How the Built Environment Influences Driving: Insights from Global Positioning System Data

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城市人居环境如何影响驱车出行：全球定位系统的应用

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How can we preserve the benefits of driving while conserving energy and reducing air pollution?

我们怎样可以节能又环保的驾车？

Solution 1: technology
Energy consumption and emission per mile
对策 #1：技术的更新
能源消耗和尾气排放率

Solution 2: built environment
Total VMT
对策 #2：人居环境的改变
驱车行驶距离总量

Total energy consumption and emissions
能源消耗和尾气排放总量
Research questions

How and to what degree does the built environment influence fuel consumption and emissions?

城市的人居环境（土地利用+路网结构）如何影响耗油量和尾气排放总量？
Conceptual framework

- Unit of analysis: individual driver
- Focus on non-work travel
- Behavioral Geography: Anchor point theory (Golledge and Stimson, 1997)
## Six research hypotheses (六个假设)

<table>
<thead>
<tr>
<th>The built environment</th>
<th>Total non-work VMT 非工作出行的驱车距离</th>
<th>Fuel rate/ emission rates 耗油率和尾气排放率</th>
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<td>Compact, mixed-use developments near home/work 家庭和工作周围的多样密集型环境</td>
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<td>Compact, mixed-use developments along commuting routes 上下班道路两次的多样密集型环境</td>
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Study area and research data

- 7 counties in the Southeast Michigan metropolitan area
- UMTRI GPS data:
  - 78 drivers over 30 days
  - Second-by-second
  - Position, speed, and time
  - 9,582 trips and 83,000 miles of driving
- Business establishment data
- Road network provided by the Center for Geographic Information in Michigan
Research methodology

- Quantifying driving behavior with GPS data
  量化驱车出行行为
- Calculating energy consumption and emission
  计算耗油量和尾气排放总量
- Measuring the built environment
  量化城市人居环境
- Testing the six hypotheses by multiple regressions
  验证6个假设
Quantifying driving behavior with GPS data

- Preprocessing （前期数据处理）
- Visit frequency* （出行频率）
- Trip purpose: identify home and work locations* （出行目的）
- Tour-based typology （出行种类）
- Commuting routes identification: map matching （确定上下班路线）
- Intermediate stops* （中间目的地）

Estimating fuel consumption and emissions

- Comprehensive Modal Emissions Model (CMEM)
- Instantaneous models (瞬时模型的一种)
- Wide application (400 types of vehicles) (模型可以应用到400种汽车上)
Built environment measurements: how to measure?
如何量化人居环境？

A cell-based approach: 200 x 200 meter$^2$ cells
基于栅格的测量方法
Built environment measurements: what to measure?

- **Business density** (商业密度)
  - number of business employees
- **Business diversity** (商业多样性)
  - the variety of distinct business types
- **Road connectivity** (路网通达性)
  - four-way intersection density
- **Road functionality** (路网等级)
  - the ratio of the length of low function roads to all roads
Calculations of cell weights and final built environment scores

如何给人居环境打分

$B_{\text{home/work}} = v \sum_i \frac{b_i}{d_i^2}$

$B_{\text{route}} = \frac{1}{n} \sum_j v_j a_j \left( \sum_i \frac{b_i}{d_{ij}^2} \right)$
Twelve built environment variables and three composite factors

12 个变量和 3 个综合指数

Home-related business density
Home-related business diversity
Home-related road connectivity
Home-related road functionality

Work-related business density
Work-related business diversity
Work-related road connectivity
Work-related road functionality

Route-related business density
Route-related business diversity
Route-related road connectivity
Route-related road functionality

Home composite factor
家庭人居环境指数

Work composite factor
工作人居环境指数

Route composite factor
上下班道路环境指数
Determining the connections 多元线性回归验证6个假设

Main tools: descriptive statistics, correlation analysis, and multivariate regression analysis (step-wise models)

Driving outcome variables:
1. VMT
2. Fuel consumption and emission rates
3. Total fuel consumption and emissions

\[ D = \sum_{i=1}^{n} B_i \beta_i + \sum_{j=1}^{m} C_j \alpha_j + \epsilon \]

Control variables: gender and age

Built environment variables or factors
## Six research hypotheses (六个假设)

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- Total non-work VMT: 非工作出行的驱车距离
- Fuel rate/emission rates: 耗油率和尾气排放率
- Total fuel consumption / emissions: 耗油量和尾气排放总量
Research Finding #1

- Compact mixed-use developments near drivers’ home may not associate with beneficial fuel consumption and emission outcomes.

家庭周围的密集多样性发展模式并不意味着低能耗和低排放
- Does not mean reduced VMT
- Does mean higher fuel/emission rates能耗率和排放率有可能升高

- Policy implication: a combination of green technologies and non-motorized transportation alternatives

相关政策：双管齐下
Research Finding #2
结论二

- Built environment along commuting routes matters and compact and mix use developments along routes have statistically significant associations with beneficial energy and environmental outcomes.

上下班道路两旁的环境布局要引起我们的重视；合理的布局会减少能耗和尾气排放

- 1 unit increase in route factor is associated with about 13% reduction in non-work VMT, fuel consumption, and CO₂

- **Policy implication: promote multi-functional corridors**

相关对策：建立多功能多用途通道

- Commuting purposes + non-work purposes
- Drivers + bikers, walkers, bus riders
Research Finding #3

GPS technology combined with GIS are powerful tools to study the links between the built environment and travel outcomes.

全球定位系统有很强的应用

Policy implication: GPS technology combined with computer-assisted-self-interview (CSI) will provide promising opportunities for researchers to understand travel outcomes.
Thank you & Questions?
谢谢！

HYBRID Green Vehicles
混合动力绿色汽车
Built environment ranking

Business density (1,2,3,4)

Business diversity (1,2,3,4)

Road connectivity (1,2,3,4)

Road functionality (1,2,3,4)
### Regression example:

**VMT as dependent variable**

<table>
<thead>
<tr>
<th>Model</th>
<th>R Square</th>
<th>Independent variables</th>
<th>Unstandardized Coefficients</th>
<th>Std. Error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.153</td>
<td>(Constant)</td>
<td>1303.117</td>
<td>151.598</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td>-9.796</td>
<td>3.479</td>
<td>.007</td>
</tr>
<tr>
<td>2</td>
<td>.239</td>
<td>(Constant)</td>
<td>1223.472</td>
<td>149.693</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td>-7.850</td>
<td>3.449</td>
<td>.028</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Route factor</td>
<td>-115.157</td>
<td>52.042</td>
<td>.032</td>
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</table>

The variable with the lowest probability (or highest probability) of F statistic are added to (or removed from) models. The stepwise selection requires the probability of F to be 0.05 or less to enter a variable and 0.10 or more to remove a variable.
Are compact, mixed-use developments associated with less VMT on non-work activities?

**Yes** for route-related built environment.

上下班道路两侧的密集多样型开发和总体出行距离呈**负相关**

Uncertain for home-related built environment.

家庭周围的密集多样型开发和总体出行距离**无关系**
Are compact, mixed-use developments associated with higher energy/emission rates?

**Home factor**

- Home local roads

  - Fuel per mile: 0.03%
  - CO₂ per mile
  - CO per mile

**Route factor**

- Route intersection density

  - 0.3% increase in fuel rate and emission rate
  - 2 gallons of gas in a year = 40 miles of driving

**Yes** for home-related built environment.

家庭周围的密集多样型开发和耗油率和尾气排放率呈正相关

**No** for route-related built environment.

道路两侧的密集多样型开发和耗油率和尾气排放率无关
Are compact, mixed-use developments associated with less total energy consumption /emissions?

Yes for route BE.
路网周围的密集多样型开发和耗油总量和尾气排放总量呈负相关

No for home BE.
家周围的密集多样型开发和耗油总量和尾气排放总量无关
Limitations and future works

- Associations vs. causality
- Small sample size
- Multicollinearity among built environment variables
- Only focus on vehicle trips

- More drivers in the same region; apply to other regions
- New built environment measures
- More detailed driving behavior
- Apply to bus riders, bikers, or walkers