Impact of Route changes on Jule Transit

Increase in Length of the trip & not designing to action areas

- Bigger head ways
- Less Reliability
  - Increase in operating costs
  - Few funds to improve system
  - Negative Perception
  - Less Frequency
  - Less Fare Box

Decrease in Ridership

Reduction in Federal Funds

Increase in operating costs

Less Frequency

Few funds to improve system

Negative Perception

Less Fare Box

Decrease in Ridership

Reduction in Federal Funds
## Process to Improve Jule Transit

<table>
<thead>
<tr>
<th>Plan</th>
<th>What to do</th>
<th>How to do</th>
<th>Implement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast Supply vs Demand</td>
<td>Time of Day</td>
<td>Census Data</td>
<td>Redesign services by time of day and activity</td>
</tr>
<tr>
<td>Optimize Transit Routes</td>
<td>Activity Based</td>
<td>Traditional Surveys</td>
<td>Design new routes</td>
</tr>
<tr>
<td>Optimize Stop Placement</td>
<td>New Service area &amp; Demand</td>
<td>Online surveys</td>
<td>Create new marketing plan</td>
</tr>
<tr>
<td>Optimize Operations</td>
<td></td>
<td>Data gathering using technology</td>
<td></td>
</tr>
<tr>
<td>Measure unmet demand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suggest new bus routes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Improve mobility and access
Bolster local economies
Reduce vehicular accidents
Reduce energy and fuel consumption
Eliminate or delay street widening needs
Improve emergency response
Reduce motorist frustration and road rage
Reduce vehicle wear
Increase control of travel speeds
Reduce vehicle emissions
Approved Route Optimization Process

- Smartphone (GPS)
- Smart Fare Card (RFID)
- Points of Interest (Census)
- Transit & GIS
- Supply Model
- Demand Model
- Gap Analysis
- Clean Sheet Route Optimization
- Optimal Routes
- Duration of Stay Estimation
- Trip Segregation
- Trip Purpose Estimation
- Trip Mode Estimation
- O/D Estimation
- Airsage Proprietary Analysis of Telco Network Data
- Telco Network Data
- Smarter Travel
Smarter Travel

Revised Optimization Process

- **Recruitment**
  - Household Income
  - Household size
  - Number of Workers
  - Location

- **Smartphone Data**
  - Trip mode estimation
  - Duration of Stay Estimation
  - Trip Segmentation
  - Trip Purpose Estimation
  - Meaningful Location Classification

- **Points of Interest**

- **O/D from Smart phone**

- **O/D Airsage Data**

- **Screen line test**
  - Clean Sheet route Optimization

- **Optimal Routes**

- **Travel Diary Data**

- **Travel Diary Apps**

- **Sampling Size**

- **DMATS Four step model**

- **Travel Diary**

- **Household Travel Survey**

- **O/D Travel Survey**

- **Comparison With Travel Diary info**

- **Cell phone data**
Smarter Travel

Process & Team

1. Sampling Plan & Travel Diary
   - Chandra Ravada, ECIA
   - Dan Fox, ECIA

2. Recruitment Process
   - Developing the Outreach and Marketing Plan
   - Testing the App & Diary
   - Developing the Protocol
   - Website & Demographic Survey
   - Recruitment
   - Pilot and Pre Pilot
   - Kelley Deutmeyer, ECIA
   - Marla Quinn, ECIA
   - Holly Kueter, ECIA
   - Shubir Kapoor, IBM
   - Brent Paulovicks, IBM
   - Steve Millman, IBM

3. O/D from Traditional Survey methods
   - Stacey Bricka, TTI
   - Chandra Ravada, ECIA
   - Dan Fox, ECIA

4. O/D from Smart Phone
   - Shubir Kapoor, IBM
   - Raya Horesh, IBM
   - Jing Fu, IBM
   - Chai Wah Wu, IBM

5. Screenline test of O/D
   - Chandra Ravada, ECIA
   - Dan Fox, ECIA

   - Chai Wah Wu, IBM
   - Francisco Barahona, IBM
   - Joao Goncalves, IBM
   - JULE Transit
   - Chandra Ravada, ECIA
The project will have 750 households recruited.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Number of Households</th>
</tr>
</thead>
<tbody>
<tr>
<td>April, 2015 to June, 2015</td>
<td>250</td>
</tr>
<tr>
<td>July, 2016 to Sept, 2016</td>
<td>250</td>
</tr>
<tr>
<td>October, 2017 to Dec, 2017</td>
<td>250</td>
</tr>
</tbody>
</table>

250 volunteer households each will have Smarter Travel app and will fill Travel Diary.

Volunteer requirements

Expected to transmit data from Smart phone for 14 days. Expected to fill Travel Diary for three consecutive week days.
Phase I Sampling Plan and Travel Diary

Chandra Ravada, ECIA
Dan Fox, ECIA
### Sampling Plan

How do we pick people to participate in the study?

- **Household Demographics**
  - Household income
  - Number of people in the household
  - Number of Workers in the household
  - Transit rider

<table>
<thead>
<tr>
<th>Household Income</th>
<th>TOTAL Household</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Household Size</td>
</tr>
<tr>
<td></td>
<td>1-person</td>
</tr>
<tr>
<td>Less than $25,000</td>
<td>35</td>
</tr>
<tr>
<td>$25,000 - $49,999</td>
<td>22</td>
</tr>
<tr>
<td>$50,000 - $74,999</td>
<td>7</td>
</tr>
<tr>
<td>$75,000 or more</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>67</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Workers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No Worker Households</td>
<td>67 Households</td>
</tr>
<tr>
<td>1 or more worker</td>
<td>183 Households</td>
</tr>
</tbody>
</table>

**Transit Riders**

- 10-20 households making at least one trip today
# Sampling Plan - Location

## Sampling Plan and Travel Diary

### Phase I: Sampling Plan and Travel Diary

#### Sampling Plan - Location

![Map of study areas with labeled percentages and numbers of surveys](image)

<table>
<thead>
<tr>
<th>Area</th>
<th>% of Study Area Population</th>
<th>Number of surveys</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>58.17%</td>
<td>145</td>
</tr>
<tr>
<td>2</td>
<td>4.09%</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>1.26%</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>12.32%</td>
<td>31</td>
</tr>
<tr>
<td>5</td>
<td>18.21%</td>
<td>46</td>
</tr>
<tr>
<td>6</td>
<td>3.96%</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>2.00%</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>100%</td>
<td>250</td>
</tr>
</tbody>
</table>

*Note: The map illustrates the distribution of study areas across the population, with corresponding percentages and number of surveys conducted.*
Travel Diary

- Compare New and Established Data Collection Methods
- Travel Diary – Established Method
- Smartphone app – New Method

Travel Diary Questions

- Where did you go?
- What Did you Do?
- What was the time?
- How did you get there?
- How many traveled?
## Phase I: Sampling Plan and Travel Diary

### Trip #1
**Where Did You Go?**
Hy-Vee
- Name or Description of Place: 
- Address (or nearest intersection): Include suffix (St., Ave., lane, etc.)

Dubuque, IA
- City: 
- State: 
- Zip (if known): 

### What About Your Route?
- On your way to this location did you cross the Mississippi River? (check all that apply)
  - YES
  - NO

### What Did You Do?
- What did you do at this location? (check all that apply)
  1. Working at Home
  2. Other Home activities
  3. Work/Job (at work location)
  4. Work/Business related
  5. School
  6. Change Mode (e.g., car to bus)
  7. Dropped off passenger from car
  8. Picked up passenger from car
  9. Personal business
  10. Health care (doctor, dentist)
  11. Civic/Religious activities
  12. Eat meal outside of home
  13. Recreation/Entertainment
  14. Visit friends/Relatives
  15. Other, Specify: Groceries

### What Was The Time?
- What time did you ARRIVE at this location?
  - Time: __9__
  - Circle one: AM  PM

- What time did you DEPART this location?
  - Time: __9:45__
  - Circle one: AM  PM

### How Did You Get There?
- What was the primary type of transportation you used?
  - Walk
  - School Bus
  - Bike
  - Auto, Van, truck
  - Transit Bus (Route: ___)
  - Other

- If you used a car, van, or truck for this trip, were you the:
  - Driver
  - OR
  - Passenger

- Please indicate the following about the vehicle:
  - Year: 2004
  - Make/Model: Toyota Prius

- Was this your household’s vehicle? (check all that apply)
  - YES
  - NO

### How Many Traveled?
- Including you, how many people made this trip? ___1___
- Including you, how many people from your household were on this trip? ___1___

- What were the ages of the other household members traveling with you? 
Smarter Travel

Phase I Data Gathering Using Mobile Devices

Shubir Kapoor, IBM
Brent Paulovicks, IBM
Steve Millman, IBM
**Phase I: Overall System and Data Flow**

- **Public Internet**
  - Proxy Server
  - Anonymized location samples
  - Citizens of Dubuque

- **Private IBM Cloud**
  - Analytics Server
  - Optimization Server

**Data Sources**
- Jule data
  - Ridership by stop, route, day, hour
  - Vehicle capacity
- Airsage data
- Geospatial data
  - Points of interest
  - Demographics
  - Road network
  - Shopping areas
  - Transit Stops
  - Transit Routes

**Infrastructure**
- ECIA, DMATS, DoT, IBM
- IBM Authentication Service
The goal is to eliminate active user input, and automatically identify travel mode and trip purpose by using mobile devices and information techniques.

Smart phones (Android & iPhone) are used to provide location, speed, accuracy and route used by time of day.

Sample size: 250+ volunteers over 14 days

Cell Tower Data has been acquired from Airsage.

Sample size:
- 2 months of data. May 2014 and March 2015.
- 207 TAZs
- Population covered 150,000
- Granularity: Daily average
Smarter Travel

Phase I: Mobile Application

Infrastructure
- Private IBM cloud
- Secure and anonymized transmission of samples
- Integration with other datasets

Supported Platforms
- iOS 7.1.1+
- Android 4.3+

User Experience
- Periodic uploads
- Battery-optimized sampling
- Accuracy enhance sampling
- Client notifications

Rules of Participation:
In order to receive your $50 HyVee gift card:
- App must run for 14 consecutive days and three days must be recorded on the provided travel diary.
- After the 14 days, once participant has FULLY COMPLETED and returned the travel diary and diary matches app data, participant will be instructed on where to pick up gift card.
Smarter Travel

Phase I: Smarter Travel Control Center

List of registered users

<table>
<thead>
<tr>
<th>User ID</th>
<th>Status</th>
<th>Enrolled Date</th>
<th>Enrolled Days</th>
<th>Active Days</th>
<th>First Upload</th>
<th>Last Upload</th>
<th>Phone Number</th>
<th>Device</th>
<th>Phone Type</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>137648451712</td>
<td>Eligible</td>
<td>2015-03-03</td>
<td>16</td>
<td>16</td>
<td>2015-03-18</td>
<td>2015-03-18</td>
<td>563-212-4793</td>
<td>iPhone7,2</td>
<td>8.2</td>
<td>1.2</td>
</tr>
<tr>
<td>1309073997824</td>
<td>Active</td>
<td>2015-03-14</td>
<td>5</td>
<td>5</td>
<td>2015-03-18</td>
<td>2015-03-18</td>
<td>563-584-7370</td>
<td>iPhone6,1</td>
<td>8.2</td>
<td>1.2</td>
</tr>
<tr>
<td>193840545792</td>
<td>Active</td>
<td>2015-03-09</td>
<td>10</td>
<td>10</td>
<td>2015-03-18</td>
<td>2015-03-18</td>
<td>845-354-1654</td>
<td>iPhone4,1</td>
<td>7.1</td>
<td>1.3</td>
</tr>
<tr>
<td>139269064896</td>
<td>Active</td>
<td>2015-03-17</td>
<td>2</td>
<td>2</td>
<td>2015-03-17</td>
<td>2015-03-18</td>
<td>914-208-0067</td>
<td>iPhone6,1</td>
<td>8.1</td>
<td>1.3</td>
</tr>
<tr>
<td>1012320174080</td>
<td>Active</td>
<td>2015-03-10</td>
<td>9</td>
<td>8</td>
<td>2015-03-18</td>
<td>2015-03-18</td>
<td>914-299-5168</td>
<td>iPhone6,1</td>
<td>8.1</td>
<td>1.3</td>
</tr>
<tr>
<td>218160267264</td>
<td>Eligible</td>
<td>2015-02-09</td>
<td>30</td>
<td>30</td>
<td>2015-03-18</td>
<td>2015-03-18</td>
<td>212-666-6666</td>
<td>iPhone4,1</td>
<td>8.1</td>
<td>1.3</td>
</tr>
<tr>
<td>9318532368722</td>
<td>Eligible</td>
<td>2015-02-23</td>
<td>24</td>
<td>24</td>
<td>2015-03-18</td>
<td>2015-03-18</td>
<td>563-213-0903</td>
<td>iPhone6,1</td>
<td>7.1</td>
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<tr>
<td>539372421120</td>
<td>Active</td>
<td>2015-03-15</td>
<td>4</td>
<td>4</td>
<td>2015-03-18</td>
<td>2015-03-18</td>
<td>563-581-2453</td>
<td>iPhone6,1</td>
<td>7.1</td>
<td>1.2</td>
</tr>
</tbody>
</table>

User 754435358720 activities since registration

<table>
<thead>
<tr>
<th>Date</th>
<th>GPS Data Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-03-16</td>
<td>5282</td>
</tr>
<tr>
<td>2015-03-15</td>
<td>275</td>
</tr>
<tr>
<td>2015-03-14</td>
<td>12438</td>
</tr>
<tr>
<td>2015-03-13</td>
<td>3437</td>
</tr>
<tr>
<td>2015-03-12</td>
<td>2277</td>
</tr>
<tr>
<td>2015-03-11</td>
<td>10033</td>
</tr>
<tr>
<td>2015-03-10</td>
<td>724</td>
</tr>
<tr>
<td>2015-03-09</td>
<td>2699</td>
</tr>
<tr>
<td>2015-03-08</td>
<td>25</td>
</tr>
<tr>
<td>2015-03-07</td>
<td>1533</td>
</tr>
<tr>
<td>2015-03-06</td>
<td>2468</td>
</tr>
<tr>
<td>2015-03-05</td>
<td>720</td>
</tr>
<tr>
<td>2015-03-04</td>
<td>1356</td>
</tr>
<tr>
<td>2015-03-03</td>
<td>4</td>
</tr>
</tbody>
</table>
Smarter Travel

Phase II Recruitment Process

Kelley Deutmeyer, ECIA
Marla Quinn, ECIA
Holly Kueter, ECIA
Phase II: Smarter Travel Public Awareness and Engagement Plan

- Executive Summary and Purpose
- SWOT Analysis (Strengths, Weaknesses, Opportunities, Threats)
- Target Demographics
- Recruitment Process
- Objectives/Outcomes
- Implementation Timeline
- Project Evaluation
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Phase II: Recruitment Process

- **Phase 1**
  - Demographic Survey to Build Volunteer Database
    - Hy-Vee Partnership and Survey Flyer Distribution
    - Other Survey Promotion (Jule buses, Multi-cultural Family, Past City Smarter Pilot participants, etc.)

- **Phase 2**
  - Recruitment - 350 to get 250 valid participants
    - Participant Selection (based on location, HH size, HH income)
    - Protocol (download app, travel diary (3 weekdays), continuous monitoring through control center, compensation)
Phase II: App Testing (iPhone, Android)

- Initial Testing – IBM
- Early Testing – IBM and ECIA Project Team
- Pre Pilot Testing – ECIA staff
- Pilot Testing – 30 Hand-selected individuals in Dubuque area
- IBM monitored & communicated with ECIA staff during testing phases and adjusted apps accordingly

Weekly Conference Calls with IBM Team and ECIA Team
Phase III: O/D from Traditional Survey Methods

Stacey Bricka, TTI
Chandra Ravada, ECIA
Holly Kueter, ECIA
Phase III: O/D From Traditional Survey Methods

- Preliminary Planning
- Selection of Survey Methods
- Survey Instrumental design
- Sample design
- Pilot Survey
- Survey Implementation
- Data Coding
- Data Editing
- Data Correction and Expansion
- Data Analysis
- Tidying Up
- Presentation of Results
ROLE OF TTI

• Provide oversight
• Create O/D by trip purpose

OUTCOMES

• Data from Travel Diary will be used to validate Smart Phone Data
• Create O/D for DMATS area using the sample data
Smarter Travel

Phase III: O/D from Smart Phone Data

Shubir Kapoor, IBM
Raya Horesh, IBM
Jing Fu, IBM
Chai Wah Wu, IBM

IBM®

THE CITY OF DUBUQUE
Masterpiece on the Mississippi

ECIA

The Jule
Phase III: Data Analytics From Smart Phone

- Data from smartphones
  - Trip mode estimation
    - Duration of stay estimation
      - Trip segmentation
        - Points of Interest
          - Trip purpose Estimation
            - Meaningful Location Detection/Classification
              - O/D matrix estimation
                - Travel Diaries
                  - route optimization
                - route optimization
Phase III: Trip Segment and Trip Mode Estimation Methodology

- Converted the Longitude and Latitude to UTM Zone 15N (x and y)
- Segmented the speed into 4 modes: standing, walking, biking, driving
  - Segmented based on:
    - Walking: $1.2 \text{ m/s} < \text{speed} < 1.75 \text{ m/s}$
    - Standing: speed $\leq 1.2 \text{ m/s}$
    - Driving: speed $\geq 1.75 \text{ m/s}$
    - Biking: $1.75 \text{ m/s} \leq \text{speed} \leq 5.6 \text{ m/s}$
- Prune short (i.e. $\leq 2\text{ mins}$) walking or standing segments from driving trips
- Identify stops from the segmented speed, those stops will be used in trip purpose analysis
- Identify trips (driving/walking or biking) from the segmented speed
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Phase x: Trip Segmentation Analysis
User Id: 307279757312, Date: 2/26

Home
S1(A): 12:00 – 07:23
S1(C): 12:00 – 07:25

Day Care
S2(A): 07:34 – 07:42
S2(C): 07:35 – 07:44

Gas
S3(A): 07:50 – 07:54
S3(C): 07:51 – 07:55

Work
S4(A): 08:00 – 16:33
S4(C): 08:00 – 16:35

Day Care
S5(A): 16:44 – 16:49
S5(C): 16:44 – 16:51

Home
S6(A): 17:00 – 23:59
S6(C): 17:01 – 23:59

S_n(A) – Actual Trip
S_n(C) – Computed Trip
Phase V: Trip Purpose Classification and O/D Matrix

- Generate fine (200m X 200m) grid and map them to TAZ
- 3 categories of POIs (schools, shopping/restaurants, other)
- Map each grid cell to most likely POI category
- Classify work and home locations based on duration of stay and time of day
- Trip purpose: home-based work, non-home-based work, home-based school, non-home-based school, home-based shopping, non-home-based shopping, home-based other, and non-home-based other. These categories will be used to partition the O/D matrix
- The O/D matrix is aggregated between all the users and for different time intervals
- A methodology to combine multiple O/D matrices from different sources into a single O/D matrix for the optimization algorithm is currently being investigated and developed.
Phase III: O/D from Airsage Data

Shubir Kapoor, IBM

Jing Fu, IBM
**Phase III : Airsage data analysis**

- **Trip Purpose**: characterizes the departure and arrival zones on the trips
  - Home Based Work (HBW)
  - Home Based Other (HBO)
  - Non-Home Based (NHB)

- **Residence Class**: characterizes trips between
  - Resident
  - Visitor

- **Daily Average Count**: The number of trips made by people with given attribute, that started in the origin zone and ended in the destination zone during the given day.
Phase III: Airsage data analysis

- Weekday and weekends have different patterns
- On average Friday, followed by Saturday have the greatest trips
- Friday night (H19 – H24) have the greatest trips
- H10:15 trips are the largest
- Friday, Saturday & Sunday trips start later in the day (H10 – H15)
- Sunday morning (H00 – H06) are higher than usual. Maybe spillover from Saturday night
Phase IV: Screenline Test of O/D Data

Chandra Ravada, ECIA
Dan Fox, ECIA
Smarter Travel

Phase IV: Screenline Test of O/D Data

O/D data for the region

Travel Diary

Smartphone

Airsage

Screenlines
Phase V: Transit Route Optimization

Chai Wah Wu, IBM
Francisco Barahona, IBM
Joao Goncalves, IBM
Candace Eudaley, Jule Transit
Maurice Jones, Jule Transit
Phase V: Optimization approach

• Input data:
  • Street intersections and street links
  • Travel time of various travel modes on each link
  • Maximum number of buses and bus capacities.
  • O/D matrix

• Generate a set of candidate routes
  • Can include constraints such as hubs, limited change from current routes, etc.

• Choose an optimal set of routes minimizing average travel time by formulating objective function and optimization problem as an mixed integer program (MIP).

• Solve MIP using 2 types of algorithms: Cplex and Volume Algorithm
Phase V: Preliminary optimization tests

- Generate O/D matrix from uniform random distribution of O/D pairs
- Using a uniform O/D matrix, generate the optimal bus route on Dubuque streets in a square area about city center
  - Generated bus routes are more or less distributed around the city area.
- Using a uniform O/D matrix, generate the optimal bus route near current bus stops.
  - More compacted bus routes and overlaps more with current routes.
- Generate reduced O/D matrix from Airsage O/D data on Dubuque TAZs
  - Method 1: rounding
  - Method 2: thresholding with random assignment
- Both methods generate similar bus routes.
- These are preliminary results and need to be refined as more data are captured and more constraints are added.
Phase V: Preliminary results of generating bus routes with previous Airsage data (method 1)
Phase VI: System Calibration

Candace Eudaley, Jule Transit
Maurice Jones, Jule Transit
Smarter Travel

Phase VI: System Calibration

Smart Card rider

Smart Card reader

Ranger

Boarding Data

Location Data

Boarding data >= Target ridership

User Data

Backend Server

Wireless provider

Adjust the route

YES

Did the ridership increase after change in marketing

NO

YES

Continue Marketing

NO

Time of loading
Smart Card Loading location
Smart Card Reloading location

Location of Bus stop

Age

Income

Vehicle ownership

TAZ

Marketing

User ID

Usage

Accounting

Analysis to determine potential ridership

Adjust the route

YES

Marketing

YES

NO

Did the ridership increase after change in marketing

Adjust the route

YES

Marketing

YES

NO

Continue Marketing
Contacts

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Yorktown Heights, NY 10598, U. S. A.
IBM T.J. Watson Research Center
ph.: 914-945-1567
e-mail: cwwu@us.ibm.com

Web Sources

http://www.cityofdubuque.org/1496/Smarter-Travel

http://www.eciatrans.org/DMATS/SmarterTravel.cfm