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Opportunities for Improving the Energy Efficiency of Multi-Modal Intra-City Freight Movement

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OVERVIEW

TIMELINE

Project start date: **10/01/2016**
Project end date: **9/30/2019**
Percent complete: **17%**

BUDGET

Total project funding (DOE): **$300k**
Funding received in FY 2017: **100k**

BARRIERS

Computational models, design and simulation methodologies
Constant advances in technology

PARTNERS

DOE Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Consortium Members
Argonne National Laboratory
Idaho National Laboratory
Oak Ridge National Laboratory

Industry Partners
United Parcel Service

Other Institutions
Mid-Ohio Regional Planning Commission

Indirect Data Providers
U.S. Department of Transportation
U.S. Federal Highway Administration
U.S. Department of Homeland Security
Others

PROJECT OBJECTIVE

Analyze opportunities for freight movement energy savings via optimization and integration of existing/emerging intra-city goods delivery modes

Develop an understanding of new freight delivery technologies and strategies, and how they might impact future energy consumption at the intra-city level

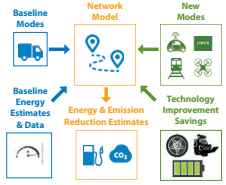
Assess efficacy of new technologies and modal scenarios through modeling and analysis

Collect and analyze baseline freight delivery data

Establish estimates for energy savings achievable through technology optimization and future modal deployment

Validate analysis approach against existing United Parcel Service data to baseline actual logistics business model attributes (consideration of package size, handling equipment, modes of conveyance, transfer, pickups/deliveries/stem routing, time, etc.)

APPROACH



Five-step process to evaluate current baseline multi-modal freight movement and future modal change scenarios:

- Gather requisite input data on energy consumption rates for existing and future modes as well as freight movement data for network development
- Develop baseline freight movement network model
- Perform simulations of current baseline freight movement scenarios using existing network with current and improved technologies
- Develop future modal network with assumptions based on new technology deployment
- Explore range of scenarios and optimize freight movement and modal shares for energy consumption while adhering to current freight movement time and cost constraints

1 Gather baseline data:

Baseline Vitals Example

Class	Applications	GVW Range (lbs.)	Gross Weight Range (lbs.)	Max. Payload (lbs.)	Fuel Economy Estimate in 2027 (mpg)	Fuel Consumption (gal per thousand ton-miles)
3	Utility Van (e.g., Ford F350)	10,001–14,000	7,900–8,750	6,200	10.5	95.2
4	City Delivery (e.g., Dodge Ram 4500)	14,001–16,000	7,900–8,750	7,200	9.5	105.3
5	Large Delivery (e.g., Ford F-650)	16,001–19,500	9,000–10,800	8,700	8.0	125.0
6	Package Trucks, Dump Trucks (e.g., GMC Topkick C4500)	19,501–26,000	11,500–14,500	11,000	6.9	145.0
7	Fuel Trucks, Beverage Trucks (e.g., GMC 7500)	26,001–33,000	17,000–18,000	15,000	6.0	166.7
8a	Dump's Trucks (e.g., Dump, Refuse Packer)	33,001–60,000	20,000–34,000	20,000–50,000	4.5	222.7
8b	Semi-Tractor Trucks (e.g., Tractor Trailer, Refrigerated, Bulk)	33,001–80,000	23,000–34,000	40,000–44,000	6.8	14.5

Gather and combine existing publicly available freight, infrastructure, and energy usage datasets:

U.S. Department of Transportation's Freight Commodity Flow Survey, Freight Analysis Framework, and Rail Waybill Database

U.S. Department of Homeland Security's National Infrastructure Database

Association of American Railroad's Freight Rail Traffic Database

National Renewable Energy Laboratory's Fleet DNA Clearinghouse

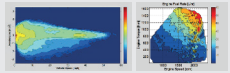
INRIX

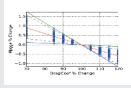
Others

2 Establish estimates for technology-based savings:

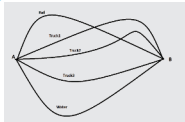
Improvements to existing technology:
Engine efficiency
Rolling resistance
Aerodynamic improvements
Alternative and renewable fuels

New and promising technology:
Freight "uberization"
Intelligent traffic routing
Consolidated deliveries
Drones
Smart/autonomous vehicles

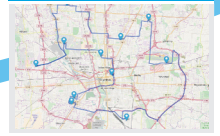




3 Develop simplified freight network model using origin-destination pairs and baseline energy consumption inputs:



4 Expand simplified model to include additional origin-destination pairs reflecting real-world intra-city baseline delivery behavior:



5 Perform simulations using baseline network to evaluate current freight movement scenarios:

Explore both current and improved technology conditions

Evaluate opportunities for energy savings and technology optimization

$$\sum_{i=1}^{n} x_i\,(speed, distance, volume, time, etc.) = cost$$

6 Develop additional network scenarios with assumptions based on future potential mode deployment:

Future Modal Options

7 Explore range of scenarios and optimize freight movement and modal shares on energy consumption while adhering to current freight movement times and cost constraints:

$$\min \sum_{i=1}^{n} \sum_{j \in V_i, i \neq j}^{n} c_{ij} x_{ij}$$

$$s.t.\ \ x_{ij} \in \{0,1\} \qquad i, j = 1, \ldots, n$$

$$\sum_{i=1, i \neq j}^{n} x_{ij} = 1 \qquad j = 1, \ldots, n$$

$$\sum_{j=1, j \neq i}^{n} x_{ij} = 1 \qquad i = 1, \ldots, n$$

$$\sum_{i,j \in S, i \neq j} x_{ij} \leq |S| - 1 \qquad \forall S \subseteq V, S \neq \emptyset$$

Example scenarios:

Additional Intra-City "Micro Depots"

Integrated Drone Delivery

Freight "Uberization"

TECHNICAL ACCOMPLISHMENTS

Compiled Mid-Ohio Regional Planning Commission, Freight Analysis Framework, United Parcel Service, and other freight movement and volume data within Columbus to characterize intra-city freight energy use; data will be used to validate freight volume, origin-destination movement, and energy-use assumptions to assess energy-saving multi-modal options (in progress)

Initiated literature review on freight-based tour model methodologies

Identified new modes and vehicle efficiency improvements and began characterization of energy profiles of potential vehicles and modes

Initiated development of a route-based predictive drive cycle model; using origin-destination routing information as inputs, this model will generate a representative drive cycle that can then be put into various existing U.S. Department of Energy tools to predict energy usage along a route

PROPOSED FUTURE RESEARCH

Identify new methods of adoption (such as neighborhood depots, person-to-person and uber-type delivery) and incorporate into tour-based models

Develop initial freight-movement network model and perform baseline simulations

Modify baseline model to examine new modes and technology enhancements

Complete predictive route-based drive cycle generation model

Work with delivery providers to characterize and optimize freight mode changes

Provide energy impacts and recommendations on adoption methods

REMAINING CHALLENGES AND BARRIERS

Need improved model data for evaluating energy benefits from modal shifts

Need to further identify and characterize new modes of goods delivery in urban environments

Need to work with delivery providers to understand adoption rates and impacts

Need more information on the energy profiles for new vehicle options such as drones

Need to further enhance tour-based models to identify finer detail on energy impacts and how to represent shifts in modes

COLLABORATION

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Other Institutions
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U.S. Department of Homeland Security
INRIX
RL Polk
Others

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