Impact of GPS-enabled routing applications on traffic

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Outline

1. Introduction
2. Illustration on the highway I-210
3. Heterogeneous game - A model for two populations of drivers
4. Application on Los Angeles road network
5. Conclusion
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L.A.'s Love/Hate Relationship With Waze Continues

One councilmember is pushing the city to partner with the app to reduce congestion on residential streets.

LAURA BLISS | @mslaurabliss | Apr 29, 2015 | 6 Comments
Problem Statement

Model

- Two categories of players: non-routed and routed.
- A ratio of routed-users $\alpha$.

Goal: quantify the impact of $\alpha$ on local and global traffic conditions on the network
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I-210 corridor
Travel times and path flows

Average travel time for one vehicle

Flow of routed users for each path

- **without nav**
- **with nav**

- **low_path**
- **hi_path**
- **mid_path**
More traffic on local routes

Average travel time for one vehicle

- Red: on local roads
- Blue: on non-local roads

0 minutes

0.00 0.05 0.10 0.15 0.20 0.25
ratio routed

0 - 20 minutes
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Mathematical notations

- a network represented as a directed graph \( G = (V, A) \)
- Two categories of drivers: \textit{routed} and \textit{non-routed}
- Origin - Destination matrices for each population
- drivers choose between paths \( p \in \mathcal{P} \)
- A flow vector \( f = [f_p]_{p \in \mathcal{P}} \in \mathbb{R}^\mathcal{P} \)
- A traffic allocation \( x_a \) on each ark \( a \in V \)

Then for each population and each path \( p \in \mathcal{P} \) we define path latencies:

\[
I_{p}^{nr}(f) = \sum_{a \in p} c_{a}^{nr}(x_a) \quad (1)
\]

\[
I_{p}^{r}(f) = \sum_{a \in p} c_{a}^{r}(x_a) \quad (2)
\]
expression of arc-costs

For routed users:
\[ c_a^r(x_a) = t_a(x_a) \]  \hspace{2cm} (3)

For non-routed users:
\[
c_a^{nr}(x_a) = \begin{cases} 
C \cdot t_a(x_a) & \text{if } a \in A_{\text{low-cap}} \\
t_a(x_a) & \text{if } a \in A_{\text{high-cap}} 
\end{cases}
\]  \hspace{2cm} (4)

This results in the following non-routed path costs
\[
\ell_p^{nr}(f) = \sum_{a \in p_{\text{high-cap}}} t_a(x_a) + C \sum_{a \in p_{\text{low-cap}}} t_a(x_a)
\]  \hspace{2cm} (5)
Equilibrium condition for routed users and non-routed users:

\[
\forall p \in \mathcal{P}_w, \ f^r_p > 0 \Rightarrow \ell^r_p(f) = \min_{q \in \mathcal{P}_w} \ell^r_q(f) 
\] (6)

\[
\forall p \in \mathcal{P}_w, \ f^{nr}_p > 0 \Rightarrow \ell^{nr}_p(f) = \min_{q \in \mathcal{P}_w} \ell^{nr}_q(f) 
\] (7)

- Cannot be formulated as a potential game
- Can be solved numerically, using the theory of variational inequality and the Frank-Wolfe algorithm
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Application on Los Angeles road network

Figure: Modelling of LA road network
Some results on LA

Figure: distribution of travel times as a function of $\alpha$
Some results on LA

**Figure:** General VMT versus VMT on local roads as a function of the percentage of routed users.
Some results on LA

**Figure:** a) Variation in VMT for 1% increase in routed users. b) Relative variation in VMT for 10% increase in routed users.
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Conclusion

Observations:
- Global positive impact of routing apps on traffic conditions...
- ...But negative impacts on low-capacity areas.

Open questions:
- What kind of information do GPS-companies actually provide?
- How to develop a fair transportation policy which takes into account the negative externalities of routing applications?