Infrastructure & Technology for Sustainable Livable Cities

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OUTLINE

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- Bike sharing
- Pedestrian lighting
- Snow-melting systems
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**INTRODUCTION**

- **Livability** is the sum of the factors that add up to a community’s quality of life—including the built and natural environments, economic prosperity, social stability and equity, educational opportunity, and cultural, entertainment and recreation possibilities *(livablecity.org)*.

- **Five fundamental aspects of livable cities**: robust and complete neighborhoods, accessibility and sustainable mobility, a diverse and resilient local economy, vibrant public spaces, and affordability *(livablecity.org)*.
Access to and mobility within small cities are challenging due to limited public transport and non-motorized facilities. Challenges are significant in cities that are subjected to severe winter weather conditions.
56% millennials and 46% active boomers prefer living in walkable, technology-enabled small cities.

81% millennials and 76% active boomers prefer walking or cycling for their daily activities rather than using cars.

In general, millennials are more likely to move into more walkable urban areas than to the outskirts.
PROJECT OBJECTIVES

Objectives: to synthesize infrastructure and technology for improving access to non-motorized traffic and mobility within cities while enhancing sustainability.

Identify research needs for improving mobility within small cities.
SCOPE OF THE PROJECT

- Communicated with city planners, engineers, and other officials to identify their priorities.
- Priorities included:
  - Bike-share programs
  - Pedestrian lighting systems and installation guidelines
  - Snow melting systems
  - Aboveground and underground non-motorized facilities
SCOPE OF THE PROJECT

Livability (Walking & Cycling)
- Bike-share infrastructure
- Pedestrian lighting
- Snow-melting systems
- Aboveground non-motorized facilities
- Underground non-motorized facilities

Sustainability
- Sustainable power sources (Solar, Wind, Geothermal, etc.)
BIKE SHARING

- Reviewed a large number of bike-share implementations.
- Interviewed planners, engineers, and other officials to gather information on:
  - Planning
  - Implementation
  - Maintenance
  - Program evaluation
  - Technology and infrastructure
  - Lessons learned from implementations
- Identified 12 bike-share station locations for the City of Kalamazoo.
Distribution of housing units in downtown Kalamazoo
Percentages of households with individuals of 65 years and older
BIKE-SHARE STATIONS
City of Kalamazoo

Employment distribution
Locations of interest within and around downtown Kalamazoo
BIKE-SHARE STATIONS
City of Kalamazoo

Existing non-motorized facilities
Planned non-motorized facilities
BIKE-SHARE STATIONS
City of Kalamazoo

Topography
BIKE-SHARE STATIONS
City of Kalamazoo

Analysis started with 30 candidate stations defined in ArcGIS.
BIKE-SHARE STATIONS
City of Kalamazoo

Location allocation models (*maximize coverage and minimize facilities*) were used to identify the optimum locations.

**Maximize Coverage Model**

Maximize \( \sum_{i \in I} a_i y_i \) \hspace{1cm} (1)

subject to (s.t.)

\( \sum_{j \in N_i} x_j \geq y_i \) \hspace{1cm} (2) \hspace{1cm} for all \( i \in I \)

\( \sum_{j \in J} x_j = P \) \hspace{1cm} (3)

Where,

\( I = \) set of demand locations,
\( J = \) set of candidate stations,
\( P = \) number of stations to be allocated,
\( x_i = 1 \) if station allocated at \( j \), \( 0 \) otherwise,
\( y_i = 1 \) if demand is covered at \( i \), \( 0 \) otherwise,
\( S = \) standard distance (impedance cutoff),
\( N_i = \{ j \mid d_{ij} \leq S \} \) set of candidates which can cover demand \( i \),
\( a_i = \) demand at node \( i \)

**Minimize Facilities Model**

Minimize \( \sum_{j \in J} x_j \) \hspace{1cm} (4)

s.t.

\( \sum_{j \in N_i} x_j \geq 1 \hspace{1cm} i \in I \) \hspace{1cm} (5)

\( x_j = \begin{cases} 1 & \text{if node } j \text{ is a facility site} \\ 0 & \text{otherwise} \end{cases} \hspace{1cm} j \in J \)

Where,

\( N_i = \{ j \mid d_{ij} \leq S \} \) demand covered
\( S = \) standard distance (impedance cutoff),
\( d_{ij} = \) distance from demand node to candidate facility
\( i = \) set of demand
\( j = \) set of candidate facilities
BIKE-SHARE STATIONS
Selected for City of Kalamazoo
PEDESTRIAN LIGHTING

- Looking for pedestrian lights with sustainable power sources.
The greatest solar insolation for Kalamazoo is observed during March - September (> 4 kWh/m²/day).

It is possible to use solar energy during these months to power bike-share kiosks and pedestrian lighting.

Reliability of solar power systems

- Charge controllers such as the maximum power point tracking (MPPT) increases battery charging efficiency.

- To provide a stable power supply, low voltage disconnect (LVD) and low voltage reconnect (LVR) features in the charge controller is used.
Reliability of solar power systems

- Battery voltage increase at the beginning of the charge cycle.
- Similarly, battery voltage drops when the charging ends.
- These factors need to be considered when LVD and LVR values are set.

Theoretical battery discharge/recharge cycle

Battery charge/discharge cycle evaluation

- With this particular charge controller charging cycle did not change to ‘float’ mode even after the ‘absorption’ period exceeded 5.5 hours.
During a typical day

During continuous operation of a load from June 30 (12:21:38 hr) to July 5 (06:09:58 hr), 2014

- LVD/LVR features in a charge controller affect battery charging performance.
- Requires a comprehensive analysis of the solar power system performance for specific site/application.
PEDESTRIAN LIGHTING

- Solar insolation variation at a specific site

Bronson Hospital, Downtown Area, Kalamazoo

Morning (8:30 AM)  Noon (1:15 PM)

After Noon (5:15 PM)  Evening (8:30 PM)
### PEDESTRIAN LIGHTING

#### Solar radiation analysis tools

<table>
<thead>
<tr>
<th>Solar radiation model</th>
<th>Software</th>
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<tbody>
<tr>
<td>r.sun</td>
<td>Grass GIS</td>
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<tr>
<td>Solar Analyst</td>
<td>ArcGIS Spatial Analyst extension</td>
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<tr>
<td>SolarFlux</td>
<td>UNIX workstation (SUN SPARCstation 2) incorporating with ArcGIS</td>
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<td>SRAD</td>
<td>ArcGIS9.x geo-processing framework/UNIX environment incorporating with ArcGIS</td>
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<td>Solei-32</td>
<td>GIS IDRISI via data format</td>
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</tbody>
</table>
PEDESTRIAN LIGHTING

- **Wind speed**
  - High wind speeds are observed in Kalamazoo during winter months (typically from November to April).
  - During this period solar insolation is the lowest.
  - There is a great potential to combine wind and solar to operate Kiosks at bike-share stations and pedestrian lights.

![Wind Speed over One Year for Kalamazoo](source: Weatherspark Beta, accessed from (https://weatherspark.com/averages/29704/Kalamazoo-Battle-Creek-Michigan-United-States))
Wind direction distribution in Kalamazoo

- The wind is most often directed from the south (15% of the time), south-west (12% of the time), west (12% of the time), and north-west (10% of the time).

- It is mandatory to observe the wind direction to identify optimal locations for bike-share stations or pedestrian lights.

- Need simulations tools.

SNOW-MELTING SYSTEM

Three basic designs:

1. **Hydronic** - uses an ethylene-glycol water mixture (similar to antifreeze) that is heated and pumped through PEX tubing to melt snow from asphalt or concrete.

2. **Electrical** - uses electrical energy to heat cables and melt snow from asphalt or concrete.

3. **Infrared Lamps** – uses to instantaneously radiate heat and melt snow.
Looking forward to

- develop implementation guides
- identify additional research needs
- develop interdisciplinary collaborative research to improve livability, sustainability, and resilience.