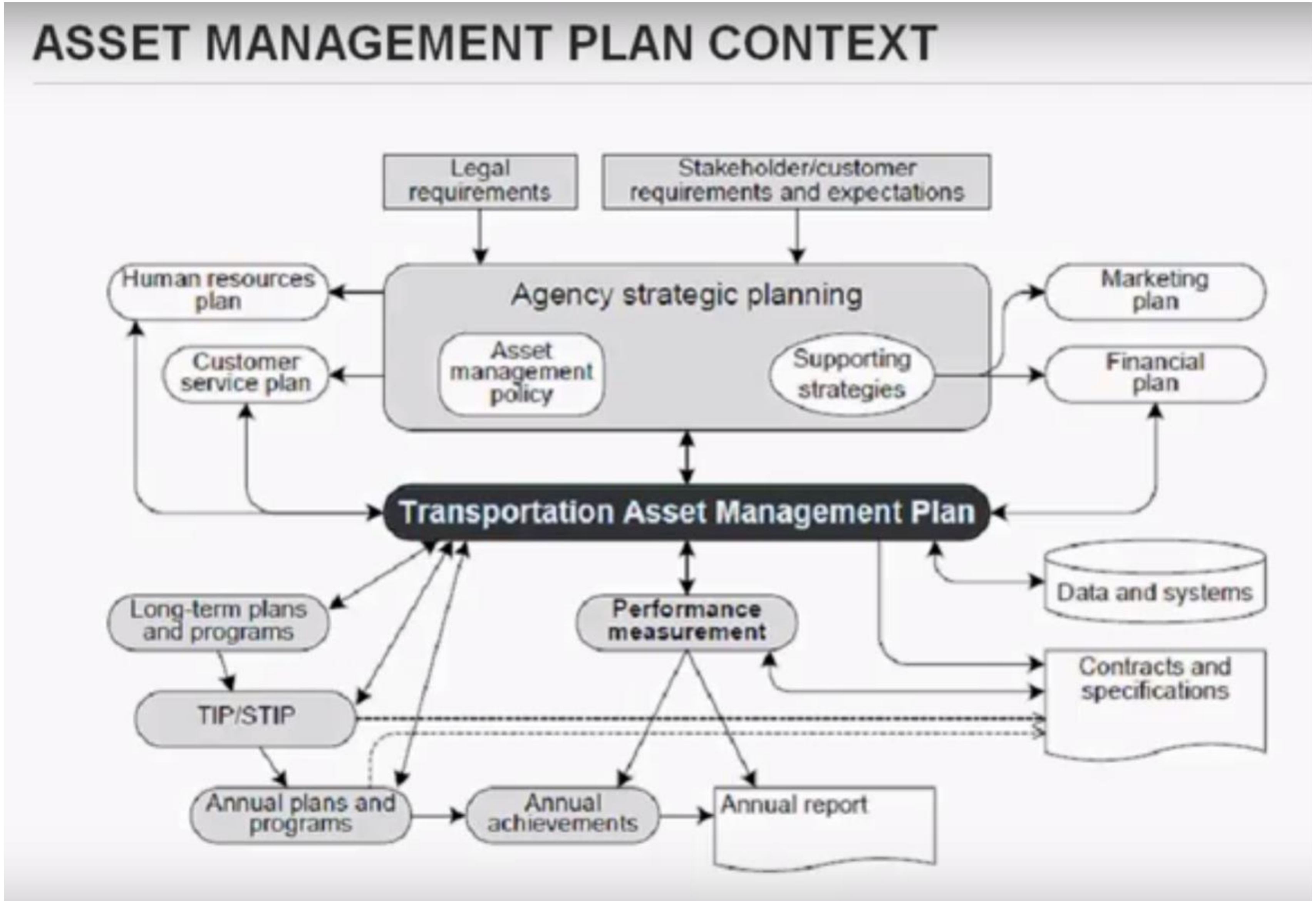


Infrastructure Asset Management Flow Chart

International Infrastructure Management Manual



Other TAMP Strategies



Key Elements of Infrastructure Asset Management

1. Taking a life-cycle approach
    - The whole-life/life cycle of an asset is considered
2. Developing cost-effective management strategies for the long-term
    - Optimization - maximizing benefits by balancing competing demands
    - resource allocation - allocation of resources based on asset needs
3. Providing a defined level of service and monitoring performance
    - Customer Focus - explicit consideration of customer expectations
4. Understanding and meeting the impact of growth through demand management and infrastructure investment
5. Managing risks associated with asset failures
6. Sustainable use of physical resources
7. Continuous improvement in asset management practices

TAMP SUB_TREE

Limit States and Performance Criteria for Whole Life-Cycle Management

Infrastructure Life-Cycle Performance Management

Limit State *Return Period*	**Utility and Functionality** Everyday	**Serviceability and Durability** 5 -20 Years	**Life Safety and Stability of Failure** 50-750 Years	**Resilience** In the case of extremely rare catastrophic events >1000 Years
Asset Management	**Operational Management**	**Maintenance Management**	**Multi-hazard Risk Reduction and Management**	**Disaster Response Planning and Emergency Management**
Performance Criteria	Minimize Disruptions Maximize Reliability • Relative Importance for Network, GDP, National Security, other • Operational efficiency, Safety and Security • Robust and predictable revenue	Effective & Economical : • Inspection • Maintenance • Repair • Rehabilitation Assurance of Lifecycle Revenue for Effective Preservation	Assurance of Life- Safety, Control of Failure Mode, & Reparable Damage: • Quick recovery of normal operations following any hazard (days-months)	Minimize Casualties and Sustain an Acceptable Level of Function for: Society, Economy, Ecology, Government and Critical Infrastructures • Resourceful and Adaptive Society, Economy, Public Health and Emergency Response • Adaptable and flexible lifeline systems • Protected escape and evacuation capacity • Non-Fragility of Interdependent Infrastructures
	Throughout entire lifecycle			

How Will This Model Attack the Problem?

- Sociotechnical concerns
  - Measuring direct feed back from "Users"
  - Checking for unforeseen consequences.
  - …
- Engineering Optimization
  - Principles of Operations Research
    - Linear Programing with objective functions and constraints that reflect the different agencies
- Traffic Engineering
  - Deterioration and Performance Modeling
  - Performance Metrics

Questions to be answered by Scenarios

1. ~~What are the impacts of **New Development** to the immediate surrounding roads and the overall performance of the network?~~
   - ~~**Set up:** Increase demand in a local area~~
   - ~~**Assessment** - Changes In: User Travel-Times and User Experienced Level of Service (ELOS); Asset and Network Performance; Asset Life-Cycle Costs (LCC); Maintenance Activities~~

2. ~~How should **assets be prioritized for resilience** retrofitting to reduce the impact from extreme weather events? (**Flooding**)~~
   - ~~**Set up:** Remove roadways that are within the 500 year flood plane;~~
   - ~~**Assessment** - Changes in traffic patterns; Identify, with multi-objective criteria, critical assets which should be prioritized to ensure maximize network flow and connectivity;~~

3. How can the **scheduling of maintenance and construction activities** impact the immediate surrounding roads and the overall performance of the network?
   - **Set up: Construction Delays** – Active road work = road/lane closure; Milled road surface = reduced condition levels to impact max travel speed
   - **Assessment**: Under different scheduling methodologies (ad-hoc; asset focused optimization; network focused optimization; socio-technical optimization) – what are the different impacts to Travel-Times and ELOS; Asset and Network Performance; Asset Life-Cycle Costs; Maintenance Activities

4. How does the **variability of future funding** effect the management decisions and LCCs?
   - **Set up:** During long term planning routine increased or decreased the **variability** of the next year's **budget**. Budget amount and variability will be based on the financing mechanisms available to the owner
   - **Assessment**: Are there changes in spending patterns? Are their any significant efficiency gains between different financing structures?

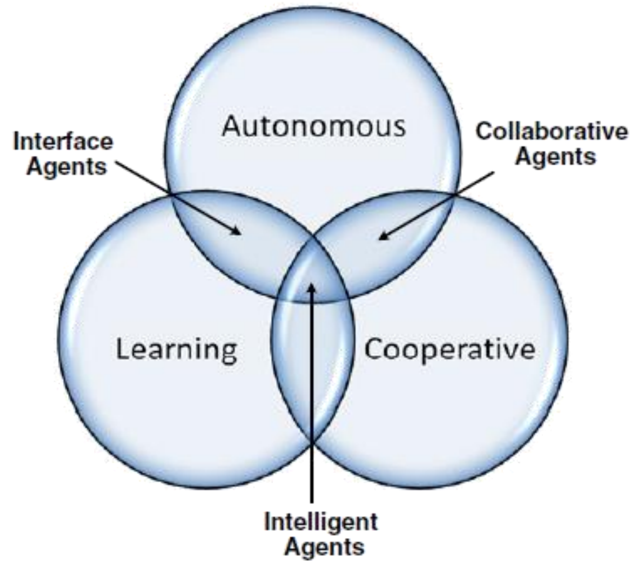
5. Is there a significant impact from **data collection and utilization methods** to the network's performance, ELOS, and owner operational behavior?
   - **Set up:** Conduct a sensitivity analysis of the owner agent's **data accuracy** (possibility of reporting no change in condition)**, resolution** (how many attributes of each asset are collected; linked to model sophistication)**, and update frequency** (how often is the data refreshed)**,** and **predication model sophistication** (regional models, simple linear regression model (local data)
   - **Assessment:** Are there significant changes to the network's performance, ELOS, and owner operational behavior?

Recap – Deliverables

- Create an ABM of the management of transportation assets in a segment of Philadelphia to assess how the different TAMP factors effect the life-cycle cost of the assets, network performance, and users' experiences.
  - The model must have the ability to:
    - Simulate of user behavior – variable driving parameters, rerouting capabilities,
    - Capture users' experience – level of service received from assets per user
    - Simulate the deterioration of roadway conditions and have the conditions effect the users' experience
      - *Max Speed* a function of *condition*
      - *Condition* a function of equivalent single axle load ESAL and possibly geographical location if the proper models can be found
      - Closeable lanes to simulate road work
    - Vary starting parameters to mimic **actual condition of existing network** and to simulate **disruptions caused by natural disasters**
    - Simulate **System Level Transportation Asset Management Decision Processes** with Owner Agent Framework
      - Owner agents must be able to develop an action plan based on a variety of inputs and constraints
        - Roadway condition data; traffic jams; accidents; predicted future needs; political pressure; Threshold Triggered Actions
    - Multi-variate system performance metrics to base optimization
      - Individual Asset and Network Cost minimizing; Network Performance Maximization; Maximize User Experience
  - Capture Sociotechnical and Engineering Interdependencies
    - Random disruptions (closures, drop in condition rate, etc. related to non-owner related construction work)
    - Link roadway condition and time lose to user experience
    - Link user experience to political component of prioritization of maintenance work done to an asset

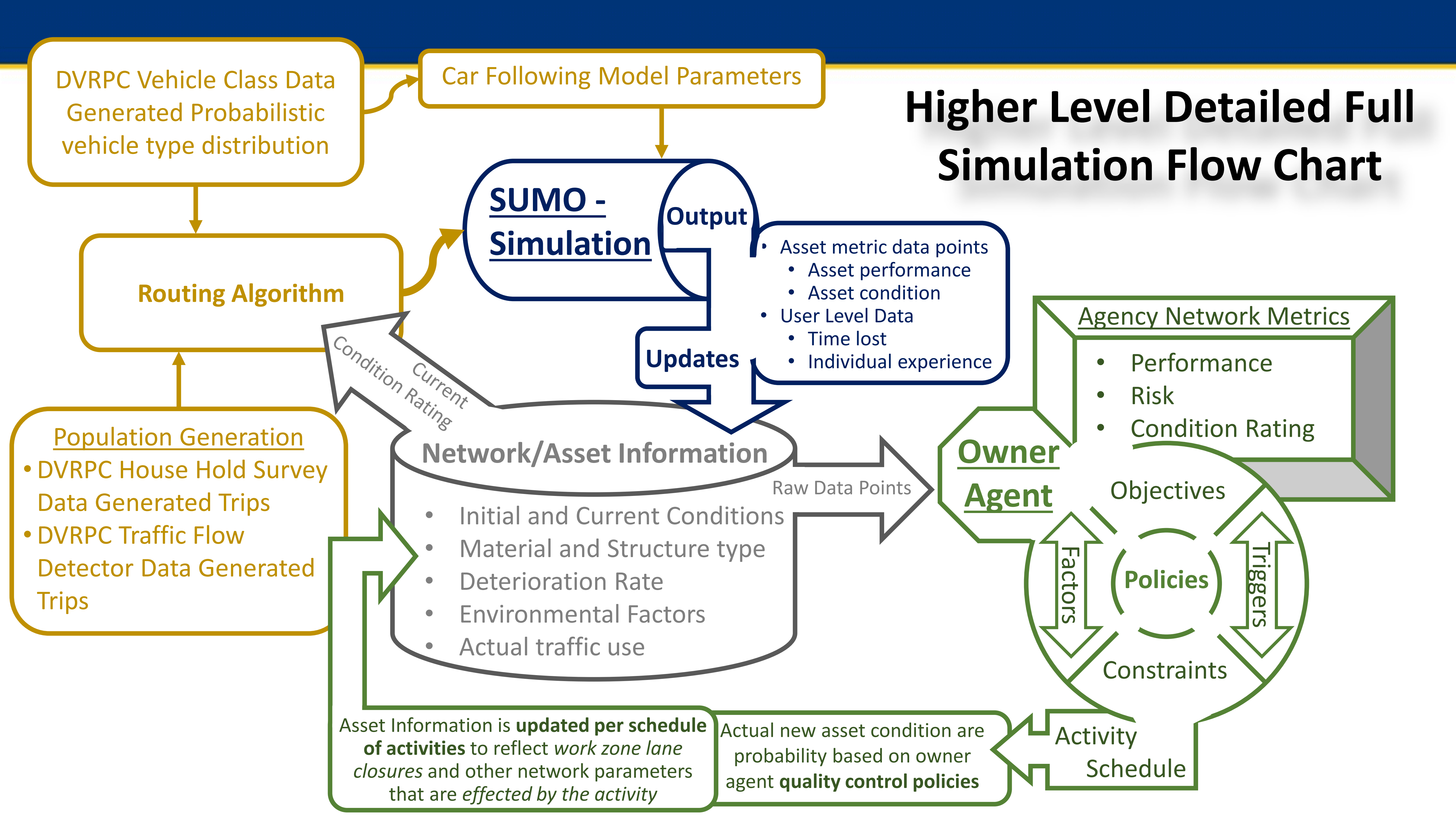
What is Agent Based Modeling?

- An agent based model (ABM) utilizes a bottom up approach to define the rules of behavior and interactions for different actors/individuals within a complex adaptable system. The purpose is to simulate the "agents" interactions to observe and study the resulting emergent behavior.
- Agents can be thought as an individual software packet that through its interactions with its environment and other agents
- Agents typically have **three basic functionalities**, the ability to operate **autonomously**, **cooperatively**, and **learn** from their encounters. An *intelligent agent* has all three capabilities (Osman, H. 2012).
  - This model will contain many different dynamic components, but the **owners**, and potentially **elected officials**, will be the ***only** true intelligent agent*
    - The other components being the **users** and **infrastructure assets** have dynamic behavior and **respond** to their environment and interactions
      - **User's** will not be able to operate in a cooperative manner
      - **Assets** will deteriorate based on their geographical location and simulated use



Agent Types *(Osman, H 2012)*

Explain Model Here



DVRPC Vehicle Class Data Generated Probabilistic vehicle type distribution
Car Following Model Parameters
Higher Level Detailed Full Simulation Flow Chart
SUMO - Simulation
Output
Asset metric data points
Asset performance
Asset condition
User Level Data
Time lost
Individual experience
Updates
Routing Algorithm
Current Condition Rating
Agency Network Metrics
Performance
Risk
Condition Rating
Population Generation
DVRPC House Hold Survey Data Generated Trips
DVRPC Traffic Flow Detector Data Generated Trips
Network/Asset Information
Raw Data Points
Initial and Current Conditions
Material and Structure type
Deterioration Rate
Environmental Factors
Actual traffic use
Owner Agent
Objectives
Factors
Policies
Triggers
Constraints
Activity Schedule
Asset Information is updated per schedule of activities to reflect work zone lane closures and other network parameters that are effected by the activity
Actual new asset condition are probability based on owner agent quality control policies

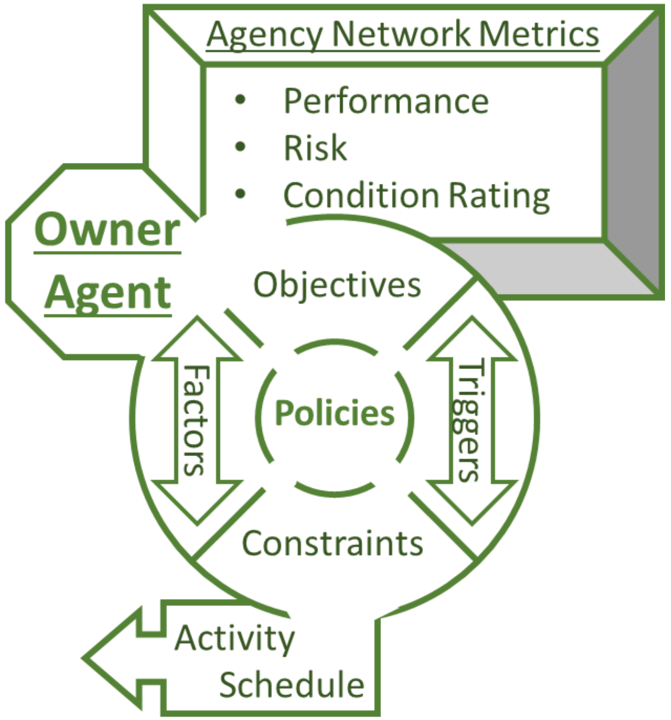
Components of the Simulation

- Graph model of physical network topology – Deterministic and Probabilistic
  - How many lanes are on each street (edge)? Where as the intersections (nodes) between the length of the street? - Deterministic
  - Control Systems
    - What are the control parameters at the different intersections – Traffic Lights (phase timing), Stop Signs, Merging, etc. - Deterministic
    - Lane designations and permissions – Turning lanes, Bus Lanes, target lanes at junctions - Deterministic
    - Speed Limits - Deterministic
    - Pavement deterioration rate – Statistical and Probabilistic
      - Based on FHWA Pavement Deterioration Models and simulated use
- Network Use – Statistical and Probabilistic
  - User – Car Following Model – Vehicle type differences: accelerations, decelerations, deviation from speed limit, driver imperfection, etc - Probabilistic
  - Demand – Trips: Who, From, To, When, How?
    - DVRPC – House Hold Trip Survey Data ~1,700 unique trips - Deterministic
    - DVRPC – Traffic count data - Statistical
    - Validation of new trips and data – Statistical
      - Matching output trends to known traffic patterns - Statistical and Probabilistic
      - Calibrator tool (adds or removes traffic during the simulation to match count data) - Probabilistic
- Simulation – Users + Trips + Network + Control Systems – *Network Performance is Non-Deterministic*
  - How were the different assets used? – Current Pavement Condition Rating
  - How did the network of assets effect the user?
    - User delayed in jam? User involved in an accident? User arrives significantly later at destination than expected?
- Transportation Agency Decision Simulator- Statistical and Probabilistic, but Simulated Emergent Behavior is Non-Deterministic

Owner Agent – Tentative Rules of Behavior – Detailed

<u>Rules of behavior</u> are Statistical and Probabilistic, but Simulated Emergent Behavior is Non-Deterministic

- Non-linear programing – Schedule Optimizer
  - Objective function variation: short term cost minimization, overall network performance maximization, LCC minimization, Holistic Livability maximization
  - Subject to:
    - Budget – next year's budget (Probabilistic) – soft constraint
    - Number of overlapping activities – (Deterministic) – hard constraint – Availability: Labor Force, Equipment, Material In-Stock, Completion time of activity (Probabilistic)
    - Available activities - (Deterministic) – Work force capabilities
    - Effectiveness of activity – (Probabilistic) – Variation in condition increase base on quality control practices
    - Cost of project – (Heuristics and Probabilistic) - variations in material cost based on seasonal adjustments and market fluctuation
    - Scope of activities – (Deterministic) – soft constraint – Policy driven – example: PWD can not contribute funds to any project that's scope is outside of their jurisdiction, due to their bonding arrangement.
    - Condition data:
      - Probabilistic – Data collection practices → probability inspection data is reported correctly
      - Deterministic – Data collection practices → condition data update rate
    - Indirect Deterioration costs – Statistical and Non-Deterministic:
      - Importance factor: i.e. - Change in vehicle flow rate per year given no maintenance activities and default flow rates.
    - User experience - Statistical and Non-Deterministic:
      - Simulated vehicle interactions create differences between the routes expected travel-time and the actual travel time, experience is quantified as the piece-wise integral of the negative intensity over the time period above the threshold.

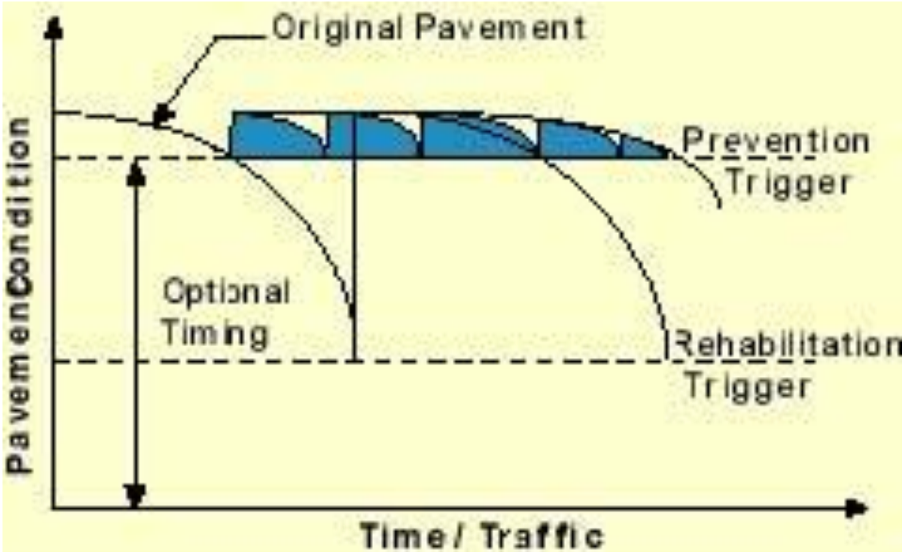


Owner Agent – Tentative Rules of Behavior

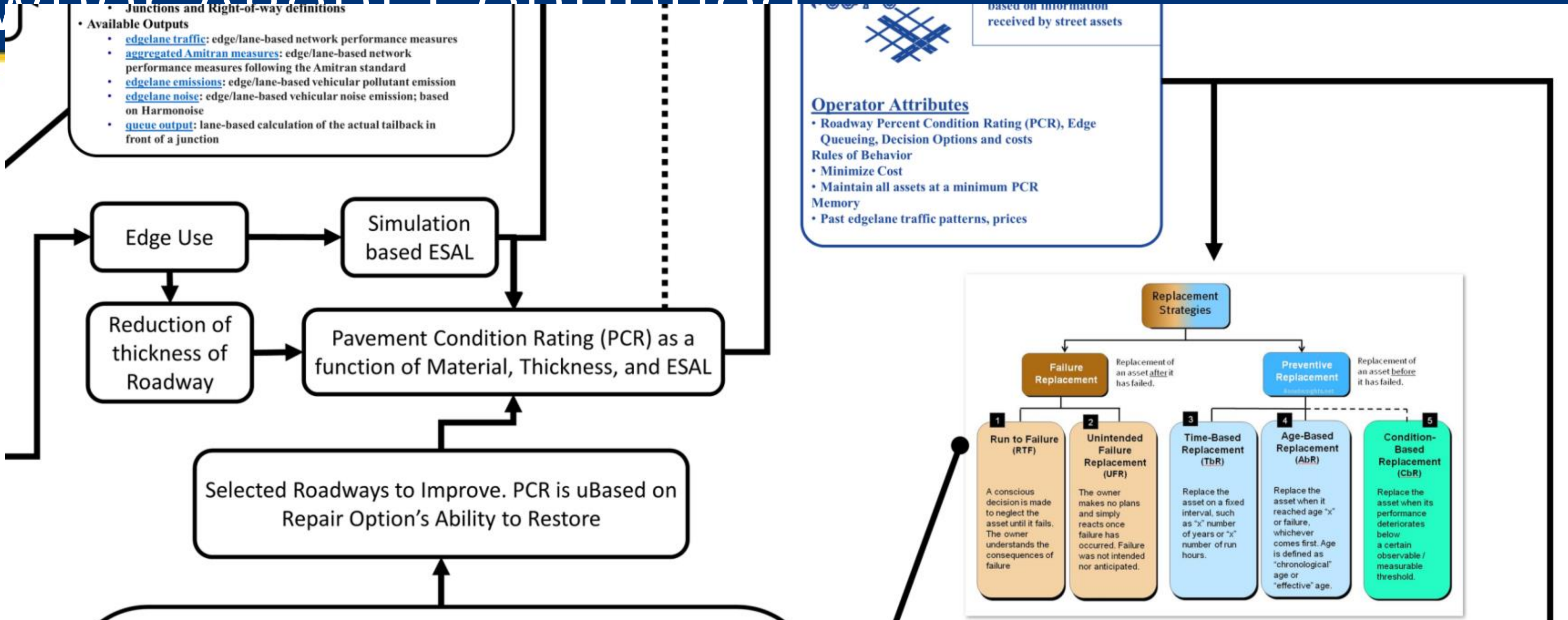
Owner Agent – Rules of behavior are Statistical and Probabilistic, but Simulated Emergent Behavior is Non-Deterministic

- Following the FHWA TAMP workplan (2013) and the new FAST Act Rules
- Owner agent receives information about the transportation assets
    - Owner types will differ through their optimization parameters, objectives, and constraints
        - Building and modifying short and long term plans based on non-deterministic simulation network performance.
            - Data is processed through different metrics and models to help build or modify agency TAMP
- Owner agent's make Transportation Asset Management decisions that directly effect the virtual network

- Simulations permits the opportunity to observe the *consequences* (good or bad) of different management policies and variations in finical and logistical parameters. – Deterministic and Statistical model parameters, but non-deterministic long term behavior



Owner Agent Continued



Replacement Optimization Algorithm: 1st Attempt

Objective Function :

$$Min \sum_0^T \sum_1^N Repair\_edge_N \binom{0}{1} @year_T * Repair\_Cost@year_T$$

Where the repair_edge variable is binomial.

Subject to:

Time since last repair less than or equal to 15 years

(TSLR) ≤ 15 yrs

The percent condition rating as a function of TSLR must be greater or equal to 50

PCR(TSLR) ≥ 50

Total Costs cannot exceed budget

$$\sum_1^N Repair\_edge_N \binom{0}{1} @year_T * Repair\_cost@year_T \leq Budget$$

The issue that I am having is that once the repair is chosen the TSLR has to be reset. Such that TSLR[i]= (TSLR[i-1]*(Repair_edge$_T$) +1

Provincetown Pavement Treatment Categories

In order to provide the Town with area-specific pavement treatment and repair alternatives the pavement condition index (PCI) was broken down into the following distribution based on typical maintenance strategies:

Table 2 Provincetown Maintenance & Repair Strategies

Maintenance & Repair Category	PCI	Condition
Base Rehabilitation	0 – 59	Failed Condition; in need of full reconstruction including base layer
Structural Improvement	60 – 72	Poor condition; in need of additional thickness to support traffic.
Preventative Maintenance	73 – 85	Fair condition; in need of surface sealing or thin overlay.
Routine Maintenance	86 – 95	Good condition; in need of crack sealing or patching.
Do Nothing	96 – 100	Excellent condition; in need of no current maintenance.

Based on the above maintenance and repair strategies the following pavement repair options and unit costs were created for Provincetown and incorporated into the MicroPAVER software:

Table 3 Provincetown Pavement Repair Options & Unit Costs

Repair Option	Unit Cost per Foot^2	PCI
Reclamation Arterial/Collector: Police, Sawcut, Reclaim, Reset Structures, Pave, Handwork, Stripe, Inspect	$7.37	0 – 59
Reclamation Local: Police, Sawcut, Reclaim, Reset Structures, Pave, Handwork, Inspect	$5.41	0 – 59
Mill/Overlay Arterial/Collector: Police, Sawcut, Mill, Tack, Pave, Stripe	$2.82	60 – 72
Mill/Overlay Local: Police, Sawcut, Mill, Tack, Pave	$2.00	60 – 72
Thin Overlay: Police, Crackseal/patch, Tack, Overlay	$1.45	73 – 85
Chipseal: Crackseal/Patch, Chipseal	$0.63	73 – 85
Routine Maintenance: Crackseal	$0.01	92 – 95
Routine Maintenance: Crackseal, Patch	$0.07	86 - 91

Spy Pond's Recommendations

[Drobox LINK]

Table 1. Recommended Revisions to PRISM Treatments

Treatment	Treatment Cost ($/sq. yd.)			Notes
	Previous	Revised	Revised w/ ADA	
Crack Sealing	0.54	0.72	0.72	used same increase as slurry seal
Slurry Seal	1.50	2.00	2.00	
Microsurfacing	3.65	4.00	4.00	change effect from resetting life to increasing life by 7 years
Hot-in-Place Recycling	4.70	9.40	37.40	used same increase as thin mill
Nova-Chip with Heater Scarification	5.00	N/A	N/A	eliminate treatment
Thin Mill and Inlay	7.00	14.00	42.00	
Cold-in-Place Recycling	3.00	87.50	115.50	
Compete Reconstruction	65.00	130.00	158.00	

Model - Limitations

- Trying to simulate a “wicked problem” is inherently inaccurate.
- There is no “right” answer to how much detail and complexity needs to be modeled to create a simulation with meaningful results.
    - I will rely on assumptions and randomness to simulate the interactions between the different systems
        - Human → Human, Human → Engineered, Engineered → Human, Engineered → Engineered, Natural → Engineered
- The output of a single simulation is not meaningful. It will take possible thousands of simulations runs for any discernable emergent behavior patterns that can be used to draw conclusions.
    - A single day can take many hours to simulate, this will limit the amount of scenarios and permutations of individual scenarios.
- Travel patterns within the network are calibrated by traffic count data that is only a snapshot (3 days) in time
- There are many factors that lead to the deterioration of an asset, this research will only account for use, weight of vehicle, sun exposure, and pavement structural composition.
    - I am still searching for a more sophisticated pavement deterioration model.
- Limited amount of historic and current condition data, unknown accuracy of data

Next Steps

SUMO (90% complete)

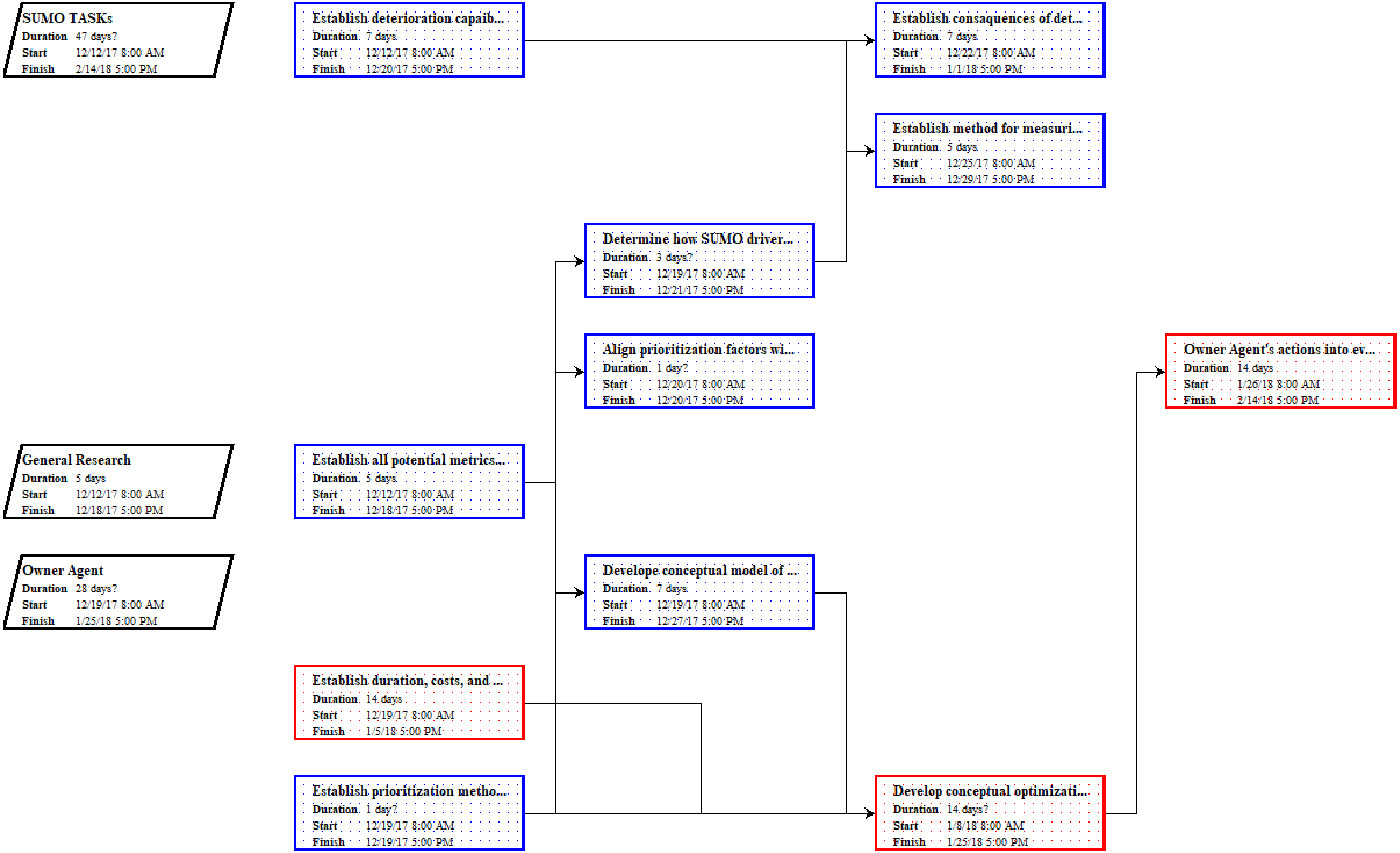
- Finalize Traffic flow calibrators for the AOI network (95%)
  - Link to DVRPC Traffic Count Excel Data Extracted from DVRPC Web App
- Incorporated the pavement deterioration function into the SUMO model and have the current condition affect the max speed over the pavement segment. (95%)
- Incorporate a user ELOS function based on user travel time, pavement condition, and accident rate to keep track of user experience (85%)
- Develop Initial or Changes to Existing Conditions for Scenarios and Assess Changes

Owner Agent – Next Page

Owner Agent (70%) – link to PowerPoint with TAMP framework components – 70%

- Translate FHWA's TAM Framework into the Owner Agent's operational parameters and functionality
  - Define and translate the different management principles into a standard linear or non-linear programing format.
    - Multi-objective constrained optimization: Short-term operations scheduling and Long-term planning
- Create a transportation asset management framework and code to interface with the SUMO simulation for managing the transportation assets.
  - Identify the critical elements from FHWA's Best Practices and PennDOT's current TAMP
  - Conduct interviews with City Streets Department to further map their pavement management process, their constraints, and objectives
  - Develop decision and finance routines to simulate owner/operator's behavior.
- Incorporate aggregate user experiences to increase political pressure (artificially rising priority) on owner agents to fix bad roads that effect the general public.

Work Plan



SUMO TASKs
Duration 47 days?
Start 12/12/17 8:00 AM
Finish 2/14/18 5:00 PM
Establish deterioration capaib...
Duration 7 days
Start 12/12/17 8:00 AM
Finish 12/20/17 5:00 PM
Establish consaquences of det...
Duration 7 days
Start 12/22/17 8:00 AM
Finish 1/1/18 5:00 PM
Establish method for measuri...
Duration 5 days
Start 12/25/17 8:00 AM
Finish 12/29/17 5:00 PM
Determine how SUMO driver...
Duration 3 days?
Start 12/19/17 8:00 AM
Finish 12/21/17 5:00 PM
Align prioritization factors wi...
Duration 1 day?
Start 12/20/17 8:00 AM
Finish 12/20/17 5:00 PM
Owner Agent's actions into ev...
Duration 14 days
Start 1/26/18 8:00 AM
Finish 2/14/18 5:00 PM
General Research
Duration 5 days
Start 12/12/17 8:00 AM
Finish 12/18/17 5:00 PM
Establish all potential metrics...
Duration 5 days
Start 12/12/17 8:00 AM
Finish 12/18/17 5:00 PM
Owner Agent
Duration 28 days?
Start 12/19/17 8:00 AM
Finish 1/25/18 5:00 PM
Develope conceptual model of ...
Duration 7 days
Start 12/19/17 8:00 AM
Finish 12/27/17 5:00 PM
Establish duration, costs, and ...
Duration 14 days
Start 12/19/17 8:00 AM
Finish 1/5/18 5:00 PM
Establish prioritization metho...
Duration 1 day?
Start 12/19/17 8:00 AM
Finish 12/19/17 5:00 PM
Develop conceptual optimizati...
Duration 14 days?
Start 1/8/18 8:00 AM
Finish 1/25/18 5:00 PM

Complete Model

- OSM base map of segment of Philadelphia's Fairmount Park
- Traffic – vehicles per hour and vehicle type distributions
  - Based on DVRPC available traffic count data
- Routes – based on heuristics
- Deterioration based on the ESAL of the simulated traffic and random events
  - Need to find a way to incorporate environmental factors for individualized decoration rates
  - Compare predicted damage (no interventions), based input date, to simulated damage. This will be a critical test to see if SUMO is worth the time and effort.
- Owner agent module
  - Creates work plan schedule to meet predefined goals
    - Random; Worst First; Corridor; Isolated Asset Group; Combined Asset Management; Service Provided; Multi-Objective Optimization
    - Constraints: Budget; Politics (geospatial distribution); Organizational
  - During simulation owner carries out schedule work or reacts to emergency events

Traffic Modeling AOI - Belmont Ave in West Fairmount Park

Open Streets Map of Area

DVRPC Traffic Data Points

How is the Simulation Validated?

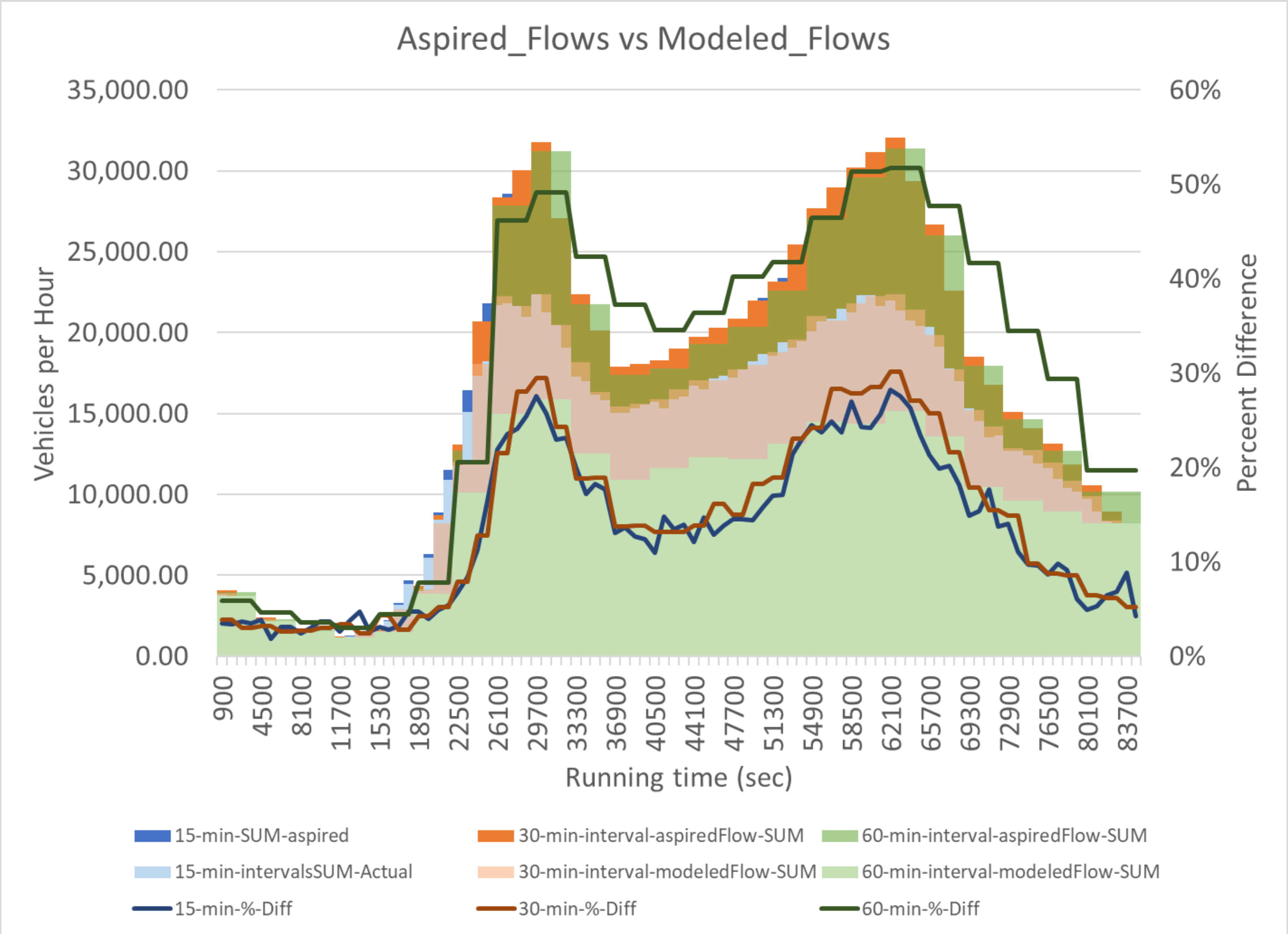
As with other simulations and models the quality and accuracy of the input data plays a significant factor in the accuracy of the output.

- The topology of the network is imported via data from the OpenStreetMap database.
- Creating realistic demands to flow across the network is a great deal more complicated.
  - ***DVRPC's House Hold Trip Survey Data*** is used to generate trips within the network.
  - ***DVRPC's Traffic Count Data*** is used during the simulation to either increase or decrease the traffic volume to match the historic records
    - **Number of traffic count locations in the AOI = 38**
  - ***DVRPC's Vehicle Class Data*** is used to determine the vehicle type distribution in the simulation
    - **Number of Vehicle Class count locations in the AOI = 3**
  - This data is integrated together to create a defined number of vehicles per hour passing over known streets. The traffic simulator's *Calibrator* element reads this information and tries to add or remove vehicles to the network to match the defined flow.
  - Other parameters such as turning permissions and traffic signal timing, can also be adjusted to match defined flows and field measurements.

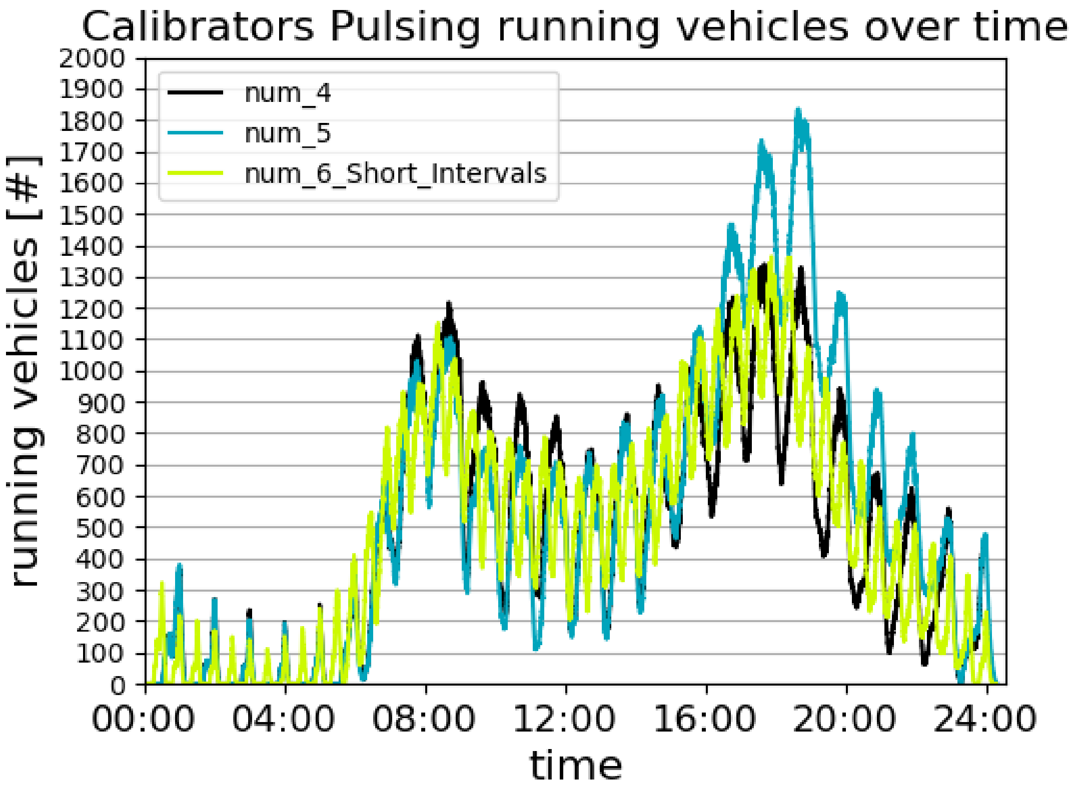
Potential Impacts

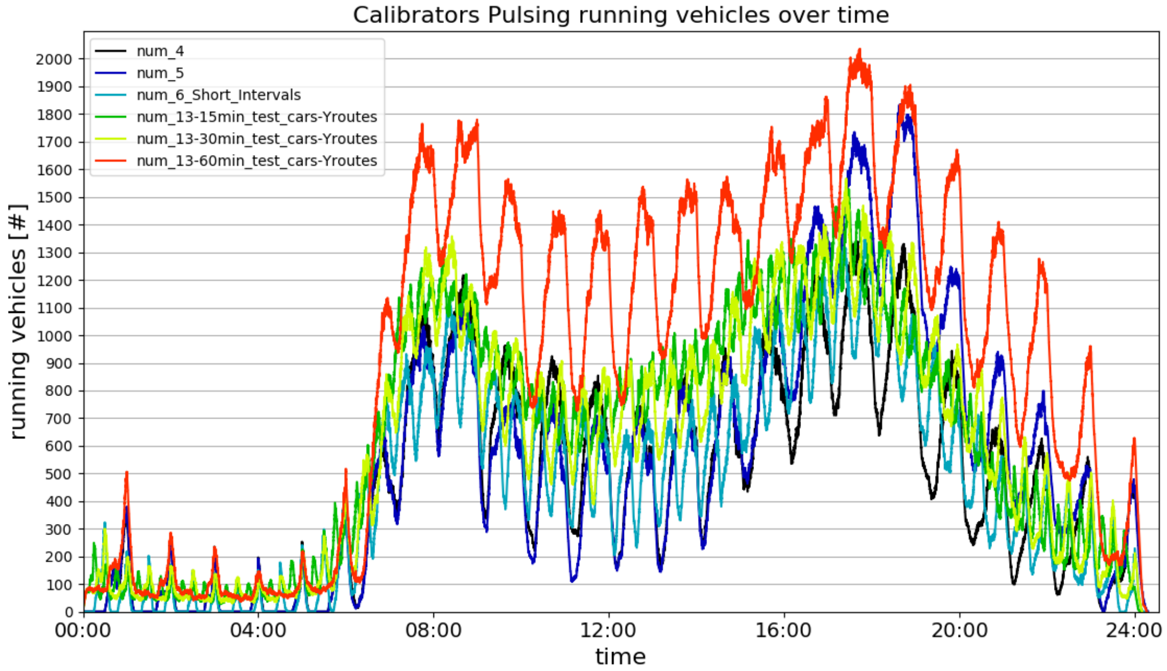
- The research model will not be 100% accuracy.
  - Goal use hard data and validated rules of behavior to validate the simulation with real life
  - Simulation must be run many times for patterns of **emergent beh**avior to be established.
  - Running the simulations under **different management principle objects** and **agency constraints** we will be able to analyze how the **small local changes can impact the greater network and performance**
- DVRPC – Has the tools and resources to continue building on their existing Transportation Improvement Models (TIM) to incorporate sociotechnical components to further the mission of improving the Livability, Sustainability, and Resilience of the region.

Calibrating the Model

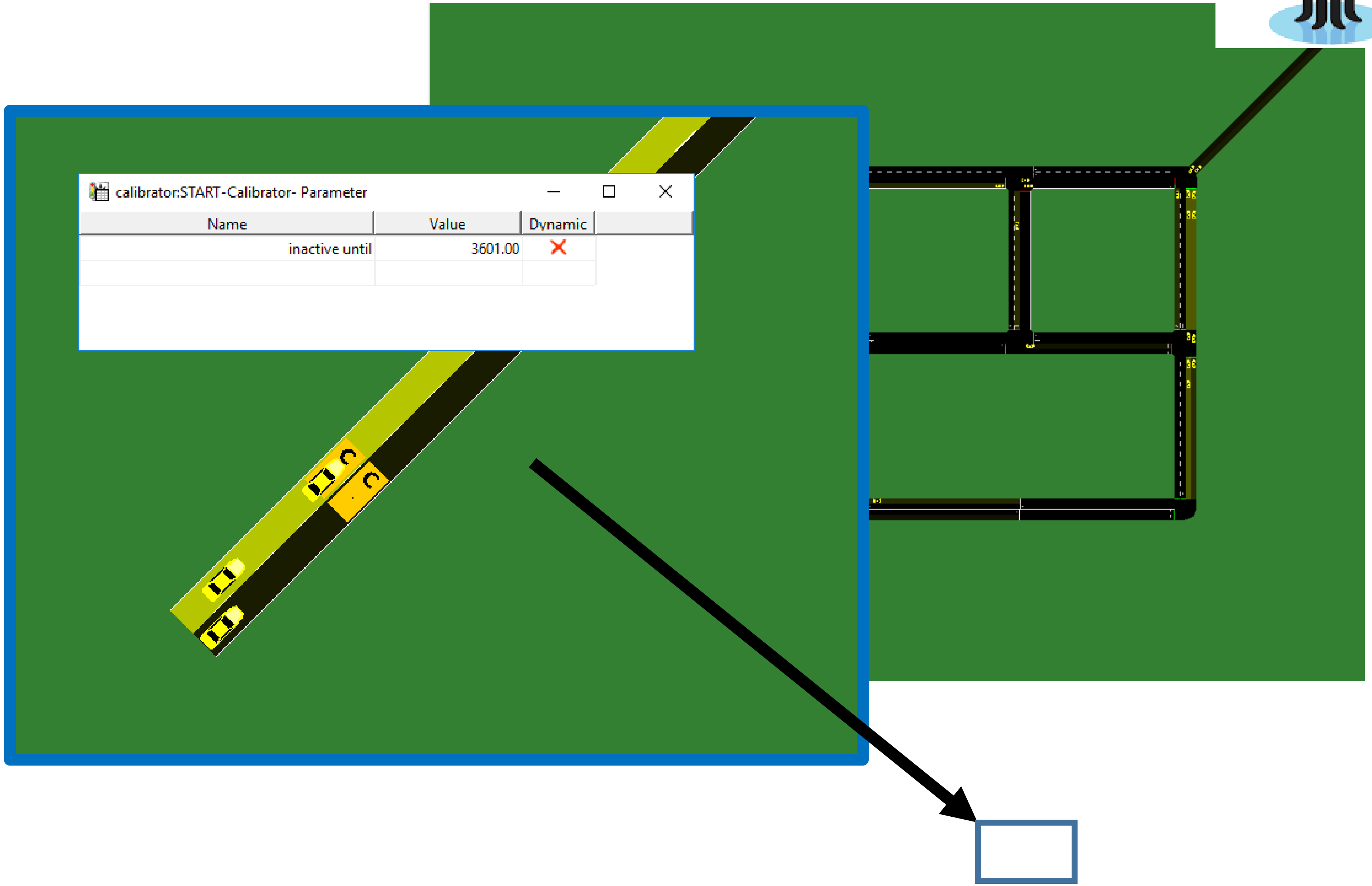


Validation

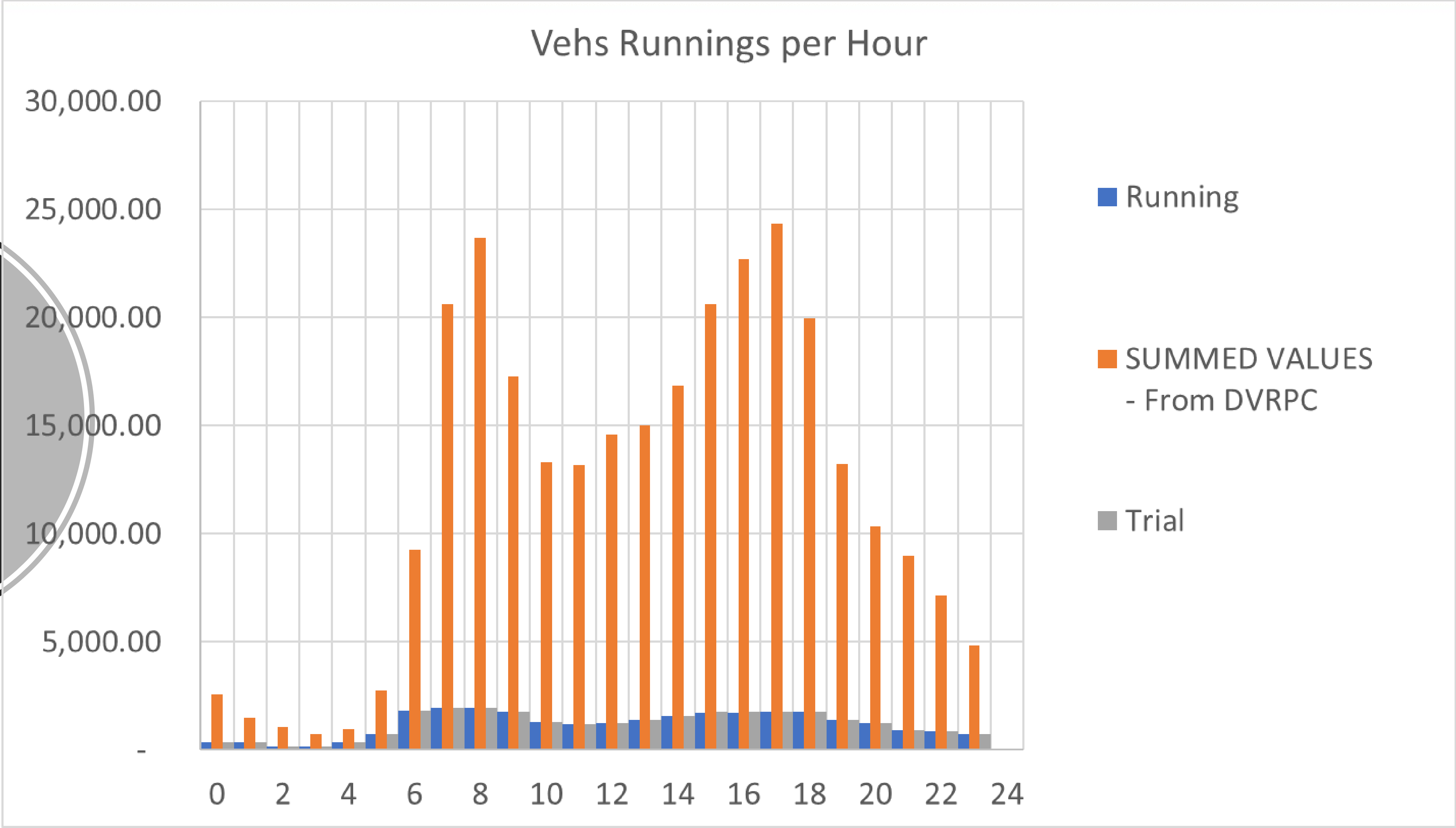

Calibrators Pulsing running vehicles over time
running vehicles [#]
time
num_4
num_5
num_6_Short_Intervals
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
00:00
04:00
08:00
12:00
16:00
20:00
24:00


Calibrators Pulsing running vehicles over time
running vehicles [#]
time
num_4
num_5
num_6_Short_Intervals
num_13-15min_test_cars-Yroutes
num_13-30min_test_cars-Yroutes
num_13-60min_test_cars-Yroutes
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
00:00
04:00
08:00
12:00
16:00
20:00
24:00

Test Bed for Calibrators



Validation



Vehs Runnings per Hour
30,000.00
25,000.00
20,000.00
15,000.00
10,000.00
5,000.00
-
0
2
4
6
8
10
12
14
16
18
20
22
24
Running
SUMMED VALUES - From DVRPC
Trial

caliTEST-NR-F20-vph-DVRPC-5-Cal **Number of Calibrators** 5 **Freq** 20 **vph** DVRPC Distribution

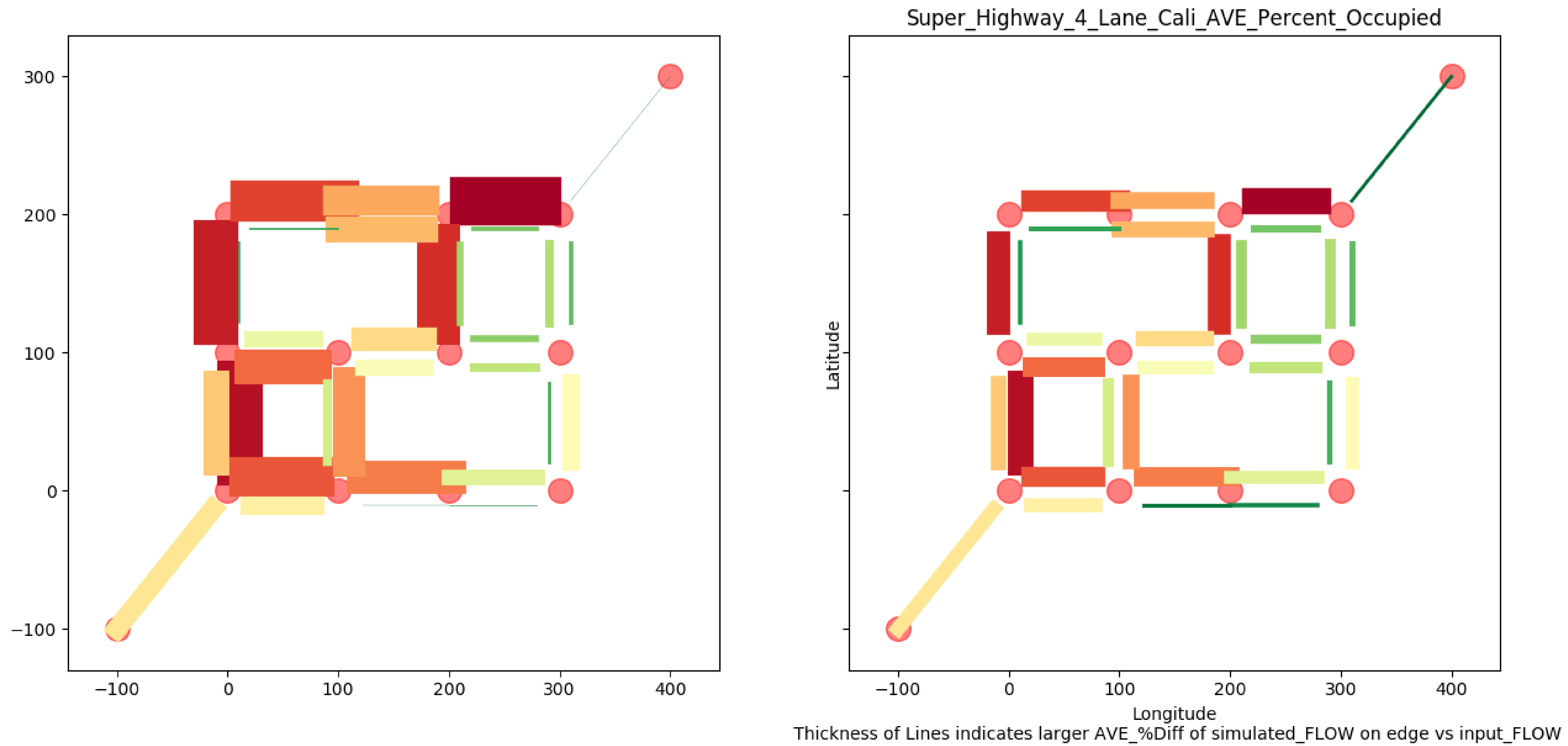
interval_id	Average Percent Diff	%Diff-3600	%Diff-7200	%Diff-10800	%Diff-14400	%Diff-18000	%Diff-21600	%Diff-25200	%Diff-28800	%Diff-32400	%Diff-36000	%Diff-39600	%Diff-43200	%Diff-46800	%Diff-50400
START-Calibrator	36%	19%	22%	19%	15%	19%	31%	35%	52%	55%	48%	41%	47%	46%	49%
2_1-1_1-Calibrator	41%	29%	29%	27%	22%	19%	31%	43%	58%	59%	53%	46%	52%	51%	56%
1_1-2_1-Calibrator	47%	40%	19%	34%	19%	25%	41%	52%	66%	68%	62%	54%	58%	62%	61%
0_0-0_1-Calibrator	50%	34%	40%	27%	24%	36%	43%	52%	68%	69%	66%	57%	61%	64%	65%
3_1-3_0-Calibrator	88%	84%	74%	71%	66%	81%	91%	94%	98%	97%	97%	95%	97%	96%	97%
	14%														

caliTEST-NR-F15-vph-DVRPC-5-Cal **Number of Calibrators** 5 **Freq** 15 **vph** DVRPC Distribution

interval_id	Average Percent Diff	%Diff-3600	%Diff-7200	%Diff-10800	%Diff-14400	%Diff-18000	%Diff-21600	%Diff-25200	%Diff-28800	%Diff-32400	%Diff-36000	%Diff-39600	%Diff-43200	%Diff-46800	%Diff-50400
START-Calibrator	28%	9%	10%	17%	15%	7%	14%	29%	48%	51%	42%	33%	37%	38%	43%
2_1-1_1-Calibrator	34%	20%	14%	12%	15%	13%	28%	36%	54%	57%	49%	40%	47%	45%	52%
0_0-0_1-Calibrator	42%	8%	26%	7%	15%	6%	40%	52%	68%	68%	64%	56%	58%	64%	61%
1_1-2_1-Calibrator	44%	34%	28%	12%	5%	22%	43%	54%	66%	66%	61%	55%	58%	60%	58%
3_1-3_0-Calibrator	89%	83%	84%	66%	76%	79%	91%	94%	97%	98%	97%	95%	96%	96%	97%
	17%														

caliTEST-NR-F5-vph-DVRPC-5-Cali **Number of Calibrators** 5 **Freq** 5 **vph** DVRPC Distribution

interval_id	Average Percent Diff	%Diff-3600	%Diff-7200	%Diff-10800	%Diff-14400	%Diff-18000	%Diff-21600	%Diff-25200	%Diff-28800	%Diff-32400	%Diff-36000	%Diff-39600	%Diff-43200	%Diff-46800	%Diff-50400
START-Calibrator	13%	6%	3%	5%	5%	4%	7%	9%	29%	30%	21%	11%	14%	15%	22%
2_1-1_1-Calibrator	16%	9%	10%	12%	2%	4%	9%	17%	27%	34%	24%	14%	20%	19%	27%
1_1-2_1-Calibrator	42%	35%	24%	17%	5%	22%	35%	50%	63%	66%	57%	49%	56%	57%	57%
0_0-0_1-Calibrator	46%	23%	0%	0%	0%	6%	30%	60%	79%	82%	77%	69%	70%	75%	76%
3_1-3_0-Calibrator	89%	85%	76%	73%	71%	85%	93%	93%	97%	98%	97%	96%	96%	95%	96%
	21%														


Super_Highway_4_Lane_Cali_AVE_Percent_Occupied
300
200
100
0
−100
−100
0
100
200
300
400
Latitude
Longitude
Thickness of Lines indicates larger AVE_%Diff of simulated_FLOW on edge vs input_FLOW

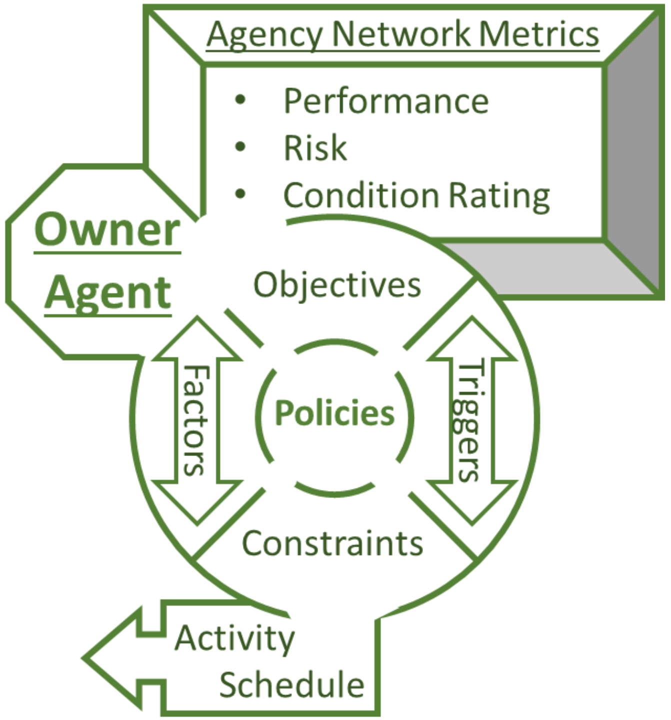
Modeling Traffic along West Belmont Avenue – Philadelphia, PA

[Link to video]

Owner Agent – Tentative Rules of Behavior – Detailed

<u>Rules of behavior</u> are Statistical and Probabilistic, but Simulated Emergent Behavior is Non-Deterministic

- Non-linear programing – Schedule Optimizer
  - Objective function variation: short term cost minimization, overall network performance maximization, LCC minimization, Holistic Livability maximization
  - Subject to:
    - Budget – next year's budget (Probabilistic) – soft constraint
    - Number of overlapping activities – (Deterministic) – hard constraint – Availability: Labor Force, Equipment, Material In-Stock, Completion time of activity (Probabilistic)
    - Available activities - (Deterministic) – Work force capabilities
    - Effectiveness of activity – (Probabilistic) – Variation in condition increase base on quality control practices
    - Cost of project – (Heuristics and Probabilistic) - variations in material cost based on seasonal adjustments and market fluctuation
    - Scope of activities – (Deterministic) – soft constraint – Policy driven – example: PWD can not contribute funds to any project that's scope is outside of their jurisdiction, due to their bonding arrangement.
    - Condition data:
      - Probabilistic – Data collection practices → probability inspection data is reported correctly
      - Deterministic – Data collection practices → condition data update rate
    - Indirect Deterioration costs – Statistical and Non-Deterministic:
      - Importance factor: i.e. - Change in vehicle flow rate per year given no maintenance activities and default flow rates.
    - User experience - Statistical and Non-Deterministic:
      - Simulated vehicle interactions create differences between the routes expected travel-time and the actual travel time, experience is quantified as the piece-wise integral of the negative intensity over the time period above the threshold.

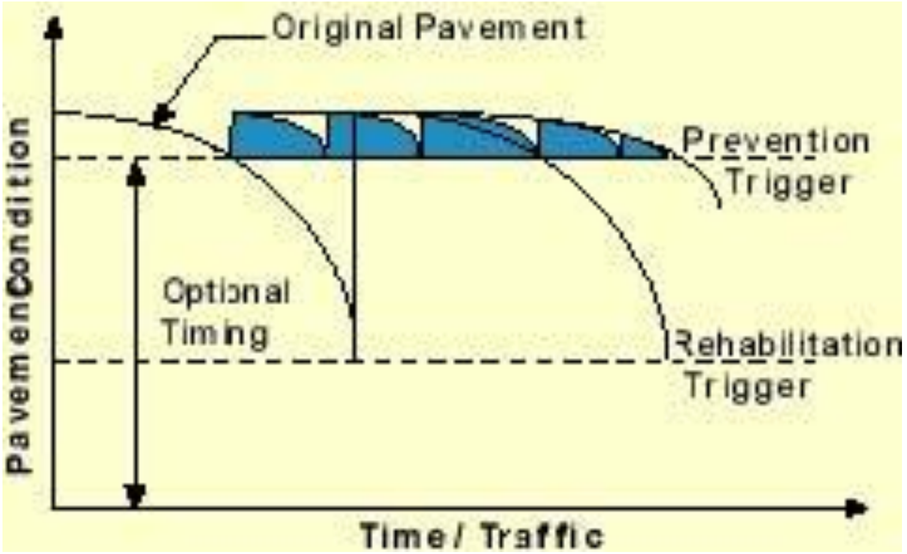


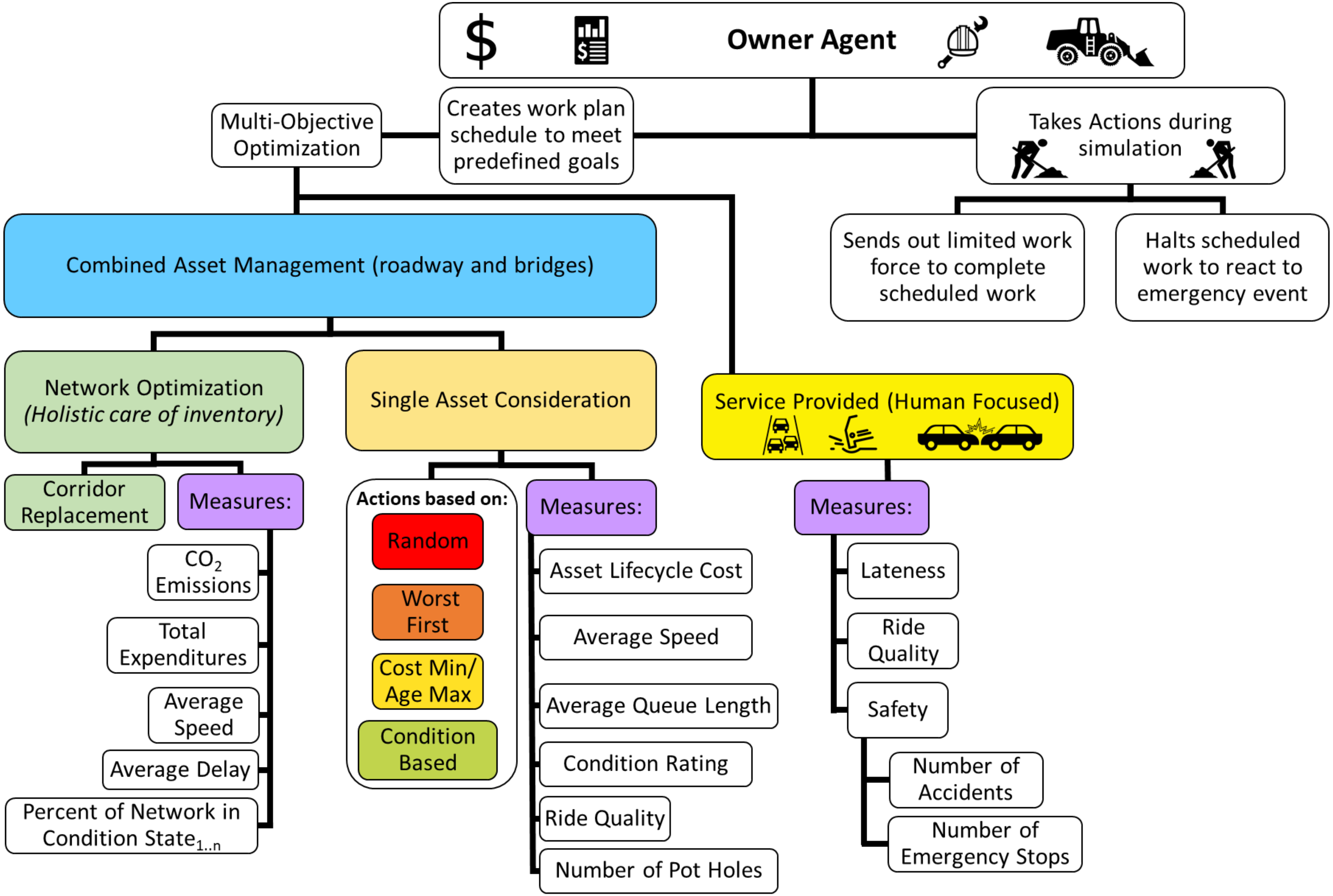
Owner Agent – Tentative Rules of Behavior

Owner Agent – Rules of behavior are Statistical and Probabilistic, but Simulated Emergent Behavior is Non-Deterministic

- Following the FHWA TAMP workplan ([2013]) and the new [FAST Act Rules]
- Owner agent receives information about the transportation assets
  - Owner types will differ through their optimization parameters, objectives, and constraints
    - Building and modifying short and long term plans based on non-deterministic simulation network performance.
      - Data is processed through different metrics and models to help build or modify agency TAMP
- Owner agent's make Transportation Asset Management decisions that directly effect the virtual network

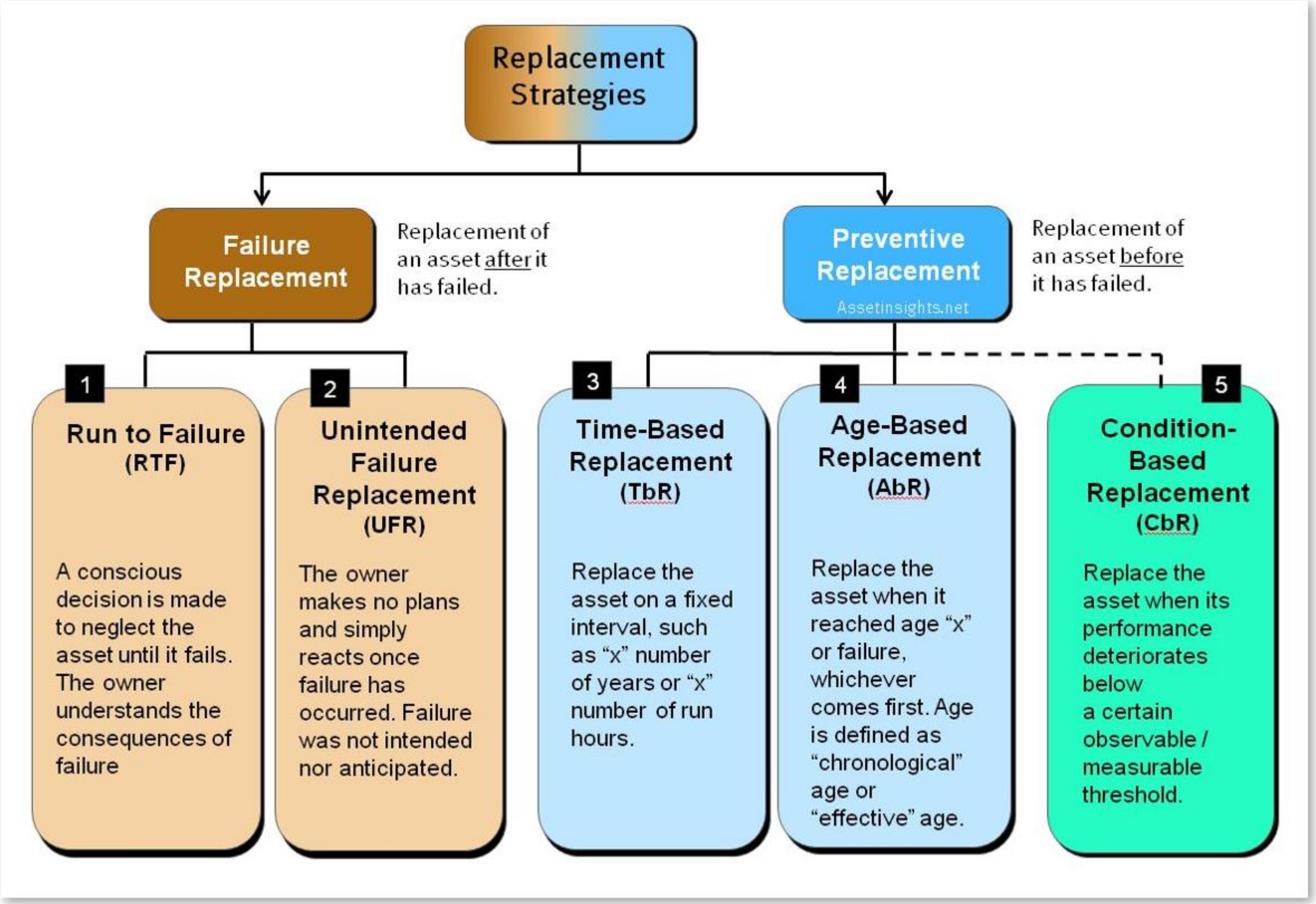
- Simulations permits the opportunity to observe the *consequences* (good or bad) of different management policies and variations in finical and logistical parameters. – Deterministic and Statistical model parameters, but non-deterministic long term behavior





$
Owner Agent
Multi-Objective Optimization
Creates work plan schedule to meet predefined goals
Takes Actions during simulation
Sends out limited work force to complete scheduled work
Halts scheduled work to react to emergency event
Combined Asset Management (roadway and bridges)
Network Optimization
(Holistic care of inventory)
Single Asset Consideration
Service Provided (Human Focused)
Corridor Replacement
Measures:
CO_2 Emissions
Total Expenditures
Average Speed
Average Delay
Percent of Network in Condition State$_{1..n}$
Actions based on:
Random
Worst First
Cost Min/ Age Max
Condition Based
Measures:
Asset Lifecycle Cost
Average Speed
Average Queue Length
Condition Rating
Ride Quality
Number of Pot Holes
Measures:
Lateness
Ride Quality
Safety
Number of Accidents
Number of Emergency Stops

Owner Agent - Replacement Strategies - Example



Why SUMO?

My final model will consist of two parts, a traffic simulator and an owner/operator module.

The open source software platform, “**S**imulation of **U**rban **MO**bility” (SUMO), will be utilized to simulate the traffic flows. Building off the existing source code, the simulator will collect and update critical information about the type of road, its age, its use, and its condition rating.

The owner and operator module will be developed as a standalone Python based module. The goal of the owner and operator module is to mimic actual maintenance and operational decision processes. The framework from the model will be based on FHWA’s transportation asset management plan (TAMP) best practices guidelines.

SUMO vs PT Visum

Similarities

- Each can interface with external Python Code during the simulation.
- Can use matrix O/D for demand
- Can import external files to generate points of interest (POIs)
- Uses traffic analysis zones (TAZ) for routing purposes
- Abilities to model multi-modal transportation systems, transportation objects, and user classes

Differences

- SUMO is an Open Source. Visum is a Professional Software Package.
- Open source lends itself to incorporating new rules and behaviors into simulation easier.
- SUMO tools are natively written in C++ and Python; adaptation of existing tools is easily accomplished.
- SUMO has a wide community of developers creating new tools and improving old tools.
- Visum’s add-on Market Place is limited, but contains a more sophisticated traffic engineering modules for modeling the TLS and roadway parameters.

The Dynamic User Assignment Routing Tool

- DUAROUTER imports different demand definitions, computes vehicle routes that may be used by SUMO using shortest path computation; When called iteratively DUAROUTER performs dynamic user assignment (DUA). This is facilitated by the tool duaiterate.py which converges to an equilibrium state (DUE).

Purpose:

A) Building vehicle routes from demand definitions

B) Computing routes during a user assignment

C) Repairing connectivity problems in existing route files

System: portable (Linux/Windows is tested); runs on command line

Input (mandatory):

A) a road network

B) a demand definition, User trip definitions

Output: Routes usable for SUMO’s simulations

Building a scenario without knowledge of routes, based on traffic count

--- LINK to SUMO.Wiki Documentation---

2

- Each road where measurements are given should receive a calibrator and a route probe detector. As soon as the first vehicle has passed the route probe detector, the calibrator will be able to use that vehicles route. For the calibrator to be able to function before the first vehicle, it needs a *fall back* route which just needs to consist of a single road or a series of routes within a distribution.

33rd and Market Traffic Count Data – Shown on next page

```xml
<routeProbe id="PA_3_EB_probe" edge="-386547297#1" freq="60"  file="output.xml" />
   <calibrator id="PA_3_EB_Edge"  lane="-386547297#1_0"  pos="0" outputfile="detector.xml"  freq="60"  routeProbe="PA_3_EB_probe" >
      <route id="PA_3_EB_Edge_FB"  edges="-386547297#1" />
      <flow begin="0"     end="3600"  route="PA_3_EB_Edge_FB"  vehsPerHour="1033.33333333333"  speed="13.41"  type="DVRPC_dist"  departPos="free"  departSpeed="max" />
      <flow begin="3600"     end="7200"  route="PA_3_EB_Edge_FB"  vehsPerHour="1065.66666666667"  speed="13.41"  type="DVRPC_dist"  departPos="free"  departSpeed="max" />
</calibrator>
<routeProbe id="PA_3_WB_probe" edge="386547297#0" freq="60"  file="output.xml" />
   <calibrator id="PA_3_WB_Edge"  lane="386547297#0_0"  pos="0" outputfile="detector.xml"  freq="60"  routeProbe="PA_3_WB_probe" >
      <route id="PA_3_WB_Edge_FB"  edges="386547297#0" />
      <flow begin="0"     end="3600"  route="PA_3_WB_Edge_FB"  vehsPerHour="739.5"  speed="13.41"  type="DVRPC_dist"  departPos="free"  departSpeed="max" />
      <flow begin="3600"     end="7200"  route="PA_3_WB_Edge_FB"  vehsPerHour="744.5"  speed="13.41"  type="DVRPC_dist"  departPos="free"  departSpeed="max" />
</calibrator>
```

TAKEN BY: JC
ROAD: PA 3 MARKET ST
DATE: 5/17/2016
PROJECT:
16-PAP
STATION ID:
SR/SEG/OFF:
20264
3010/0060/0336
FROM:
STATE:
33RD ST
PA
COUNTY:
PHILADELPHIA
TO: J F KENNEDY BLVD
MCD: 4210160110 - UNIVERSITY - SOUTHWEST
COUNT DIR: EAST **TRAFFIC DIR:**
BOTH
SPEED LIMIT: 30 **FC:** 14
DVRPC FILE #: 127975 **COUNTER #:** 1245 **WEATHER:** F **DATA SOURCE:** EXTERNAL
COMMENTS:

East Bound

Hour Beginning	Monday 5/16/2016	Tuesday 5/17/2016	Wednesday 5/18/2016	
12 AM		170	172	
1 AM		120	126	
2 AM		72	77	
3 AM		54	62	
4 AM		98	83	
5 AM		240	190	
6 AM		453	417	
7 AM		676	676	
8 AM		818	212	
9 AM		667		
10 AM		617		
11 AM		653		
12 PM		659		
1 PM	542	696		
2 PM	728	744		
3 PM	733	746		740
4 PM	728	761		745
5 PM	699	696		
6 PM	544	585		
7 PM	558	562		
8 PM	447	501		
9 PM	398	412		
10 PM	275	351		
11PM	233	283		
Total		**11,634**		

AXLE CORR. FACTOR: 0.951 **AADT:** 9,500 **AM Peak %:** 7.0 **Hour Beginning:** 8:00 AM
SEASONAL FACTOR: 0.859 **PM Peak %:** 6.5 **Hour Beginning:** 4:00 PM

114: Files

file:///C:\Users\Biko\Dropbox\PhD\Research\Models\SUMO\DVRPC\Traffic%20Counts\33rd%20and%20Market%20Counts.xlsx

file:///C:\Users\Biko\Dropbox\PhD\Research\Models\SUMO\DVRPC\Traffic%20Counts\Counts%20OSM%202%20-%20V-2\DVRPC%20Traffic%20Counts%20For%20Net%20OSM%202%20-%20V-2_D.xlsm

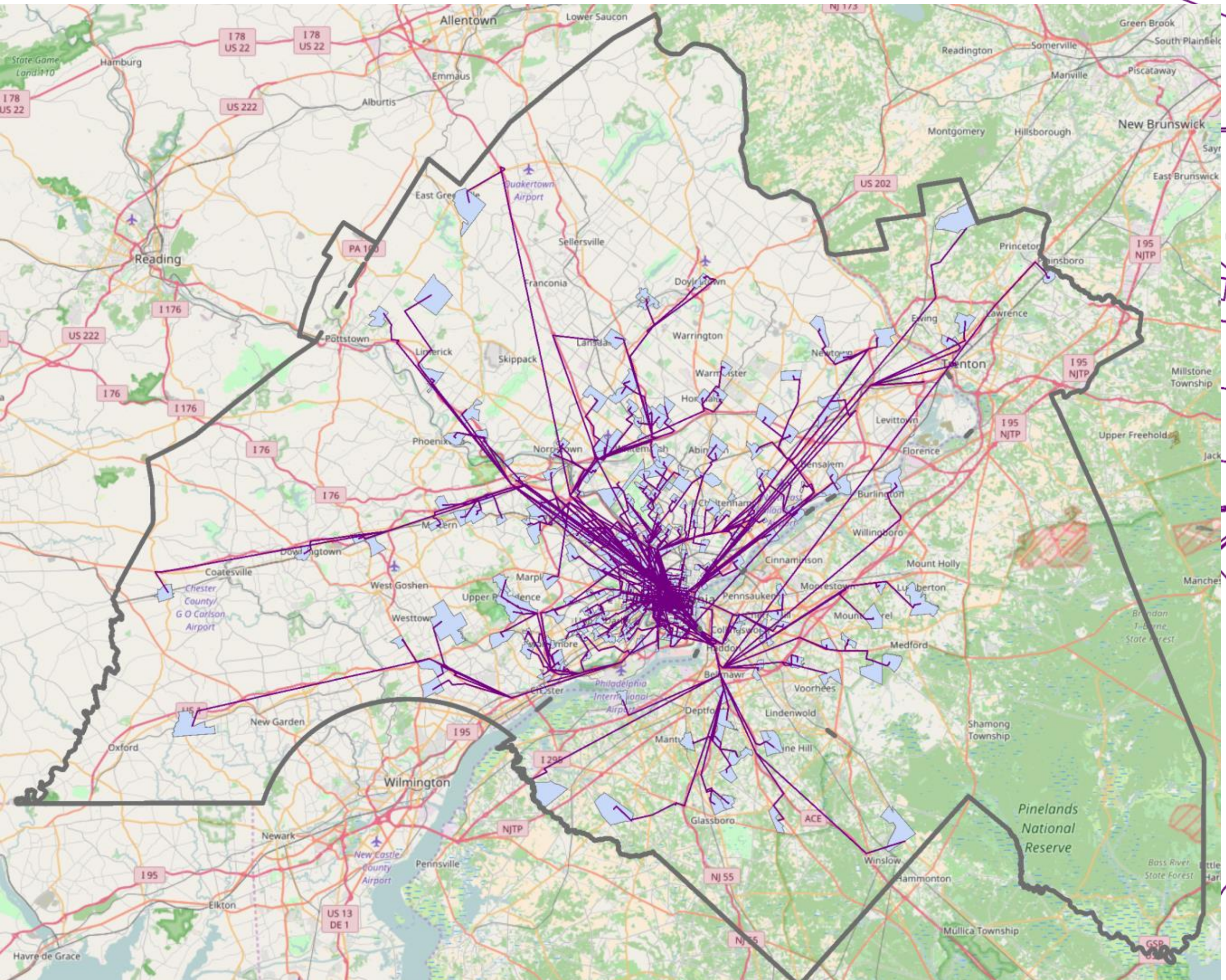
TAKEN BY: JC
ROAD: PA 3 MARKET ST
DATE: 5/17/2016
PROJECT:
16-PAP
STATION ID:
SR/SEG/OFF:
20264
3010/0061/0336
FROM:
STATE:
33RD ST
PA
COUNTY:
PHILADELPHIA
TO: J F KENNEDY BLVD
MCD: 4210160110 - UNIVERSITY - SOUTHWEST
COUNT DIR: WEST **TRAFFIC DIR:**
BOTH
SPEED LIMIT: 30 **FC:** 14
DVRPC FILE #: 127976 **COUNTER #:** 1242 **WEATHER:** F **DATA SOURCE:** EXTERNAL
COMMENTS:

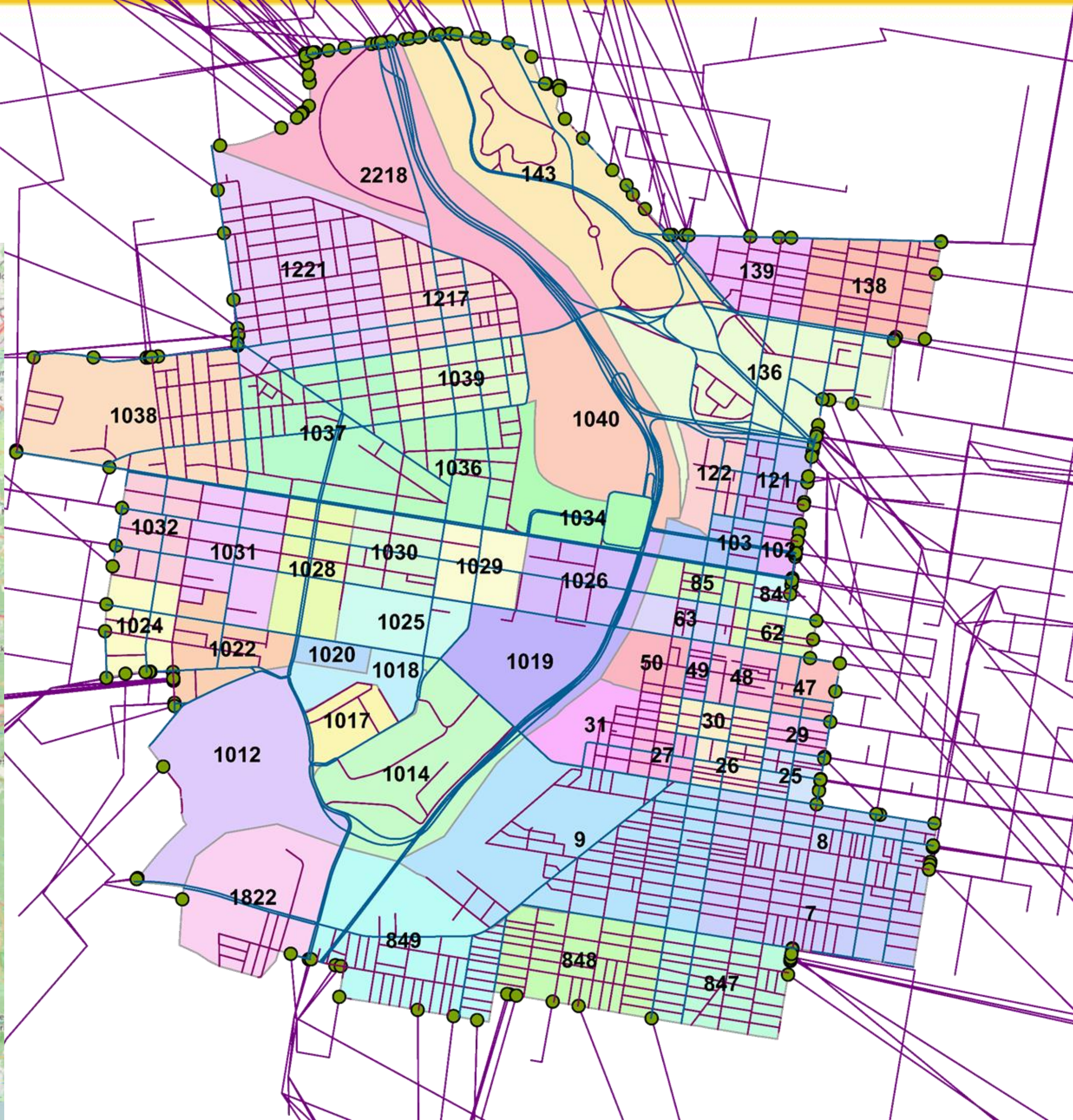
West Bound

Hour Beginning	Monday 5/16/2016	Tuesday 5/17/2016	Wednesday 5/18/2016	Thursday 5/19/2016
12 AM		239	227	255
1 AM		152	158	167
2 AM		89	88	100
3 AM		69	79	76
4 AM		121	138	117
5 AM		339	343	310
6 AM		679	659	633
7 AM		891	872	867
8 AM		985	926	971
9 AM		870	883	879
10 AM		871	823	830
11 AM		783	777	867
12 PM		865	901	
1 PM		896	912	
2 PM	999	858	958	
3 PM	1,135	949	1,016	
4 PM	1,152	1,012	1,033	
5 PM	1,230	1,062	1,167	
6 PM	1,073	914	977	
7 PM	798	759	777	
8 PM	698	643	678	
9 PM	596	580	582	
10 PM	524	446	477	
11PM	354	346	387	
Total	**8,559**	**15,418**	**15,838**	**6,072**

AXLE CORR. FACTOR: 0.951 **AADT:** 12,590 **AM Peak %:** 6.4 **Hour Beginning:** 8:00 AM
SEASONAL FACTOR: 0.859 **PM Peak %:** 6.9 **Hour Beginning:** 5:00 PM

Mapping TAZs-

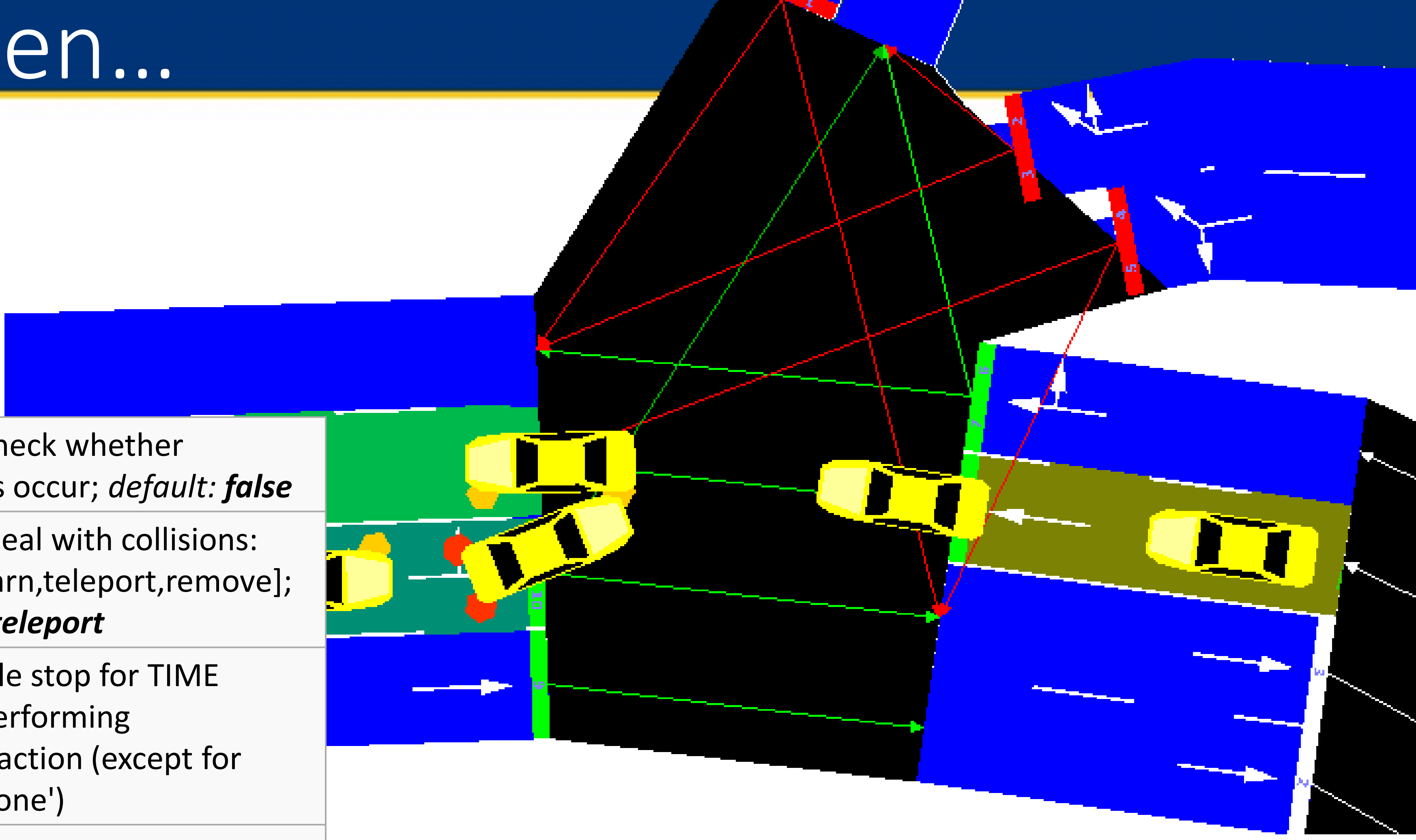




Accidents Happen…

[SUMO Simulation Accident Options]

--ignore-accidents ***<BOOL>***	Do not check whether accidents occur; *default:* ***false***
--collision.action ***<STRING>***	How to deal with collisions: [none,warn,teleport,remove]; *default:* ***teleport***
--collision.stoptime ***<TIME>***	Let vehicle stop for TIME before performing collision.action (except for action 'none')
--collision.check-junctions ***<BOOL>***	Enables collisions checks on junctions; *default:* ***false***



VISSIM STANDARDS PROJECT

Summary of Year Two Findings

June 2013

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

Table 7: Standstill Distance

	Urban	Suburban	Through/ Right	Left Turn	Aggregate
Average (ft.)	9.1	9.2	9.1	9.3	9.1
Max (ft.)	20	20	20	20	20
Min (ft.)	3	3	3	4	3
Standard Deviation (ft.)	3.1	3.3	3.0	3.3	3.2
Number of Samples	274	282	466	90	556

PC, 2013

Urban Road

The results are presented in Table 8 below.

Table 8: Urban Road Signal Throughput Results

URBAN	Left	Through
Mean (seconds/vehicle/lane)	2.21	3.07
Minimum (seconds/vehicle/lane)	1.25	1.89
Maxium (seconds/vehicle/lane)	3.40	7.17
85th Percentile (seconds/vehicle/lane)	2.67	3.93
15th Percentile (seconds/vehicle/lane)	1.75	2.21
Number of Observations	65	105
Standard Deviation	0.48	1.07
Measurement Locations	3	5

DVRPC, 2012

Table 5: Urban Road Free-Flow Speed

URBAN ROAD	
Measurement Locations	15
Sample Size	1,650
Base Speed	25
Mean Speed	-6.4
Median Speed	-7.5
5th Percentile Speed	-13.0
20th Percentile Speed	-11.0
80th Percentile Speed	-3.0
85th Percentile Speed	-1.0
95th Percentile Speed	3.0
Standard Deviation	6.29

speed = m/h DVRPC, 2012

Table 10: Rolling Stop Results

ROLLING STOP		
Measurement Locations		17
Sample Size		456
	Seconds	m/h
Mean	2.19	4.67
Median	2.00	5.11
5th Percentile	3.90	2.62
20th Percentile	2.70	3.79
80th Percentile	1.45	7.05
85th Percentile	1.33	7.72
95th Percentile	1.08	9.51
Standard Deviation	0.92	0.18

DVRPC, 2012

Dynamic Network Analysis & Real-time Traffic

Final Report 2016 - Carnegie Mellon & PennDOT - http://weima171.com/docs/WO004_final.pdf

Executive Summary

This project developed a general regional network model to estimate/predict time-varying traffic evolution on all highways and major arterials in Philadelphia Metropolitan Region. A case study was conducted for assessing the dynamic traffic impact of road closures on freeways and/or major arterials in the Philadelphia Region; and propose real-time traffic detour plans as a way of using travel demand management (TDM) strategies to mitigate overall impact caused by closures

…The historical O-D demand data was also obtained from DVRPC in the format of VISUM. The O-D matrix is represented by a 3399 × 3399 matrix and in float precision. DVRPC also provided a main O-D pairs profile, which contains 10,000 main O-Ds. O-D connectors are also contained in the TIM2.1 model, the total number of O-D connectors is 11,553,201.

2.1 Route choice model

Route choice model is a crucial part to real-time traffic simulation. Under static network setting, the route choice of travelers is usually determined by a user equilibrium (UE) flow pattern (Sheffi 1985). In dynamic context, there are generally two types of UE in the literature. One is the so-called Boston User Equilibrium (BUE) (Friesz et al. 1993), which is an adaption of the static Wardroppian UE. It assumes a traveler chooses the shortest route only based on the prevailing traffic condition at the time of his choice decision (Kuwahara & Akamatsu 2001). The other UE type is the so-called Predictive User Equilibrium (PUE). Under this behavioral assumption, travelers choose the shortest route based on “anticipated" travel times, or travel times that they actually experienced from previous days. **The result is a UE in which the actual travel times/costs for travelers from any O-D pair are minimal and identical (Friesz et al. 1993), regardless the routes they take.** In reality, traveler’s route choice behavior is likely to be more complicated and unpredicted than BUE and PUE. For example, travelers may not consider all the possible routes but have several pre-trip routes in mind prior to their departure, which are selected from their day-to-day traveling experiences. Moreover, these pre-selected routes may not be user-optimal ones. **In view of this, a hybrid traffic assignment model was purposed to model both equilibrium and disequilibrium traffic conditions (Qian & Zhang 2013). We adopt the hybrid model in this project with the diversion ratio indicating how reactive travelers are in choosing routes.**

2.2 Flow evolution model

The flow evolution models describe the dynamic relationship between vehicle density, speed and volume for one road segment. Three models are most adopted by various mesoscopic traffic simulation tools: Point Queue (PQ) (Jin 2015), Spatial Queue (SQ) (Balmer et al. 2004; Breuer 2001) and Cell Transmission Model (CTM) (Daganzo 1995; Daganzo 1999). Though mathematically and practically simple, **PQ and SQ are considered to underestimate** the network congestion during the simulation (Zhang et al. 2013). **CTM as a finite element approximation to the partial differential equation of fluid evolution is proved to best simulate the flow propagation on road segments. A vital issue exists for all dynamic flow evolution models, which is the unrealistic “gridlock” caused by improper routing behavior and misbehave of flow evolution models (Mahmassani et al. 2013).** -- In this project, we adopt CTM to simulate the flow propagation on links, and the unrealistic gridlock condition is eliminated by calibrating behavior model parameters and network dynamic features.

VISUM

Functionality

- Used by Dr. Pradhan’s PhD Student
  - “Dongle” is active, but no support is available
- Educational / Researcher’s License
  - $1,950 – one-time purchase
  - 2 year – technical support
  - Includes Visum, Visim, Viswalk

- **PTV Visum Functions**
  - **Network modelling**
  - **Demand calculations**
  - **PrT assignment procedures**
  - **PuT assignment procedures and operations**
  - **Traffic engineering**
  - **Create analyses and reports**
  - **Interfaces**

Theatrical Capacity of Roadways

Click for new presentation

Risk : $\varphi\,\psi\,(\Phi$ Hazard $*\ \Theta$ Vulnerability $*\ \mathfrak{z}$ Exposure)

φ Factor to account for **uncertainty**; ψ Factor to account for **risk tolerance of culture**

Φ Factor to account for the attributes of Hazard; Θ , $\mathfrak{z}$ Factors to account for **resilience;**

Hazard: Severity, Impact area, Precedence/Return Period, Natural/Manmade, Warning;

Earthquake: collapse, fire, liquefaction, landslide, tsunami;
Hurricane, storm surge, tornado, flood, impact, floating, scour;
Accident, collusion, vehicle/ship impact, vehicle fire, deterioration, corrosion, fatigue;
Radiation, hazardous waste spill, chemical/gas leaks, bio-hazard, explosion, explosive, bomb;
Leaks/ruptures, erosion, sinkhole, climate change, sea-level rise, drought, deluge, epidemic;

Vulnerability: **Of socio-technical systems** – Fragility of community (lack of preparedness, demographics, economic losses), organizations (gov, emergency response, emergency management, triage/medical care, shelter, food, school, transportation, communication; **Of engineered and constructed systems -** Fragility or lack of resilience of the built environment and especially the lifelines, cascading of failures due unknown interdependencies; **Of natural systems** - negative long-

Carrier Goals

Continue to work towards and research topics related to increasing the current and future livability of cities

- Stay involved and connected to Complex Sociotechnical Systems
  - Work in some capacity with City infrastructure systems or City Planning
  - Exploring coordination between strongly interdependent systems, departments, and agencies
    - Can incentives be created in which agencies' actions promote increased citywide LSR and not just focused on asset or specific systems.
- Work directly with transportation infrastructure assets
  - Performance based risk asset management
  - Or hands on design-build work
- Continue working in Education
  - At any level
- Obtain my P.E.

Appendix

Python_Code

GitHub