Investigating Travel Behavioral Changes Throughout 10 Years: A Case Study on Southeast Michigan

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Abstract

This paper presents a descriptive analysis of travel behavior over ten years using household survey data collected by the Southeast Michigan Council of Governments (SEMCOG) in 2005 and 2015, respectively. The data used in this work were 12,000 and 6,500 sample sizes for 2005 and 2015, respectively. Generally, results indicated that a 12% reduction for all trip rates occurred during the study period. On the other hand, trip rates for multiple age ranges, including the elderly, increased from 2005 to 2015. Also, the average travel distance for all modes increased during the study period, and transit was mainly used for long travel distances. Also, several spatiotemporal changes in human travel behavior were analyzed using different travel indicators, namely: travel time, trip purpose, travel mode, and travel distance. The analysis results show the change in travel behavior across different counties in the SEMCOG area during the study period. The study indicates that the travel time changes across different travel modes, as well as trip purposes, were influenced by the economic impact change along the study period. It was found that travel time distributions for most purposes are concentrated on trips of travel time shorter than 40 minutes.

Introduction

Successful urban development requires efficient and equitable mobility. Changes in urban development may negatively impact the transportation system. Nevertheless, the projects and policies needed to mitigate these adverse effects on mobility take years or decades to fund and complete. This issue has led to the development of transportation demand forecasting, which aims to predict future mobility needs, so projects and policies can be planned for years in advance. The key to transportation forecasting is understanding the travel behaviors of different households and then creating models based on these behaviors. Urban development and changes in human activities result in fluctuations in travel. For instance, research utilizing the California Household Survey revealed that, compared to households without young children, households with young children are associated with more auto usage and lower active transport (walking and cycling) (Chakrabarti and Joh, 2019). Travel behaviors take place for different purposes, such as work, shopping, social gatherings, tourism, etc. The selection of transportation modes is influenced by several factors, including cost, travel time, distance, safety, and comfort (Goulias et al., 2019). Travel behavior changes over time due to the development of transportation systems and changes in social-economic conditions. Travel is a complex behavior that depends on several factors that may have short-term or long-term impacts. Short-term impacts include changes in route choice, time of day that trips are made, mode choice, trip frequency, trip chaining, and destination choice. Long-term effects may include changes in automobile ownership, residential location, workplace location preference, and land development patterns (DeCorla-Souza and Cohen, 1999). Such impacts are influenced by the economic background, demographics, and price changes (Probasco, 2013).

Travel behavior modeling requires frequently updated massive datasets that cover a wide range of locations and the needs of transportation user types. Household travel survey data is mostly used for this purpose. Household Travel surveys are instruments used to have all household members self-report their transportation trips over a given period, along with crucial household socioeconomic characteristics. Household travel surveys are widely used in transport planning (Kulpa and Szarata, 2016).
Effective modeling of travel behavior based on household surveys requires massive data collection, data entry, and investigation effort. Many studies used household surveys to model travel behavior (Al-Khasawneh et al., 2022; DeCorla-Souza and Cohen, 1999; Kulpa and Szarata, 2016; Long and Thill, 2015; Mahmoudi, 2022). During the last 30 years, metropolitan planning organizations (MPOs) have done hundreds of urban area household travel surveys to be implemented in travel forecasting models. Such surveys aim to collect data on trip generation rates, zone-to-zone trip tables, and trip length frequencies. Traditionally, household surveys use cross-sectional sampling based on household size, number of cars in the household, and household income.

The Southeast Michigan area has been experiencing major social, economic, and infrastructural changes over the last decades, including the aging of infrastructures, a slowdown in economic growth, etc. Identifying the changes in travel behavior provides the basis for policy and decision-makers to take the necessary actions for the transportation system. Nevertheless, the travel change analysis assesses individuals' responses to the policy measure before or after its implementation. However, it is challenging to understand individuals' responses to policy measures that their associations induce. Frequent studies of travel behavior change are essential to understand such complexity to prevent the population's unforeseen and unintended transportation impacts. Transportation policies and measures may have social and economic impacts on the population.

In this study, the change in the travel behavior of the Southeast Michigan area is analyzed using data from surveys conducted in 2005 and 2015. The change was modeled using different parameters, including trip time, travel mode, trip purpose, and frequency. Previous studies were also presented to examine the use of household surveys for modeling travel behavior. The outcomes of this study are expected to assist policymakers in understanding household travel patterns and barriers and help design communities to promote better travel behavior. Moreover, they could be useful in transportation planning, decision-making, fund splitting, transit desert areas, transportation system coverage, and the necessity of having better accommodations for the first/last-mile travel mode.

**Literature Review**

Mobility is the basic human activity that enables individuals to access goods and services and participate in various social and economic activities (Aiello, 2010). Transport systems in urban areas are complicated due to their technical, organizational, and socioeconomic interrelations. Several studies analyzed travel behavior changes using data from household travel surveys. Household travel surveys help to identify the overall characteristics and changes in travel behavior. Nevertheless, other studies utilized fusion and multisource traffic data to study travel behavior (Abu-Aisha et al., 2021; Gong et al., 2012; Jang, 2010; Long and Thill, 2015). In general, it is important to understand the influence of socioeconomic conditions on the travel patterns of different groups in society and how they interact with the transportation infrastructure.

Changes in socioeconomic conditions and transportation systems influence individual travel behavior. Thus, studying the change in travel behavior is important to measure the response to the applied policies. Moreover, the level of development of the transportation systems significantly influences the selected mode
of mobility. Hillier et al. (Hillier et al., 1993) suggest that the characterization of the urban network is the main influencing factor of movement patterns. Cervero and Kockelman (Cervero and Kockelman, 1997) found that population density, the mix of land use, and urban design reduce travel rates and increase travel by more active modes, such as pedestrians and bicycles. However, Villaça (Villaça, 2011) suggests that the production of urban areas is permeated by practices that use space as a tool of social limitation. The wasted time on trips by the privileged population is an example of social domination through space.

Household surveys were conducted over decades in several countries. In the early days, household travel surveys were conducted by telephone and face-to-face interviewing. Today, face-to-face surveys have become more expensive and dangerous to conduct as the interviewers’ safety is threatened. Computer-assisted telephone (CATI) surveys are North America’s most widely used method. However, the overall response rate of such surveys is low (Stopher, 1998).

A tremendous increase was noticed in internet use and computer-mediated communication in the past 20 years, which led to an increase in the use of online surveys. Different studies took advantage of that to increase the use of online surveys. On the one hand, it has some advantages, including access to individuals in distant locations, the ability to contact participants that are not easily accessible, and the convenience of having automated data collection, reducing the researcher’s time and effort. In contrast, the disadvantages, such as uncertainty over the validity of the data and sampling issues and concerns surrounding the design, implementation, and evaluation of an online survey, are also evident (Spitzberg, 2006). To overcome the shortfall in trips CATI, some countries, such as the United States of America and Switzerland, try to have household traffic surveys utilizing GPS location devices. However, it also faces some problems, such as high expenses and signal loss. GPS devices are expensive, with passive devices capable of storing many days’ worth of data, costing US$750 each. Moreover, severe signal degradation often occurs in various circumstances, including tunnels, urban canyons, heavy tree canopies, and certain types of vehicles.

The travel behavior and land-use studies were conducted using the Dutch National Travel Study (OVG). The study found an interrelated relationship between travel distance and mode choice. Also, it indicated that personal characteristics substantially impact travel behavior (Van Acker and Witlox, 2005). Aditjandra (Aditjandra, 2013) studied the impact of urban development patterns on travel behavior. The analysis uses qualitative and quantitative data derived from two studies: the regional (macro) integrated transport and land-use model data and the micro-analysis of ten selected neighborhoods, both of which have taken place in the Northeast of England. The study argues that the land use and transport provision changes are relatively marginal compared to the existing development. The study demonstrated that the attitudes of citizens, rather than neighborhood characteristics, play the biggest role in influencing the patterns of car travel.

The Southeast Michigan Council of Governments (SEMCOG) has undergone a strong economic crisis over the last decade and is now dealing with an aging population. As a result, it is critical first to recognize the overall change in travel behavior to understand possible individual reactions to applied policies better and to improve future transportation policy implementation. Thus, this paper examines the major changes in
travel behavior in time and space over the last decade in the SEMCOG area. The purpose of this paper is to define travel behavior in terms of both travel characteristics and transportation/social setting components. Travel features include the trip’s purpose and the transportation mode used.

Southeast Michigan

Michigan is a US state in the Great Lakes and Upper Midwest regions of the United States of America. It is the tenth most populous state, with a population of approximately 10 million. Southeast Michigan is a seven-county region in the Lower Peninsula of the state of Michigan. It is bordered in the northeast by Lake St. Clair, and in the southeast by Lake Erie, and the Detroit River, which connects these two lakes (Department of History, 2006). Southeast Michigan has most of the state's businesses and industrial resources, with a population of 4,768,427 in 2020 (SEMCOG, 2021). The major economic activity in Southeast Michigan is car manufacturing. The main manufacturing cities are Warren, Sterling Heights, Dearborn, and Detroit. Most people in Livingston, Macomb, Monroe, Oakland, Washtenaw, and Wayne Counties live in urban areas. Over the decades, urban development has sprawled to the areas of Canton, Commerce, Chesterfield, and Clinton townships, Figure 1.

The transportation system of Southeast Michigan provides the spine for all economic activities. Infrastructure development is integral in supporting the region's economy and the quality of life for residents. Transportation investments are part of the state's overall social and economic development strategy. Such investments are important given that vehicle manufacturing is Michigan's largest industry. An efficient transportation system saves time and money for individuals and businesses. This enhances productivity, competitiveness, and promotes the economic growth of the Southeast Michigan area and Michigan State overall. This created tremendous pressure on state government agencies to provide, maintain, and develop the transportation system.

Changes in travel behavior in the Southeast Michigan area provide insights into the changing demographic structure of households and give useful measures for urban planning and policymaking. An increase in households creates more travel demand. Nevertheless, the geographic patterns of changes in households and household size present additional challenges to communities in terms of transportation planning. Communities with an increasing number of households with young people may have to plan for increased vehicle traffic. In contrast, rural communities with an increasing number of senior households will have to grapple with providing alternative transportation options.

The economic situation is concerned with household income and the welfare of society, which largely impacts travel behavior. The Southeast Michigan area observed a significant slowdown in economic growth. The last decade experienced an economic boost at the beginning and a slowdown afterward. This is somewhat due to the United States' subprime mortgage crisis that occurred between 2007 and 2010. Social and economic conditions help to understand the changes in travel behavior over time. However, it does not always provide clear associations.

Survey Design and Administration
SEMCOG and the consultant developed a sampling plan to ensure the collection of adequate samples for analysis. A total of 12,000 and 6,500 samples in 2015 and 2005 were budgeted for the survey. These samples had to be allocated among the eight geographical areas in the SEMCOG: East Wayne, West Wayne, Oakland, Macomb, Washtenaw, Monroe, St. Clair, and Livingston. Seven of these areas are counties, while East and West Wayne are one county split into two areas. The sample size was selected based on a statistics-based method for calculating the sample rate. The sample size was further adjusted for each region based on the distribution of household sizes and household incomes. Then the region-level sample sizes were randomly proportionally allocated to the post-stratification cells based on the relative number of households in each post-stratification cell, reported in the American Community Survey (ACS).

Statistically, methods for weighting and expanding the sample data were necessary to account for biases in the survey, and to ensure that the data accurately adopted a person-household reflected the transit riding population when used for analysis. Traditionally, the weighting and expansion process has involved calculating control totals based on the number of people boarding at stop locations (among other factors). The survey sample expansion process adopted a person-household two-dimensional weighting procedure. This new approach improved both household and person trip rate estimations and provided a solid background for this paper.

The collected data characteristics and the analysis scheme are illustrated in Figure 2. Many different variables can be used to describe behavioral changes. In order to detect changes in travel behavior over time and space, this study uses variables to represent trip rate, mode, and spatial and temporal characteristics of travel behavior. The most representative characteristic of travel behavior is frequency, which can reflect both travel's spatial and temporal aspects. The distance and duration of each trip reflect the spatial characteristics of travel. The timing of a trip during the day represents temporal qualities. Importantly, such changes in travel behavior may manifest themselves in different ways in different parts of society.

**Analysis Results**

The following sections describe the results of the data analysis. The section starts with a general household summary of statistics for the household, followed by data fusion by trip purpose. Afterward, different trip rates were extracted based on HH, trip purpose, and age group. Then more details of traveling behavior are presented. These details cover the travel mode, different trip characteristics, and trip temporal and spatiotemporal analysis.

**Statistics of Household Travel Survey in SEMCOG**

The obtained HH data covers different information, including the household's home Traffic Analysis Zone (TAZ), the work TAZ of each household worker, and some demographic and socioeconomic information about the household (e.g., household income, housing tenure, household size, and life-stage status). Such information can be used to construct the outcome variable (residential location choice at the TAZ level). A summary of generally selected indicators from the 2005 and 2015 surveys is shown in Table 1.
The change in different types of trip rates was investigated per household (HH) to track the change in the trip pattern over the study period. After comparing the rates of home-based shopping (HBSH/HH), home-based work (HBW/worker), and home-based shopping per person (HBSH/person) between 2005 and 2015, the data showed that there is a reduction of 6%, 12%, 1%, and 7% in these rates, respectively. These changes in travel behavior, along with other socioeconomic parameters, are presented in table 2, along with the rates of NHB (None Home Based), HBO (Home Based Other), and HBW (Home Based Work).

### Table 2: Average trip Statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>HHS 2005</th>
<th>HHS 2015</th>
<th>% Diff</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH Size</td>
<td>2.54</td>
<td>2.40</td>
<td>-5.5%</td>
<td>-95.2544</td>
<td>0.0000</td>
</tr>
<tr>
<td>Trips / HH</td>
<td>9.59</td>
<td>9.33</td>
<td>-2.7%</td>
<td>2.7608</td>
<td>0.0058</td>
</tr>
<tr>
<td>Workers / HH</td>
<td>1.19</td>
<td>1.03</td>
<td>-13.4%</td>
<td>-1.7e+02</td>
<td>0.0000</td>
</tr>
<tr>
<td>HBSH Trips rates</td>
<td>0.92</td>
<td>0.88</td>
<td>-4.4%</td>
<td>27.54</td>
<td>0.0000</td>
</tr>
<tr>
<td>Trips/ Person</td>
<td>5.90</td>
<td>4.05</td>
<td>-31.4%</td>
<td>473.7</td>
<td>0.0000</td>
</tr>
<tr>
<td>HBW Trips / Worker</td>
<td>1.30</td>
<td>1.13</td>
<td>-13.0%</td>
<td>139.5</td>
<td>0.0000</td>
</tr>
<tr>
<td>HBSH Trips / Person</td>
<td>0.42</td>
<td>0.48</td>
<td>14.3%</td>
<td>-77.76</td>
<td>0.0000</td>
</tr>
<tr>
<td>Autos / Driver</td>
<td>1.05</td>
<td>1.06</td>
<td>1.0%</td>
<td>-10.8</td>
<td>0.0000</td>
</tr>
<tr>
<td>NHB Trip rates</td>
<td>2.88</td>
<td>3.16</td>
<td>9.7%</td>
<td>-60.1</td>
<td>0.0000</td>
</tr>
<tr>
<td>HBO Trip rates</td>
<td>3.64</td>
<td>3.39</td>
<td>-6.9%</td>
<td>61.6</td>
<td>0.0000</td>
</tr>
<tr>
<td>HBW Trip rates</td>
<td>1.56</td>
<td>1.10</td>
<td>-29.5%</td>
<td>264.7</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

However, table 2 shows that the HBW trip rate has the highest significant (at 95% confidence level) reduction rate (-29.5%, p=0.000) between 2005 and 2015 as compared with the NHB and HBO rates.
More than 30 parameters were collected in both the 2005 and 2015 surveys. These parameters were categorized into socioeconomic and demographic parameters. Specifically, parameters include age, occupancy, gender, income, car ownership, number of trips, trip type, and trip Origin-Destination (OD). In this study, each trip was summarized by five main parameters, including OD, trip purpose, travel mode, travel time, and travel distance. Table 3 shows an example of HBW trips where travel mode, trip time, and trip distance are presented.

Table 3: Summary of HBW Trips

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Detroit</td>
<td>1.05</td>
<td>26.21</td>
<td>2.30</td>
<td>24.16</td>
<td>5.70</td>
<td>55.50</td>
<td>9.03</td>
<td>26.50</td>
<td>8.40</td>
<td>29.76</td>
</tr>
<tr>
<td>Out Wayne</td>
<td>0.80</td>
<td>33.36</td>
<td>1.41</td>
<td>14.61</td>
<td>9.67</td>
<td>42.70</td>
<td>10.07</td>
<td>24.84</td>
<td>10.04</td>
<td>25.13</td>
</tr>
<tr>
<td>Oakland</td>
<td>1.00</td>
<td>6.56</td>
<td>2.31</td>
<td>15.79</td>
<td>15.71</td>
<td>53.34</td>
<td>11.43</td>
<td>27.90</td>
<td>11.35</td>
<td>27.83</td>
</tr>
<tr>
<td>Macomb</td>
<td>2.12</td>
<td>24.40</td>
<td>1.81</td>
<td>15.00</td>
<td>5.59</td>
<td>41.86</td>
<td>11.34</td>
<td>26.86</td>
<td>11.22</td>
<td>27.01</td>
</tr>
<tr>
<td>Washtenaw</td>
<td>1.22</td>
<td>17.45</td>
<td>2.76</td>
<td>19.80</td>
<td>3.30</td>
<td>29.75</td>
<td>12.85</td>
<td>25.78</td>
<td>11.50</td>
<td>25.63</td>
</tr>
<tr>
<td>Monroe</td>
<td>0.52</td>
<td>10.65</td>
<td>1.80</td>
<td>18.41</td>
<td>5.82</td>
<td>44.90</td>
<td>12.67</td>
<td>22.68</td>
<td>12.33</td>
<td>22.22</td>
</tr>
<tr>
<td>St. Clair</td>
<td>1.01</td>
<td>15.54</td>
<td>1.00</td>
<td>20.00</td>
<td>2.57</td>
<td>51.54</td>
<td>14.01</td>
<td>26.05</td>
<td>13.50</td>
<td>25.81</td>
</tr>
<tr>
<td>Livingston</td>
<td>1.00</td>
<td>1.00</td>
<td>0.37</td>
<td>5.00</td>
<td>6.77</td>
<td>32.57</td>
<td>20.40</td>
<td>35.08</td>
<td>20.02</td>
<td>34.70</td>
</tr>
<tr>
<td>Total</td>
<td>1.18</td>
<td>19.28</td>
<td>2.13</td>
<td>19.75</td>
<td>6.22</td>
<td>47.26</td>
<td>11.35</td>
<td>26.68</td>
<td>11.06</td>
<td>27.10</td>
</tr>
<tr>
<td>HBW% of ALL</td>
<td>3.60%</td>
<td>12.70</td>
<td>25.00</td>
<td>16.10</td>
<td>15.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Trip Rate by Trip Purpose, HH Group, and County**

Table 4 presents the different trip rates per different HH group characteristics. Unlike Table 3, different trip rates were computed per different household characteristics. The trip rate difference was presented for all trip types, including HBW and HBSH trips.
Household socioeconomic groups were classified into six groups based on their car ownership, the number of workers per HH, HH income, and HH age. Specifically, the six groups are zero-auto, zero-worker, zero-children, low income, 2-adults-2-children, and all people over 65 years old. This grouping follows several previous transport planning studies (Chatterjee, A., and Venigalla, 2004) and is confirmed by data inspection. Different types of trip rates for given household groups were compared in Table 4 to determine the travel characteristics and to check the change in different trip purpose rates within the same group throughout the study period. Table 4 indicates that the 2-adults-2-children group is associated with a reduction in total trip rate (trip/HH) over the study period, while other groups showed an increase in the total trip rate. However, table 4 also illustrates a significant reduction in work-related trips for all groups, where the household with zero auto group is associated with the highest reduction (-39%). Similarly to the total household trips, shopping-related trips only show a trip rate reduction in 2-adults-2-children group. This can be explained by decreasing the number of work-related trips, and the HBSH trip will shape the total trip rates.

Results of HBW rates indicated that the zero-auto group had the highest trip rate, which is around 2 trips per HH, while the zero-children group had around 1.25 trips per HH, and the other groups had less than 0.50 trips per HH. Comparing the HBW rates in 2005 and 2015, most groups maintained the same rate, except for the low-income HH group. On the other hand, a low-income group is defined as a person with a household income is less than $20,000 in 2005 and $25,000 in 2015. The HBW trip rate for the low-income group in 2015 increased by 0.1 compared to their rate in 2005.

In addition, home-based shopping (HBSH) trip rates showed a different pattern when compared with HBW throughout the study period, as shown in Table 4. It was noticed that all HH groups had a relatively similar HBSH trip rate. The number of HBSH trips per HH increased from 2005 to 2015 for all groups, except for the 2-adult-2-children group. The HBSH rate for the 2-adult-2-children group decreased from 1 to 0.8 trips per HH. Unexpectedly, the elderly and low-income trip rates increased across all types of trips, which implies that the elderly and low-income were making more trips.

Another trip frequency indicator is the rate of trips per person. To specify this indicator in a general form, people were grouped by their age. This way, the trip rate per person per specific group age was computed to check the trend in the trip rate over the study period, as shown in Figure 3.

<table>
<thead>
<tr>
<th>Household Group</th>
<th>Total trips per HH</th>
<th>HBW trips per HH</th>
<th>HBSH Trips per HH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-auto HH</td>
<td>28% (67.78)</td>
<td>-39% (-73.08)</td>
<td>28% (42.89)</td>
</tr>
<tr>
<td>Zero-worker HH</td>
<td>10% (54.30)</td>
<td>-9% (-8.27)</td>
<td>24% (74.86)</td>
</tr>
<tr>
<td>Zero-Children HH</td>
<td>2% (22.52)</td>
<td>-6% (-3.21)</td>
<td>6% (2.69)</td>
</tr>
<tr>
<td>Low income HH</td>
<td>18% (71.57)</td>
<td>-17% (-31.31)</td>
<td>30% (63.18)</td>
</tr>
<tr>
<td>2-adults-2-children</td>
<td>-5% (-37.89)</td>
<td>-8% (-37.62)</td>
<td>-5% (-8.94)</td>
</tr>
<tr>
<td>All people over 65</td>
<td>2% (11.59)</td>
<td>-16% (-37.26)</td>
<td>23% (70.88)</td>
</tr>
</tbody>
</table>
Figure 3 shows the trip frequency per person for different age groups during the study period. Results indicated that people in the middle range (their age is between 35 and 44 years) conducted more trips than other groups during the study period. Also, results indicated that people aged 35 years and younger conducted more trips in 2015 than the same group trip rate in 2005. In contrast with the trip rate of groups 55 years old or older, over the study period, their trips decreased (95% confidence level).

**Trips Temporal Analysis**

Trip temporal characteristics for different socioeconomic parameters were investigated for modeling the behavioral change in trip timing with respect to the elderly and low-income as they should be the most significant changes during the study period according to the results indicated in Figure 4 along with Figure 6.

In order to analyze the temporal trip rates, different trip purposes were aggregated based on the time of conducting trips. As shown in Figure 4, there is no significant change in trip rates at any specific hour throughout the study period. Figure 5 shows an increase in elderly trips throughout the study period, which is caused by the increases in the elderly percentage of involvement in trips and activities. It is worth mentioning that results indicated that the morning peak of trips occurred around 10-11 am, and trip rates increased throughout the different hours except for the late after 7 pm.

Figure 7 shows the change in the percentage of departure time for the low-income group. There is an apparent reduction in morning peak percentage by around 2%, whereas there is an increase in after morning peak time and noon by around 2%. This can be explained by the fact that they do not have jobs or part-time jobs.

**Trip Mode Analysis**

This section presents and discusses the aggregated travel behavior characteristics, including trip travel time and travel distance, using different travel modes. Travel distance and travel time of 2005 and 2015 data were used to investigate the change in these characteristics, as shown in Figure 7 and Figure 8, respectively.

Average trip distance and duration for different trip purposes were computed for each travel mode in order to compare these two leading indicators between the different travel modes. These indicators could assist different travelers in choosing the most efficient travel mode to complete their trips. Not surprisingly, it was observed that people were using transit to conduct trips with long travel distances more than autos. At the same time, transit trips' travel time remains constant throughout the study period. This could refer to the reliable transit bus schedule. Generally, the average travel distance in all modes of transportation increased in 2015 trip data except for the walking mode trips. According to the data in Table 1, this could be explained by the increase in the number of auto/licensed drivers. Surprisingly, the bicycle mode increased the travel time while the distance remained the same. This could be explained by the increase in bike numbers compared to the same bike infrastructure capacity.
Trips Spatial Analysis

Study trip characteristics in different counties are presented in this section. Three main indices are presented here, namely: trip rate per household, trip rate per person, and trip travel distance. These main three indices provide a comprehensive understanding of trip change along the study period in each county per person, per household, and trip travel time in each county. These three indices are presented in Figures 9, 10, and 11 for trips per HH, trips per person, and trip travel distance in each county, respectively.

Generally, it can be seen in Figure 11 that the overall total number of trips per household in each county decreases. Specifically, total trips per HH in each county decreased from 3%-10% along with the different counties, as shown in Figure 11. Figure 11 indicates that the highest drop in trip numbers occurs in Washtenaw County. This drop was estimated to be equal to 10%. Figure 10 shows the trip rate per person in each county. The presented results indicate no change in trip/person rate in both Macomb or Monroe during the study period. However, for the other counties, there is no general trend in the trip rate per person in the remaining counties.

Regarding travel distance, results indicated that Livingston County had the highest total travel distance while Detroit had the lowest. All counties observed an increase in total travel distance in 2015 compared to 2005. It was noticed that Out-Wayne and St. Clair the highest change was observed.

Temporal Characteristics

This section presents travel times for different trip purposes along with the study period. The travel time distribution for each trip purpose in both 2005 and 2015 was compared for the different trips’ purposes, as shown in Figures 12 through 14 below. In comparison, the trip travel time for each mode of transportation for each travel purpose is presented in the upcoming section.

Figure 12 (a) shows the HBW travel time distribution between 2005 and 2015. Results indicated that the HBW trips’ travel time range changed throughout the study period. Specifically, HBW travel time in 2005 was shorter than HBW trips in 2015. HBW trip travel time is concentrated between 10 minutes and 40 minutes, while HBW 2015 travel time distribution is concentrated on travel time less than 20 minutes.

Figure 12 (b) shows the travel time distribution for home-based shopping (HBSH) trips in both 2005 and 2015. Surprisingly, travel time distribution changes dramatically over the study period. Comparing 2005 to 2015, HBSH trips’ travel time was concentrated in a range of 9 to 39 minutes in 2005, while in 2015 most of the HBSH trips took between 9 and 52 minutes. Also, results indicated that the HBSH trips in 2005 were less than the HBSH trips in 2015.

Figure 13 (a) depicts the travel time distribution for HBO trips throughout the study. Generally, there is no significant increase in both the number of trips and their travel time. On the other hand, NHBO trips have different patterns than the previous trips; NHBW trip travel time is shown in Figure 13 (b).
Figure 13 (b) illustrates the NHBW trips' travel time throughout the study period. The travel time for the NHBW trips was reduced to less than 20 minutes. While in 2015, trips' travel time was concentrated on longer than 30 minutes. The last trip purpose is the NHBO. The travel time distribution of this trip type along the study period is shown in Figure 14.

Figure 14 shows the NHBO trips during the study period. Interestingly, over the study period, there is no significant difference between the concentration of the travel time for both trips in 2005 and 2015 (95% confidence level). They both concentrate on 30 minutes or less of travel time.

**Trips Spatiotemporal Analysis**

This section presents the travel time for different modes of transport and purposes across the studied regions. The different average travel times for each travel mode and trip purpose for 2005 and 2015 data are presented in Figure 15. The analyzed data shows a huge difference between the trip travel time and travel mode for the studied regions.

Most of the trip travel time across all regions did not exceed 30 minutes, except for home-based schooling and non-home-based others. There is a huge difference in the travel mode and travel time across different counties during the study period for the same trip purpose. Across all the county, for all trips' purposes, the longest travel time was associated with auto and transit transportation modes. Comparing HBW to HBS, the longest average travel time for HBW trips occurred in 2015. The average travel time was 25 minutes in Livingston County using transit mode. Compared to HBW, HB shopping had a lower average travel time; the longest travel time was associated with using auto. In most counties, the average travel time for other modes except the auto was less than 10 minutes, except Monroe and Oakland, where the second-longest travel time was transit. HBO for most counties across all modes except transit mode in Livingston, Out-Wayne, and Oakland, all the modes have an average travel time of fewer than 10 minutes. Home-based schooling has the longest average travel time compared to the HBW and HBS.

**Discussion**

This work reported the change in travel time, distance, and travel mode throughout the study period. The study findings showed that the highest trip frequency along the study period is associated with the two adults-two children. The middle range two (their age is between 35 and 44 years) conducted more trips as compared with other groups along the study period, and this is following previous work (Hensher and Reyes, 2000). Furthermore, results showed that the age group of 55 years old or older had the lowest trip rate, and their trip time is concentrated during daylight hours, as demonstrated from a study by Alsnih (Alsnih and Hensher, 2003).

More importantly, an analysis of the travel time for different trip purposes has been done. The analysis indicated that home-based shopping has the longest travel time compared to other trips, which is also the reason for the reduction rate in HBO. This might be because shopping trips include routine daily grocery trips and major shopping events. When trip purposes were compared to travel mode, the results of this
study confirmed that the auto has the shortest travel time according to previous work (Dieleman et al., 2002; Jiao et al., 2020; Yan, 2020). Also, travel time varies significantly across the county and modes of transportation. Transit riders would spend more time traveling when compared with auto travelers.

Although trip rates per household in each county decreased from 2005 to 2015, the average travel distance has increased. This could be explained by people's tendency to live in suburban areas and avoid urban areas. Furthermore, because major automakers laid off most of their employees (Eberts et al., 2019), there has been some shifting in some industrial locations as a result of the economic downturn.

While the automobile remains the primary mode of transportation, other modes were used more frequently in 2015 compared to 2005, such as walking, biking, and transit use. This is because communities throughout the region continue to emphasize non-motorized travel enhancements. For instance, in 2010, the only on-road bike lanes in the region were part of small, disjointed networks in a few larger cities. The region's cycling network had grown to more than 200 miles by the time SEMCOG's Bicycle and Pedestrian Travel Plan was adopted in 2014, and it had expanded its reach with other forms of infrastructure (SEMCOG, 2021).

The current analysis suggests that such changes in travel behavior are due to the area's economy experiencing a slow recovery, and thus the results suggest some main implications. First, the details of changes in travel behavior in time and space throughout the last 10 years reveal the overall picture of changes in the transportation system and social settings. Changes in travel behavior have been attributed to an aging society, new working policies (telecommuting), and economic difficulties. The elderly population impacts on growing their total trips, HBW, and HBSH trips during the 10 years.

**Conclusion**

This paper aims to analyze the major changes in travel behavior in time and space over the past 10 years by analyzing household (HH) survey data collected in the Southeast Michigan area (SEMCOG) in 2005 and 2015, respectively. The HH survey consists of travel information behaviors such as location, mode of transportation, trip type, trip purpose, and departure and arrival time. The study found from the analysis of the HH survey that whereas the period from 2005 to 2015 observed a decrease in the number of HHs, people, workers, licensed drivers, and autos due to the area's economy, travel distance and duration have overall increased. Therefore, this required a more detailed analysis of changes in travel behavior in time and space while controlling for travel and socio-geographical characteristics. Moreover, transit trips increased both in distance and duration, while trip distance for the walking mode decreased. This indicates an improvement in the public transportation system in the region since 2009 (SEMCOG, 2021). The findings also show that trip duration increased, but trips by bicycle did not show any noticeable changes. Trips by auto distance and duration increased. That was because people tended to live in suburban areas and households grew ("Where are Michigan's fastest-growing cities? See population changes from 2010-2020 - mlive.com"). The people over 65, low income, and zero-worker HH groups experienced the biggest change in total trips per HH behavior during the period, where households with 2 adults and 2 children decreased. That's because rural communities have an increasing number of senior households. On the other hand, the
results show that 65 group's home-based work trips per HH increased slightly, while zero-auto HH did not change during the period, and low-income HH increased noticeably. In home-based shopping per HH trip frequency, low-income HH, zero auto HH, zero worker HH, and all people over 65 experienced the biggest increase in trip frequency during the period, when households with 2 adults-2 children decreased. Surprisingly, the middle three age groups (45-54) experienced a decrease in total trips per person in 2015, while the youth age group (16-24) and the middle age group (25-34) showed an increase in total trips per person during the same period. In addition, the impact of economic difficulties during the study period was observed clearly in increasing the travel distance and duration in transit mode, as well as increasing bicycle mode usage duration. Regarding to the analysis regions, Detroit regions showed an increase in total trips per person in 2015, while Washtenaw County experienced the most significant decrease. All regions showed a high increase in travel distance and a decrease in total trips per HH This is because of Detroit's central manufacturing city.

Even though the study investigated the change in travel behavior between 2005 and 2015, Further implications of an aging society must be investigated. Furthermore, advanced spatial analysis per county can explain, for instance, why some counties changed more than others, such as Washtenaw and St. Clair. More statistical analysis can be performed to test the association of changes in travel behavior in time and space throughout the last 10 years.

References


**Figures**
Figure 1

Map of seven Southeast Michigan counties
Figure 2

Collected data characteristics and analysis scheme
**Figure 3**

Trip Frequency per person per Age Group
Figure 4

Temporal Trip Distribution for Total Trips
Figure 5

Temporal Trip Distribution for Elderly Driver
Figure 6

Temporal Trip Distribution for Low Income
Figure 7

Average Travel Distance Per Mode
Figure 8

Average Travel Time Duration Per Mode
Figure 9

Average Travel Distance in Each County
Figure 10

Trip Rate per Person Per County
Figure 11

Trip Rate Per Household in Each County

Figure 12

(a) and (b)
Figure 13
(a) HBW (b) HBSH travel time distribution between 2005 and 2015

Figure 14
(a) HBO (b) NHBW Travel Time Distribution in 2005 and 2015
Figure 15

Spatiotemporal Analysis for Different Trips purposes.