NYC Taxi Drive Cycle Development and Simulation Study

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Overview

- **Timeline**
  - Project start date: Nov. 2011
  - Project end date: May 2012
  - 95% complete
- **Barriers**
  - Unique vehicle mission, drive cycle
  - Limited data availability (HVAC)
  - Charging infrastructure
  - Vehicle readiness
- **Budget**
  - New project, FY12 funding
  - FY12 funding: $ 100 k
  - Field Data Provided (Ricardo)
  - FY13 (current) funding: $0k project completed
- **Partners**
  - Oak Ridge National Laboratory
  - NYC Taxi and Limousine Commission
  - Ricardo
  - INL, ANL, NREL

Objectives

- **Obtain “in-use” HEV Taxi cab field data (Ricardo - Escape HEV Taxi Deployment)**
- **Develop appropriate drive cycles using ORNL’s DC_Gen Tool**
- **Construct basic Nissan Leaf™ simulation model in Autonomie**
- **Simulate and project vehicle performance using ORNL developed drive cycles.**

Vehicle Technology Program (VTP) - Relevance

- **VTP Multi-Year Program Plan (2 key goals from VSST Subprogram)**
  - **Demonstrate market readiness of grid-connected vehicle technologies by 2015.**
  - **Support the laboratory and field evaluations of large-scale demonstration fleets of advanced commercial and passenger PHEVs and EVs.**

- **Barriers**
  - **Public acceptance of electric drive as central vehicle choice**
  - **Battery cost and durability**
    - **Though not directly evaluated in this program, right sizing components for mission design is critical – consumer behavior and understanding of expectations (HVAC)**

Background NYC Taxi Fleet - Relevance

- Largest taxi fleet in the United States
- The New York City Taxi and Limousine Commission (TLC) was established in 1971 with jurisdiction over the city's medallion (yellow) taxicabs and “for hire” service vehicles
- 48,000 cabbies in New York & 13,000+ licensed “Medallion” taxicabs*
- Huge fleet operation costs/logistics

  HEV fuel use in 2010 – Operators noted a reduction of nearly $20/day

  Ford used HEV Taxi’s from west coast to evaluate battery performance**

*http://www.nyc.gov/html/tlc/html/current/current_licensees.shtml

**http://wardsauto.com/news-amp-analysis/hybrid-battery-durability-stuns-ford

Leaf Taxi Pilot Project - Relevance

- New York City Taxi & Limousine Commission
- Opportunity to Green the NYC Fleet
- 4 Vehicles in pilot program – DC "Fast Chargers" located around city
- Reduce operational cost (current Crown Victoria avg < 12 mpg)
- Idaho National Laboratory (INL)
  - PI - Jim Francfort
  - Field data collection and analysis
- Nissan NV200 – Taxi of the Future, proposed all EV driveline 2016-17 (Prototype is currently being tested by FedEx® in Europe)

Approach

- **Obtain Ford Escape HEV NYC field use data**
  - **Ricardo FTP Site access and data format help**
  - **Utilizing ORNL's DC_Gen tool develop "NYC TAXI" drive cycles based on field data; High load & nominal cycles**
    - **HVAC load estimates and projected impacts**
- **Develop 'Autonomie' base Nissan Leaf model**
  - **Battery Mule calibration and estimation work overlap**
  - **ANL test runs on 2011 Leaf utilized for model validation**
- **Conduct simulations in Autonomie**
- **Project performance of EV in taxi service**
  - **Future analysis of field usage data, adjust drive cycles as needed**

Milestones Status

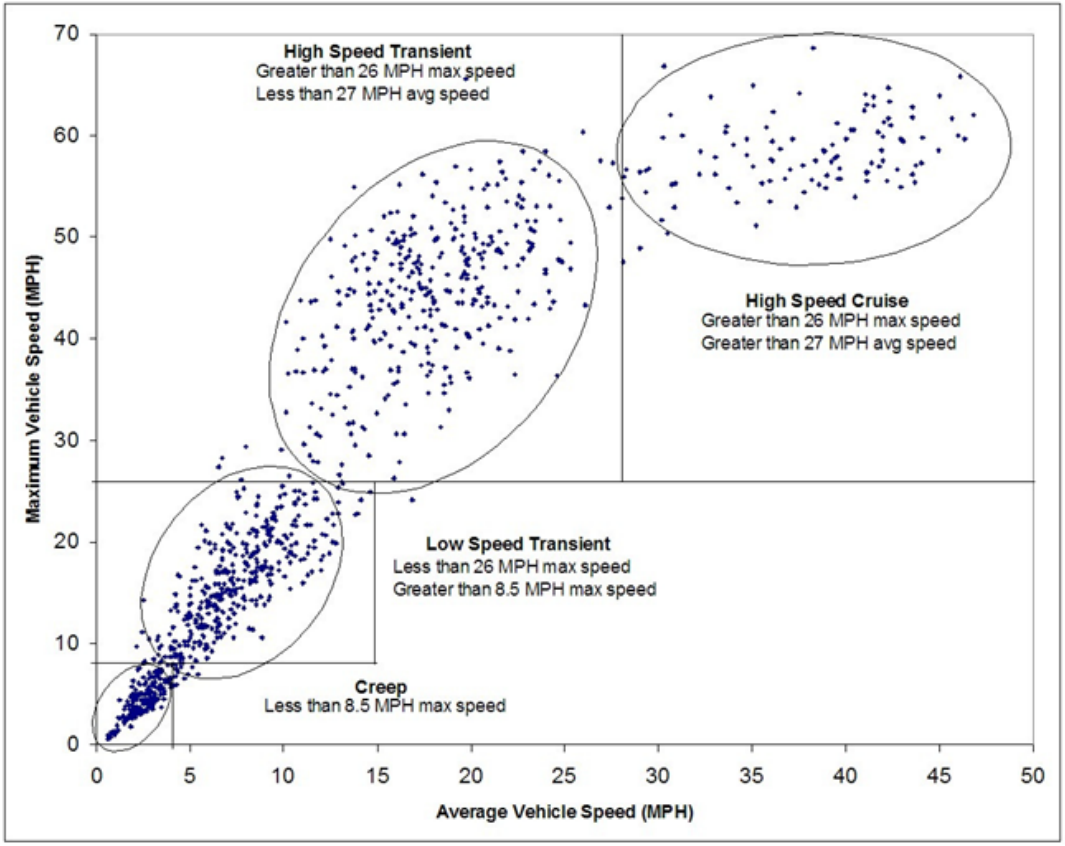
- **Milestone #1, January 2012:**
  - **Data received in usable format from Ricardo**
  - **Histogram generation and analysis**
  - **Baseline Nissan Leaf Autonomie model created**
- **Milestone #2, February 2012:**
  - **Drive cycle modules created from ORNL DCgen Tool**
  - **Full drive cycles developed and simulations performed using Leaf model in Autonomie**
- **Milestone #3, March 2012:**
  - **VSATT presentation**
  - **Presentation to NYC Taxi and Limousine Commission**

AOP Project Objective:

The purpose of this task is to create a representative drive cycle for simulation and performance projections of all electric vehicles placed into taxi cab service in New York City.

Project Focus Area – Taxi Drive Cycle Creation

- 1 month of single vehicle data
- Around 3000 trips
- Daily Range 252-360 miles per day (mpd)
- Average range 270 mpd



http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2515

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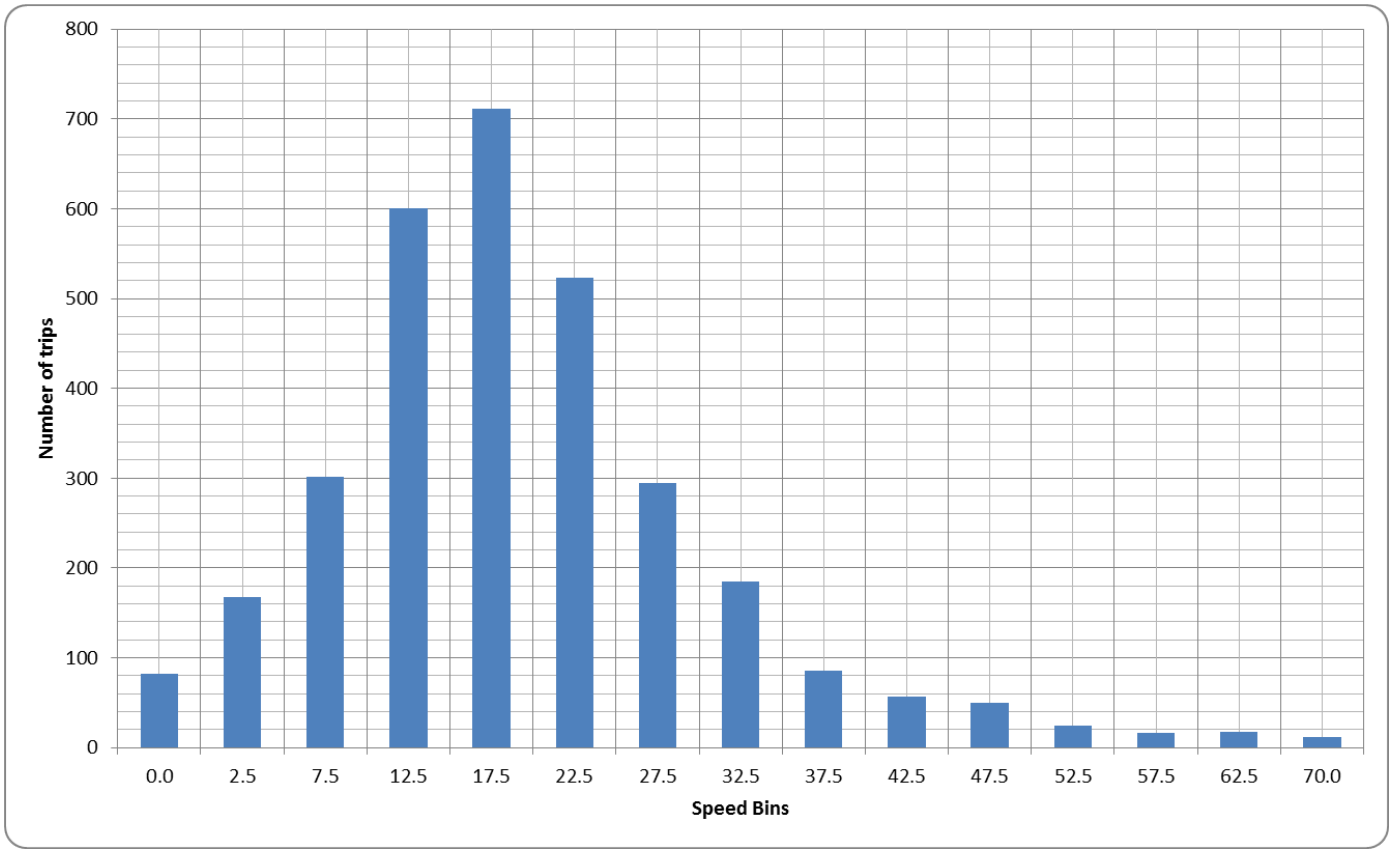
Drive Cycle Development – Field Data Analysis

Speed Ranges [km/h]	# Trips	% Total Trips	
(0-5)	168	5.52%	
[5-10)	**301**	**9.89%**	15.40%
[10-15)	601	19.74%	
[15-20)	**711**	**23.35%**	
[20-25)	523	17.18%	60.26%
[25-30)	**294**	**9.66%**	
[30-35)	185	6.08%	15.73%
[35-40)	**86**	**2.82%**	
[40-45)	57	1.87%	
[45-50)	50	1.64%	
[50-55)	24	0.79%	
[55-60)	16	0.53%	
[60-65)	17	0.56%	
>=65	12	0.39%	8.60%
	3045		

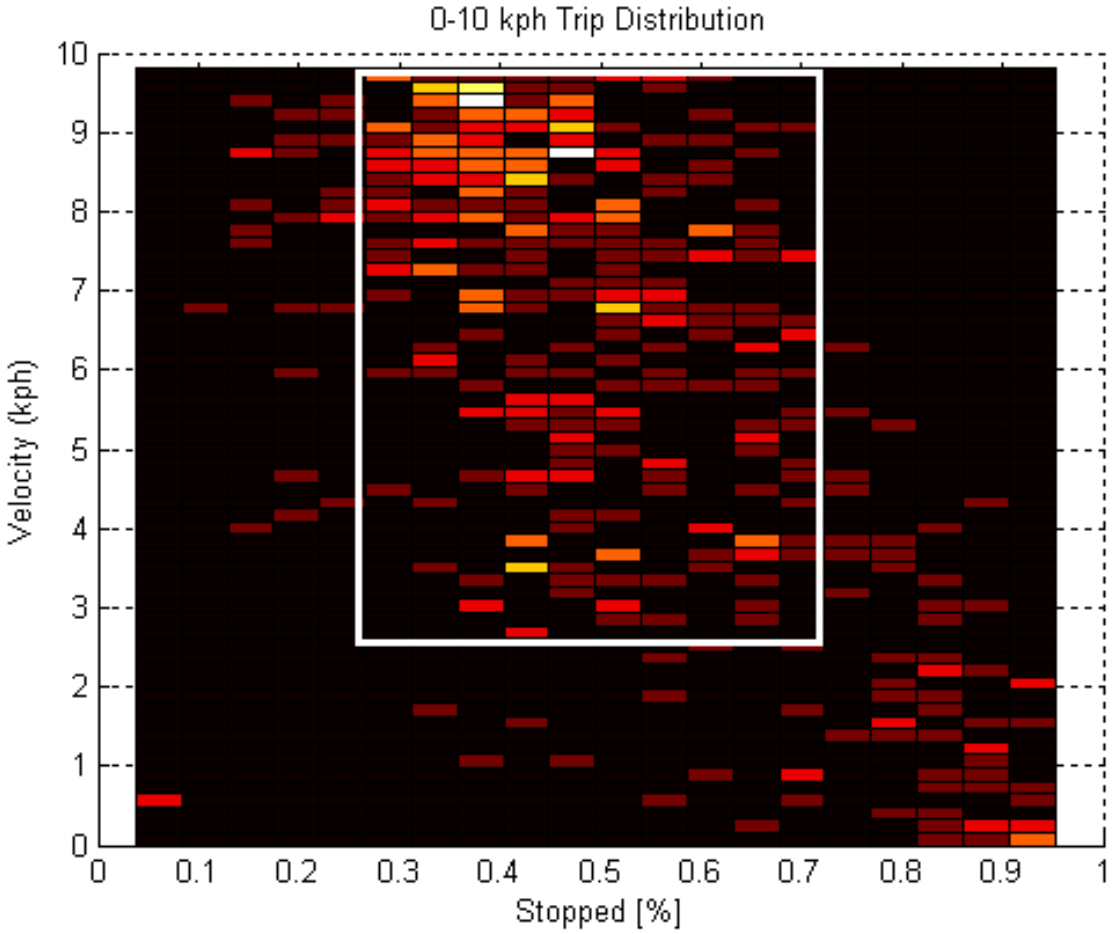
NYC HEV Taxi field data

Drive Cycle Development – Module Category Determination



NYC HEV Taxi field data

Test Drive Cycle Development - Low Speed (LS) Synthesis

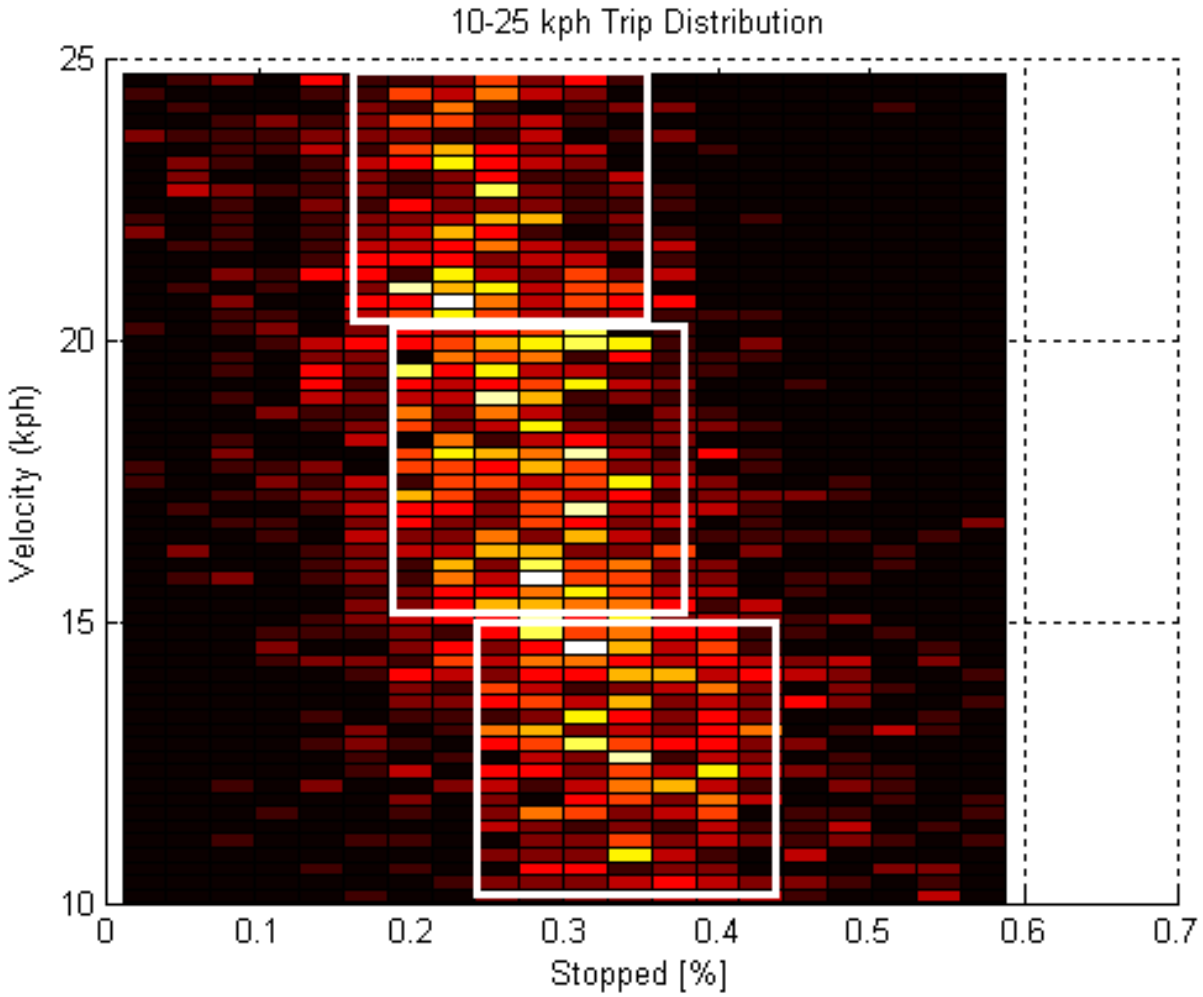


15% of all trips

ORNL DC Gen Tool Histogram

Test Drive Cycle Development - Approach

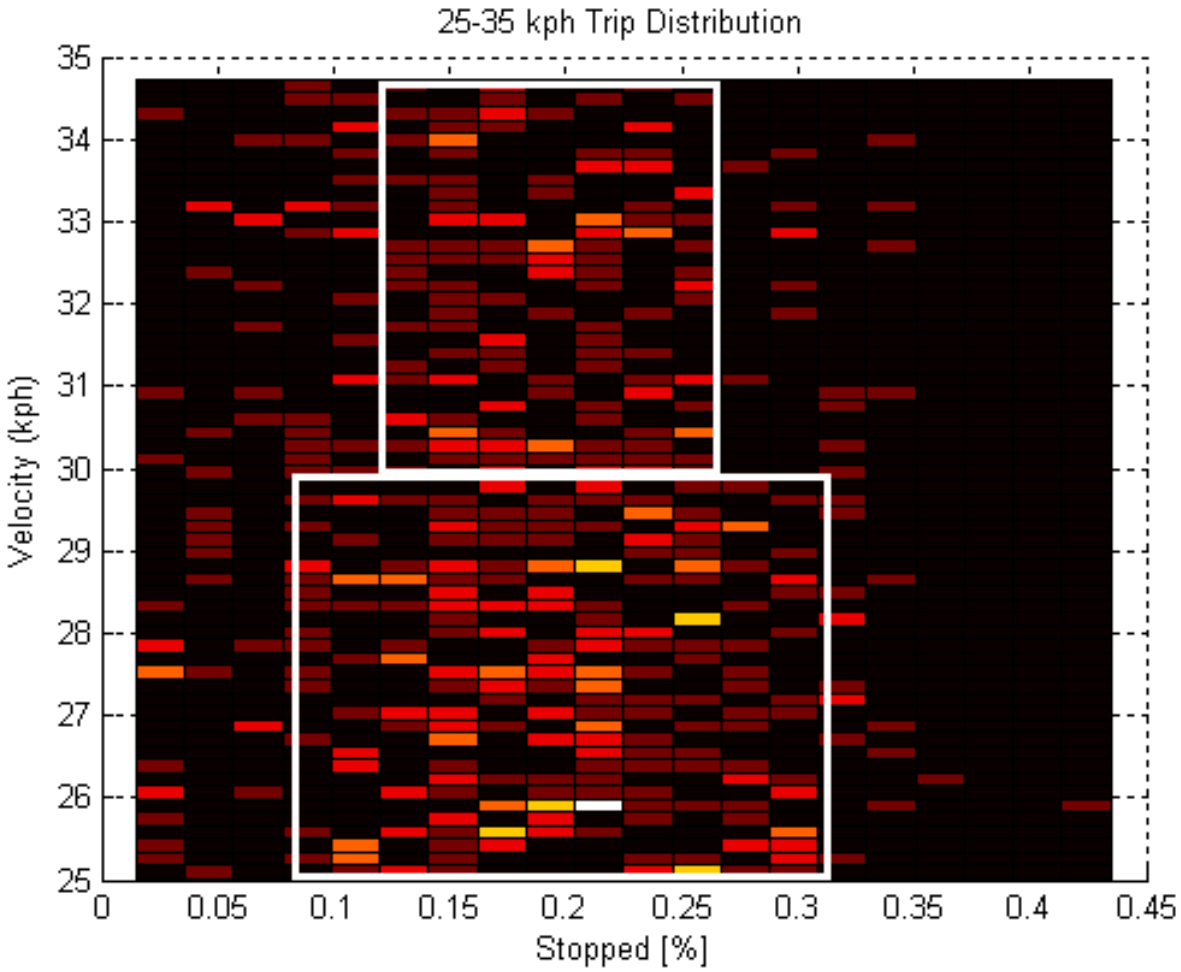
- **Medium speed band**



60% of all trips

Test Drive Cycle Development - Approach

- **Medium high speed band**



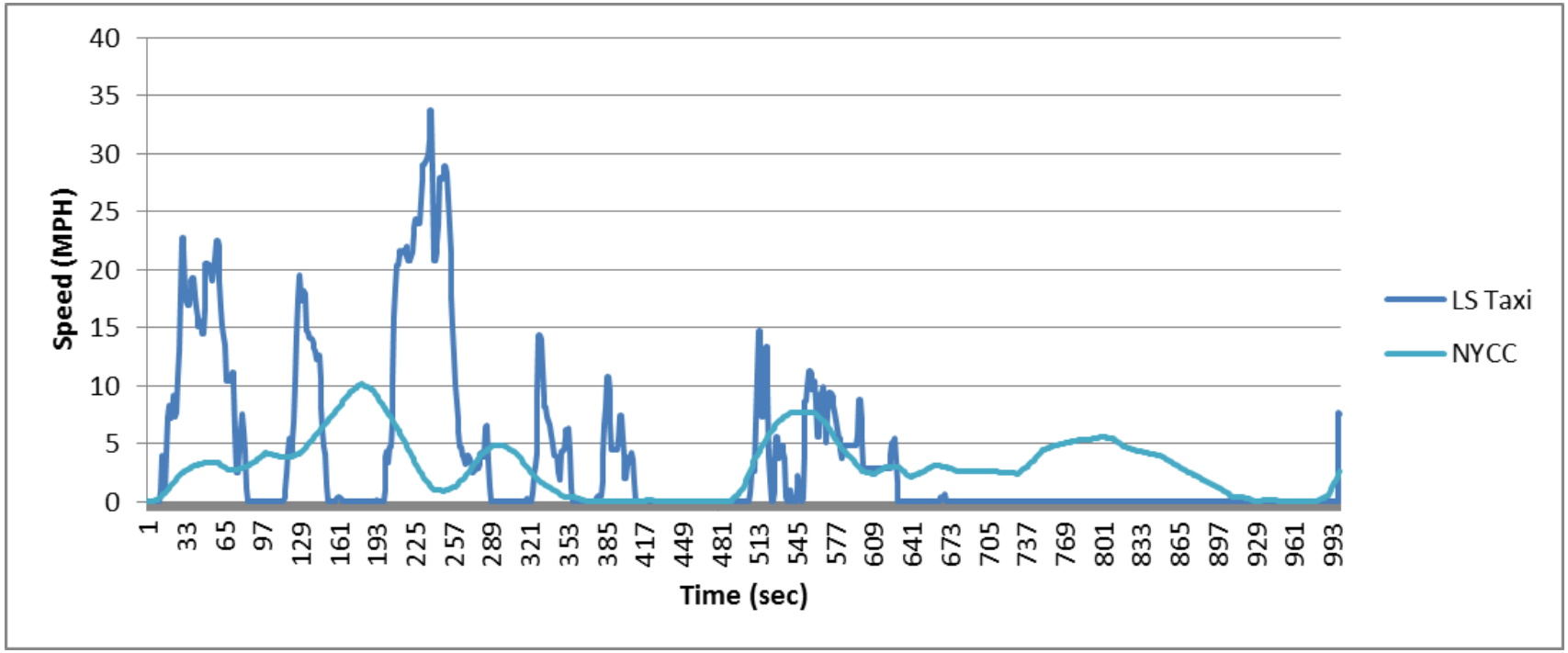
15% of all trips

Drive Cycle Development – Low Speed (LS) module

- **Drive cycle modules created for four speed ranges (final speed bins)**

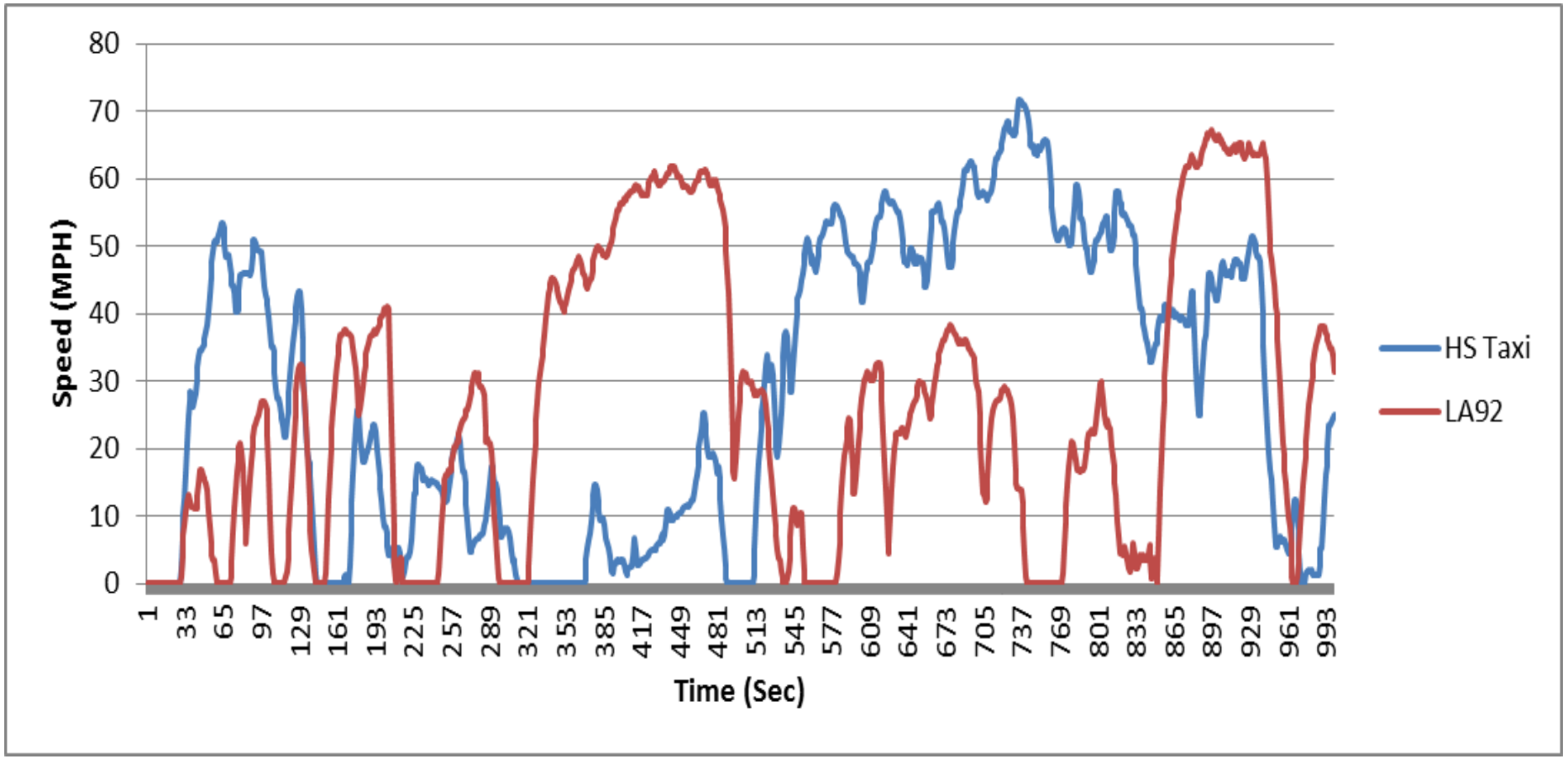
  Influenced by maximum trip lengths and existing drive cycles - approx. 1800 sec

- **Synthetic cycles appear aggressive when compared to historical drive cycles**



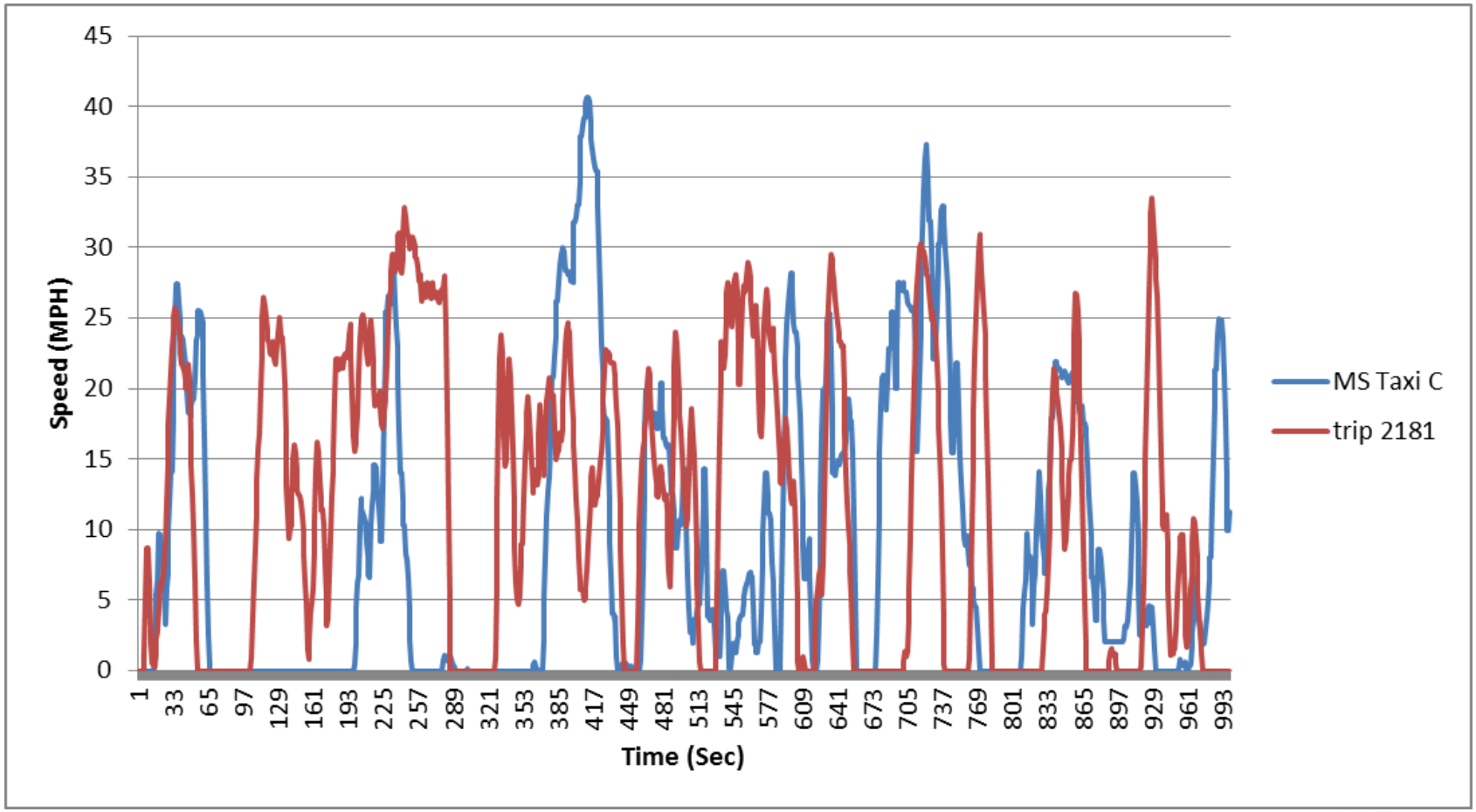
Drive Cycle Development – High Speed (HS) module

- **Synthetic cycles have similar traits when compared to <u>updated</u> drive cycles**



Drive Cycle Development - Synthesis

- **Synthetic cycles show characteristics of field data when overlaid.**



Drive Cycle Development - Synthesis

Module Plug and Play Method

- **Operator shift based drive cycle length**

  Early simulation results deemed 8 hour cycle would result in low SOC

- SOC limits for “24/7” operation – fast charge limitations for SOC (80%)
- ‘High Load’ versus ‘Nominal’ drive cycles vary use of modules

Drive Cycle	Module Type and Number			
	LS	MS	MH	HS
Nominal	1	5*	1	1
High Load	1	4**	2	1

* Varied modules ** All from high speed bin

Assumptions - HVAC Load Impact on EV Operating Range

- **Previous electric vehicles research for vehicle preconditioning***
  - This analysis shows that typical climate control loads can reduce CD range up to 35% for heating loads.
- **Due to the unique HVAC loads of a taxi cab (due to constant ingress and egress) the 2kW estimated typical load for cabin conditioning was not deemed sufficient**
  - For these simulations non-drive loads ranged from 0.5kW (assuming little to no HVAC use) to 3.5kW , these estimates will be updated once testing on the Nissan Leaf is completed later this year.
- **Regional temperature data is not enough**
  - Taxi cab use is linked directly to local ambient conditions – not just temperature. Driving characteristics as well as customer usage traits change with precipitation as well. Number of trips per hour – indicator of number of door openings per hour. What are the customers expectations - responses to interior temperature of vehicle

* **Analysis of Off-Board Powered Thermal Preconditioning in Electric Drive Vehicles**

Robb A. Barnitt, Aaron D. Brooker, Laurie Ramroth, John Rugh, and Kandler A. Smith

National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401, U.S.A

Drive Cycle Development - Summary

- **Utilization of field data**
  - **Limited to a summer month of operation for one vehicle**
  - **Averaged 21 hours/day operation (only 5 days operated less than 20 hours)**
  - **No limitations to service routes**
  - **Typical daily mileage exceeds any current EV range (recharging required)**

- **NYC Taxi drive cycle overviews**
  - **Based on field data developed modules**

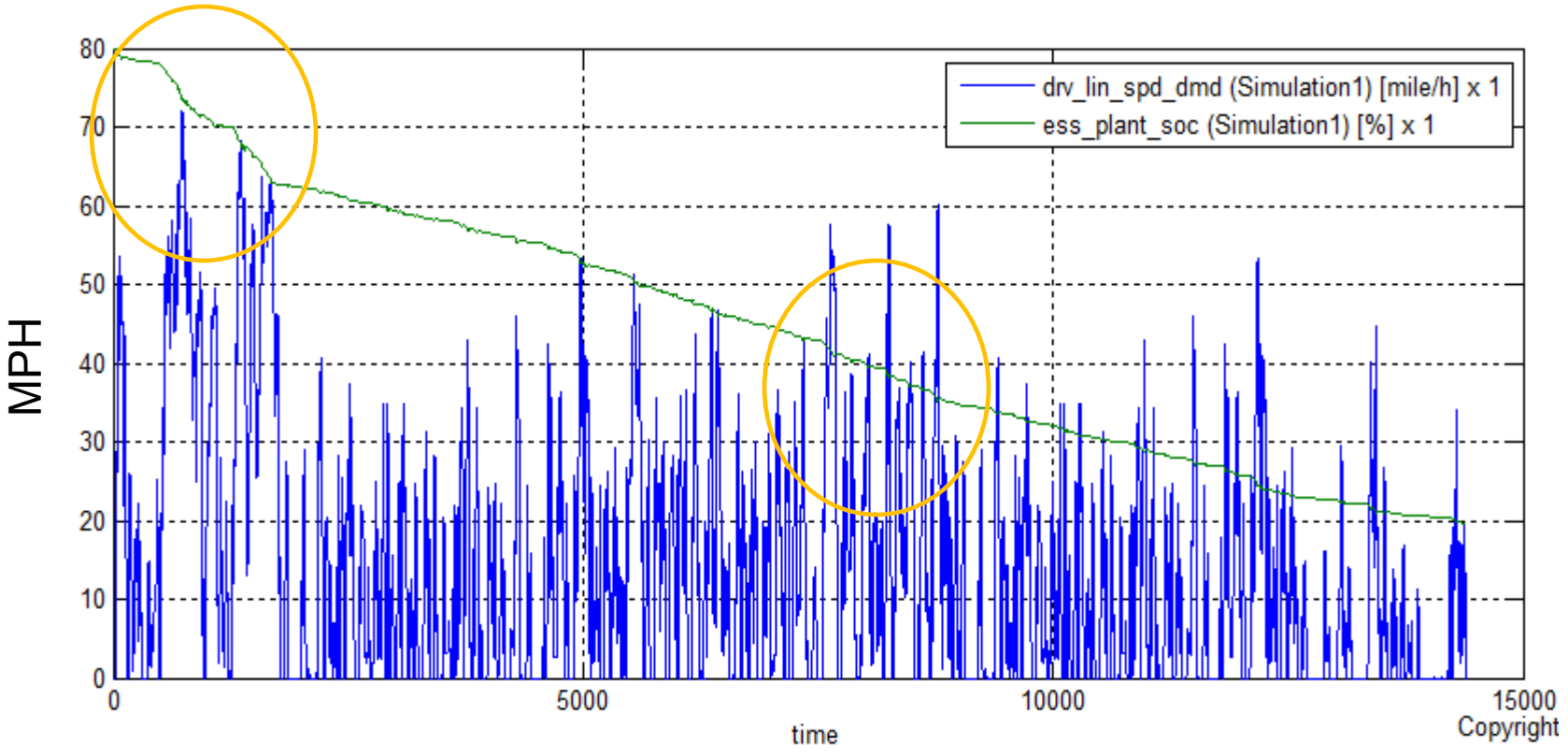
Drive Cycle	Specifications			
	Time (hours)	Distance (miles)	Avg Spd (mph)	Avg Spd (kph)
Nominal	4	56.0	14.0	22.5
High Load	4	69.4	17.3	27.8

Vehicle Simulation Results

Vehicle Configuration	Nominal cycle	High Load	Comments
Base Vehicle	238 wh/mi	231 wh/mi	0.5kW, 80% SOC
Base Veh w/ Htr	584 wh/mi 39.1 / 56.0mi	553 wh/mi 42.8/ 69.4 mi	3.5kW heater load, 80% SOC

Yellow highlighted areas indicate vehicle does not complete 4 hour drive cycle

Drive Cycle Development – Simulation Result



Electric Taxi Performance Projection Summary

- **Expected operational time with no HVAC loads is above 4 hours for Nominal drive cycle only**
  - **Recharging locations critical to reduce "lost fairs" and route restrictions may be needed to avoid issues**

- **Additional HVAC load data required for accurate estimations as well as impact of changes with 2012 Leaf cold package.**
  - **Based on field data developed modules**
  - **ANL is collecting data as part of cold ambient Leaf testing**

- **'High Load' drive cycle placed vehicle in more efficient range of operation**
  - **Key for future vehicle design parameter generation, NV200 is larger, 99 mph top speed not required.**

Accomplishments – Model, Drive Cycle and Data Sharing

- **Creation of new project specific drive cycles and vehicle model**
- **Simulated initial vehicle performance using new drive cycles and ORNL developed model of vehicle**
- **Summarized vehicle information for field data comparison and future test procedure modifications**

Collaboration and Coordination with Other Institutions

- Ricardo -Vehicle data transfer
- Taxi & Limousine Commission

National Laboratory information sharing (ANL, NREL, INL)

- Preliminary Leaf Test Results
- HVAC load estimations
- Future field data

Future Work

- Obtain in-use EV Taxi field and charging data
  - Validate ORNL developed drive cycle and simulation model
- Opportunity for regenerative breaking algorithm modifications in simulation.
- HVAC Load information for various temperatures in high duty cycle use (multiple ingress and egress - door openings)
- Opportunity charging route analysis

Overall Project Summary

- **NYC Taxi Driving Cycles were developed using Ricardo gathered field data from a Hybrid Ford Escape operating in NYC**
  - **High load and Nominal load driving cycles were developed and compared to historical cycles and field data.**
- **A baseline Autonomie model of the Nissan Leaf was created to predict performance of this vehicle used as a NYC taxi cab**
- **Considerations for impact of HVAC loads were incorporated into the simulation as well as DC "Fast Charge" SOC boundaries**
  - **Typical cab '24/7' availability may require route restrictions and recharging process standards to ensure maximum hours of operation.**

Acknowledgements and Contacts

DOE Vehicle Technologies Program:

- ***Lee Slezak, Vehicle Systems Manager***

Oak Ridge National Laboratory (ORNL)

- ***David E. Smith, Advanced Vehicle Systems Program Manager***

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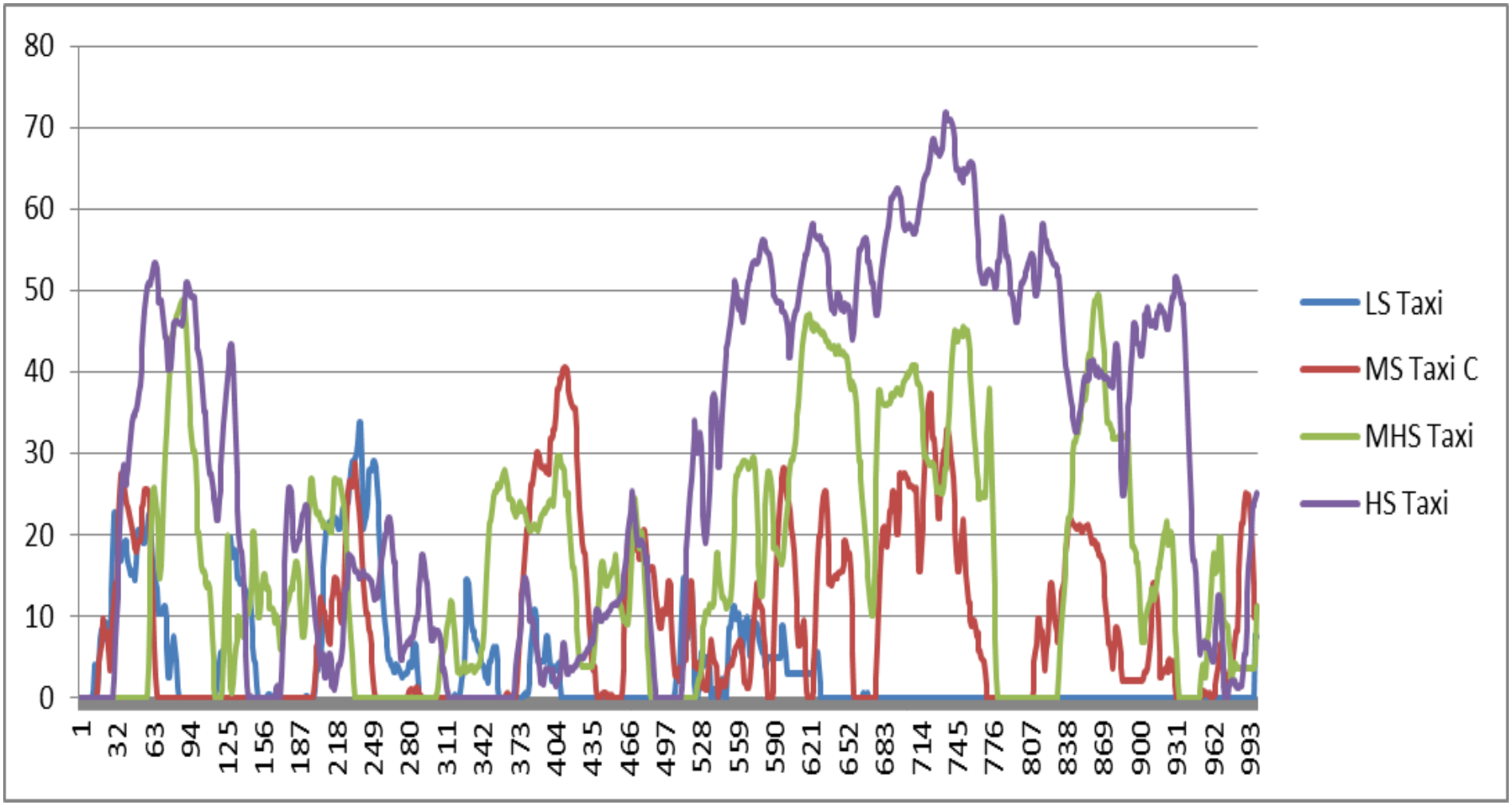
- ***Adam Siekmann***

Thank You

Technical Backup Slides

Drive Cycle Development - Synthesis



Characteristics of synthetic modules when over laid. (first 100 sec)