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MICROMOBILITY INTEGRATED TRANSIT AND INFRASTRUCTURE FOR EFFICIENCY (MITIE)

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OVERVIEW

**Timeline**

- Project start date: 09/01/2020
- Project end date: 09/30/2023
- Percent complete: 17%

**Budget**

- Total project funding: $2,680,000
  - DOE share: $2,680,000
- Funding for FY 2020: n/a
- Funding for FY 2021: $894,000

**Barriers**

- Barriers addressed:
  - Vehicle-Mobility Systems Analysis Tech Team (VMSATT) future mobility systems scenarios
  - VMSATT evaluation and augmentation of capabilities for Mobility Energy Productivity (MEP) at scale

**Partners**

- Interactions/collaborations
  - Tom Wenzel, Lawrence Berkeley National Laboratory (LBNL)
  - Elliot Martin, University of California, Berkeley
  - Simeon Iliev, Argonne National Laboratory (ANL)
- Project lead
  - Andrew Duvall, NREL
RELEVANCE: OBJECTIVES

- Overall Project Objectives (April 2020–March 2021):
  1. A comprehensive set of micromobility scenarios to be integrated into Workflow
     • Initial scenario parameters identified
  2. Estimated energy impacts for low-, medium-, and high-adoption scenarios
     • Framework for initial estimates
  3. Analysis of interconnected transit/micromobility use
     • Engage with transit operators; evaluate data availability
  4. Behavioral models of current and hypothetical micromobility, induced demand
     • Develop framework for Fundamental Influencing Factors (FIF) model
  5. Energy optimization estimates of micromobility operations
     • Engagement with stakeholders; identify shared micromobility challenges
  6. Quantitative energy estimation of microfreight
     • Engagement with stakeholders; identify microfreight vehicle types
RELEVANCE: MITIE CONTRIBUTIONS

- The MITIE project supports Energy Efficient Mobility Systems (EEMS):
  - Advancing technologies and systems to improve MEP when adopted at scale
  - Exploring modes that have not been well studied in the context of energy impacts

- The MITIE project will be relevant to:
  - **Reduction of energy costs** by replacing large vehicles, improve transit & delivery
  - **Increased energy security** by reducing fossil fuel dependence
  - **Clean energy technology to move people and goods** by using highly efficient vehicles with simple and proven electric vehicle (EV) technologies

- MITIE addresses research barriers by defining future mobility scenarios and integrating equitable options.
MILESTONES

FY2021
Q1 (Completed): Execution of stakeholder agreements; Identification of vehicles with high-value data gaps
Q2 (Completed): Literature review of metrics for efficiency of transit and micromobility operations, available trip-level data
Q3 (In progress): Baseline FIF behavior modeling framework
Q4 Initial scenarios for micromobility and transit/micromobility multimodality behavioral models, and microfreight simulations in preparation for Workflow integration; Data collection for one emerging form of transport completed
Go/No-Go: Integration of output from micromobility modeling and simulation tasks to inform Workflow scenarios for Workflow modeled cities.

FY2022
Q1 Summary of mature FIF behavior modeling framework; Summary of data and methods to validate micromobility functions in four BEAM1 cities
Q2 Summary of microfreight scenarios for BEAM; Report from BEAM simulations of micromobility as first/last mile to transit scenarios in BEAM cities; Research new vehicles with high-value data gaps
Q3 Report on operational energy optimization and scenarios for shared micromobility
Q4 Micromobility scenarios for representative cities from other size cohorts
Go/No-Go: Integration of output from micromobility modeling and simulation tasks to inform Workflow scenarios.

1. Behavior, Energy, Autonomy, and Mobility model

Any proposed future work is subject to change based on funding levels.
APPROACH: PROJECT EMPHASIS AREAS

1. Energy estimates of micromobility for Workflow scenarios
   - Augment the Workflow approaches to modeling urban travel

2. Multimodal connection with transit
   - Evaluate multimodal travel patterns enabled by micromobility, including assessing how to reduce barriers of inequity of access to mobility options and destinations

3. Mode choice, induced demand, and infrastructure
   - Understand the mode shift induced through micromobility, supportive infrastructure

4. Energy optimization of micromobility operations
   - Evaluate micromobility operations parameters and operations scenarios

5. Microfreight
   - Characterize microfreight activities, energy effects and geospatial analyses
APPROACH: CONTRIBUTIONS TO SMART MOBILITY EFFORTS

Unique aspects of this work augment SMART Mobility:
- Enhancement of Workflow models to include micromobility scenarios for agents in the models based on real-world data and observations
- Behavioral model that is mode-agnostic—meaning that as-yet unknown micromobility modes can be modeled by characteristics

Addresses technical barriers by:
- Working toward ranges of generalizable and transferrable micromobility assumptions and transit interconnection
- Accounting for specifics of location and demography in micromobility use

Integration within SMART Mobility:
- BEAM CORE: Closely working with modelers to inform scenario integration
- Freight: Microfreight as a component of overall freight
- Curb space: Micromobility and microfreight impacts on curb activity.
**TECHNICAL ACCOMPLISHMENTS: ENERGY ESTIMATION/SCENARIO DEVELOPMENT (TASK 1)**

**Scope:** Energy estimates of micromobility for Workflow scenarios
- Developed literature review of metrics for quantifying efficiency of transit and micromobility operations
- LBNL incorporated docked and dockless shared bike/scooter modes into BEAM.

**Summary:**
- Close coordination with the BEAM CORE team in scenario development
- Initial scenarios identified; progress toward FY2021 Q4 milestone.

**Table 1. Micromobility scenarios for Workflow modeling (bold are prioritized)**

<table>
<thead>
<tr>
<th>Lever</th>
<th>Baseline</th>
<th>Low scenario</th>
<th>CORE scenario</th>
<th>High scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Present-day state</td>
<td>Present-day state</td>
<td>50% of present-day cost by 2050</td>
<td>50% of present-day cost by 2035</td>
</tr>
<tr>
<td>Prevalence of on-demand summon,</td>
<td>Current baseline is 0%</td>
<td>Current baseline is 0%</td>
<td>Replace 20% of current fleet with automated micromobility vehicles by 2050</td>
<td>Replace 20% of current fleet with automated micromobility vehicles by 2035</td>
</tr>
<tr>
<td>automated redistribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micromobility mode preference</td>
<td>Calibrated parameter</td>
<td>80% of calibrated parameter</td>
<td>Calibrated parameter</td>
<td>120% of calibrated parameter</td>
</tr>
<tr>
<td>Docked vs. dockless micromobility</td>
<td>Present-day state forward</td>
<td>All docked</td>
<td>Present-day state forward</td>
<td>All dockless</td>
</tr>
<tr>
<td>Repositioning fleet makeup (% battery electric vehicle [BEV])</td>
<td>Current % BEV as private fleet</td>
<td>0% forward</td>
<td>120% as many BEVs as private fleet</td>
<td>150% as many BEVs as private fleet</td>
</tr>
<tr>
<td>Privately owned e-bikes/e-scooters/</td>
<td>Baseline assumed 10% shared,</td>
<td>20% shared, 80% private</td>
<td>50% shared, 50% private</td>
<td>All micromobility is shared</td>
</tr>
<tr>
<td>manual bikes vs. shared use (% trips shared vs. private)</td>
<td>90% private</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novel freight paradigm: microfreight</td>
<td>Baseline is freight current</td>
<td>Baseline is freight current</td>
<td>Replace 5% of current freight fleet with microfreight vehicles</td>
<td>Replace 20% of current freight fleet with microfreight vehicles</td>
</tr>
<tr>
<td></td>
<td>state in BEAM model (no novel</td>
<td>state in BEAM model (no novel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>freight use)</td>
<td>freight use)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TECHNICAL ACCOMPLISHMENTS:
ANALYSIS OF TRIP-LEVEL DATA FOR MICROMOBILITY
(TASK 2)

Scope: Analyze micromobility trip data

- LBNL analysis of docked bikeshare data in five cities (San Francisco Bay Area, Austin, Detroit, New York City, and Jersey City)

- General bikeshare feed specification (GBFS) persistent bike identification, estimated the fraction of all trips and all VMT that are repositions

- Analyzed average trip distance, duration, and speed by type of day (weekday vs. weekend) and hour

- Analyzed dockless bike/scooter share data collected by UC Berkeley in three cities (SF Bay Area, Austin, Detroit).

Summary:

- Rides vary seasonally, and were initially negatively affected by the pandemic

- Large, high-density systems appear to experience higher use and shorter, faster trips

- Completed FY 2021 Q2 milestone; progress toward FY 2021 Q4 milestone.
TECHNICAL ACCOMPLISHMENTS: MODE-choice, INDUCED DEMAND, and INFRASTRUCTURE (TASK 3)

Scope: Produce fundamental influencing factor (FIF) modeling modules
   — Identified availability of trip-level data to be analyzed and incorporated into FIF framework for micromobility and non-micromobility trips
   — Three cities identified and data summarizing effort ongoing: Washington, D.C.; New York, NY; and Kansas City, MO

Summary:
   - Micromobility and non-micromobility trip data accessed from key cities
   - Data to inform initial FIF behavioral module for FY 2021 Q3 milestone
   - Supported completion of FY 2021 Q1 milestone.

Table 2. Micromobility and non-micromobility data availability for key cities: Washington, D.C.; New York, NY; and Kansas City, MO.

<table>
<thead>
<tr>
<th>City</th>
<th>Data Collection</th>
<th>Non-micromobility trips</th>
<th>Micromobility trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington, DC</td>
<td>non-micromobility</td>
<td>Regional travel survey data: October 2017 through December 2018</td>
<td>Multiple vendors Starting 2018 summer</td>
</tr>
<tr>
<td></td>
<td>micromobility</td>
<td></td>
<td>Citibike data, docked shared bike, 2017-now</td>
</tr>
<tr>
<td>NYC, NY</td>
<td>non-micromobility</td>
<td>City wide mobility survey: 2017, 2018, 2019</td>
<td></td>
</tr>
<tr>
<td>Kansas City, MO</td>
<td>non-micromobility</td>
<td>MARC Household Travel Survey: 2019 Mar, Apr, May</td>
<td>Bird, Spin starting 2019 Jun 28</td>
</tr>
<tr>
<td></td>
<td>micromobility</td>
<td>[ ]</td>
<td></td>
</tr>
</tbody>
</table>
### TECHNICAL ACCOMPLISHMENTS:
**ENERGY OPTIMIZATION OF MICROMOBILITY OPERATIONS (TASK 4)**

**Scope: Evaluation of micromobility operations**
- Many vendors consider repositioning practices to be proprietary, and use ad hoc strategies with independent management
- LBNL analysis of GBFS data:
  - Repositions are 9%–13% of trips, 13%–17% of VMT (2% and 4%, respectively, in NYC)
  - Repositions occur within a 1–4-day window on average, by program

**Summary:**
- Repositioning/maintenance practices vary widely, and by systems of different sizes and in different geographies
- Cities seek info on optimized number of stations, vehicles, and operators
- Large, dense systems may require less repositioning
- Progress toward FY 2021 Q4 milestone.

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#### Key Findings from GBFS Data Analysis

<table>
<thead>
<tr>
<th>Program</th>
<th>Percent of Total VMT for Repositions</th>
<th>Average Reposition Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF BayWheels</td>
<td>15%</td>
<td>3 days</td>
</tr>
<tr>
<td>NYC CitiBike</td>
<td>10%</td>
<td>4 days</td>
</tr>
<tr>
<td>Austin BikeShare</td>
<td>7%</td>
<td>2 days</td>
</tr>
<tr>
<td>Detroit MoGo</td>
<td>5%</td>
<td>1 day</td>
</tr>
<tr>
<td>Jersey City CitiBike</td>
<td>3%</td>
<td>2 days</td>
</tr>
</tbody>
</table>
TECHNICAL ACCOMPLISHMENTS:
ASSESSMENT OF MICROMOBILITY OPTIONS (TASK 4A)

Scope: Collection and dissemination of micromobility energy use and performance data
- Laboratory or in-field testing
- Overall watt-hours/mile energy consumption of the vehicle for various payload mass and ambient conditions
- Component-level efficiencies

Micromobility vehicle focus
- Bird One e-scooter (in-house at ANL)
- E-assist bicycles and microfreight vehicles (for in-field instrumentation)

Summary:
- Bird One scooter purchased by ANL and undergoing instrumentation
- Small, lightweight, and low-cost data collection device for in-field data collection under development
  - Battery voltage and current, GPS (distance and speed), inertial measurement unit (IMU)-based acceleration and road grade information
- Progress toward FY 2021 Q4 milestone.
TECHNICAL ACCOMPLISHMENTS: MICRO-FREIGHT (TASK 5)

Scope: Evaluate microfreight energy, behavior potential
— Microfreight scenarios: Lit review of microfreight research and deployment
— Identify data needs for energy analysis (Table 3)

Summary:
– Lit review accepted for conference presentation (2021 World Symposium on Transport and Land Use Research)
– Data needs relayed to industry contacts for field-based data collection
– Progress toward FY 2021 Q4 milestone.

<table>
<thead>
<tr>
<th>Variable need</th>
<th>Required?</th>
<th>Instrument</th>
<th>Invasive?</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery current</td>
<td>Required</td>
<td>Current clamp</td>
<td>No (may require some assembly)</td>
<td>May be available instead from onboard data</td>
</tr>
<tr>
<td>Battery voltage</td>
<td>Required</td>
<td>Voltage tap</td>
<td>No (may require some assembly)</td>
<td>May be available instead from onboard data</td>
</tr>
<tr>
<td>Battery state of charge</td>
<td>Highly desirable</td>
<td>Existing onboard info preferred (e.g., Controller Area Network [CAN])</td>
<td>No</td>
<td>Energy consumption and efficiency will change to some degree depending on the state of charge</td>
</tr>
<tr>
<td>Vehicle speed [m/s]</td>
<td>Required</td>
<td>Existing onboard info preferred (e.g., CAN); GPS as backup</td>
<td>No</td>
<td>Prefer onboard instrument with higher data frequency than GPS; GPS can be spotty</td>
</tr>
<tr>
<td>Vehicle mass [kg]</td>
<td>Required</td>
<td>Constant</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Driver/rider mass [kg]</td>
<td>Highly desirable</td>
<td>Estimated weight of human driver/riders</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Payload mass [kg]</td>
<td>Highly desirable</td>
<td>Weight of freight</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Road grade [%]</td>
<td>Highly desirable</td>
<td>Existing onboard info preferred (e.g., CAN network); GPS as backup</td>
<td>No</td>
<td>Road crown, loading dock ramps, and even sidewalk ramps affect energy consumption</td>
</tr>
<tr>
<td>Route track</td>
<td>Required</td>
<td>GPS</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Energy evaluation data requirements for microfreight, as presented to prospective industry partners
RESPONSES TO PREVIOUS YEAR REVIEWERS’ COMMENTS

- This is a new project that was not reviewed last year.
COLLABORATION AND COORDINATION

National lab research partners
- Lawrence Berkeley National Laboratory: co-PI partner
- Argonne National Laboratory: co-PI partner
- Pacific Northwest National Laboratory: complementary research

Non-lab research partners
- MIT: complementary research
- University of Colorado, Boulder: complementary research
- US EPA: complementary research led by LBNL
- DOE Arctic Energy Office: complementary research

Industry Stakeholders: inform approach, data, insights
- Colorado Energy Office
- Bird Mobility
- Washington, D.C. Department of Transportation
- City of Columbus, OH
- City of San Francisco
- City of Denver
- City of Boulder, CO
- City of Fort Collins, CO
- North American Bikeshare Association
- Forth Mobility
- Reef Technologies

- Collaborative relationships are essential to gain access to data, and to understand needs and trends
- High-quality relationships with research and industry partners have yielded access to critically important data and insights
- Collaborations have led to publication opportunities
- Additional partners continue to emerge
REMAINING CHALLENGES AND BARRIERS

Acquisition of micromobility data continues to be a challenge
- The pandemic posed disruptions from supply chains to operations
- Wariness of data-sharing in competitive commercial environment

Building collaboration with stakeholders remains important
- Continued interaction is critical for refining and understanding how micromobility adoption and use occurs

Micromobility continues to evolve
- New vehicles, use cases, and practices must be identified to inform Workflow models and derive accurate energy estimates
- Relative low cost and ease of access of micromobility for underrepresented communities is an opportunity to expand mobility electrification and address equity concerns.
PROPOSED FUTURE RESEARCH

• FY 2021:
  • Continue development of FIF behavior model for micromobility
  • Initial scenarios for micromobility and transit/micromobility multimodality behavioral models and microfreight simulations in preparation for Workflow integration. **Key milestone for Q4.**
  • Finish energy intensity data collection for representative e-scooter (Bird One model).

• FY 2022:
  • Refinement of micromobility scenarios for Workflow to include new data, emerging practices
  • Energy use instrumentation for in-field data collection for high-value data gap micromobility and microfreight vehicle variants
  • **Key milestones:**
    • FY 2022 Q2: Summary of microfreight energy opportunities and scenarios for integration into BEAM
    • FY 2022 Q4: Scenarios for Workflow of micromobility scenarios for smaller representative cities

• The project undergoes constant refinement and review from DOE technology managers and partners to address barriers and mitigate risk to ensure milestones are met.

Any proposed future work is subject to change based on funding levels.
SUMMARY

Micromobility is rapidly evolving as a viable mode
– This project contributes to characterization of micromobility use cases and behavioral adoption for Workflow modeling
– Collaboration opportunities continue to emerge as micromobility applications expand

Initial findings suggest micromobility returns energy benefits
– Benefits from direct mode replacement may be modest, but micromobility with transit and shared modes reduce car dependence

Continued research will further refine models to estimate energy, emissions, and social benefits through behavioral adoption
– Micromobility may mitigate some equity barriers to mobility for low-income groups with limited options