Empirical studies on road traffic response to capacity reduction

How do drivers behave when the network changes?

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Introduction

- Study: Licence plate data collected before and during a planned roadworks. Statistical models fitted to data.
- Aim: Find information about how drivers change behaviour when network is changed.
- Context: "Highway capacity reduction" (Cairns et al 1998), Streetworks (DfT).

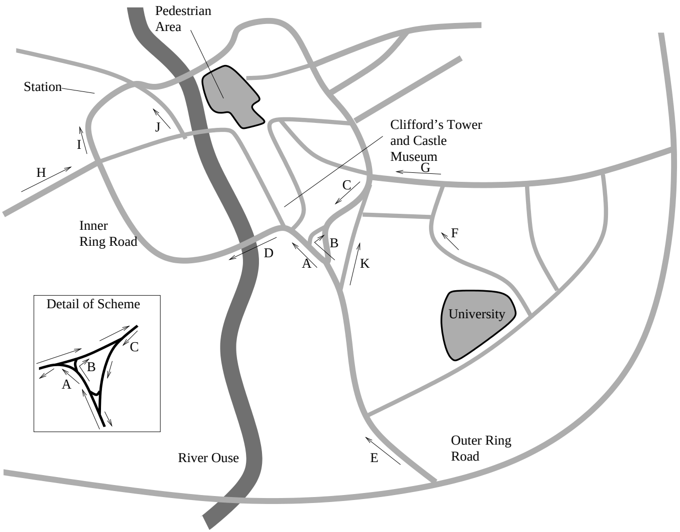
Main results

"See you next Wednesday" effect – vehicles recurr with day of the week.
"It'll be alright by Friday" effect – changes due to scheme decrease as scheme persists.

Fishergate survey overview

- Manual partial number plate survey — 11 sites, 14 days, am peak only.
- Based around a lane closure in one direction at Fishergate (inner ring road).
- Survey to establish ambient variability before and dynamics during.
  1. Six before days (25-29 June + 2nd July 2001).
  2. Seven during days (3–6, 11,12,16 July 2001).
  3. One "problem" day (13 July 2001).
- Plate matching allows partial routes to be inferred. Sites chosen to try to find three point matches for vehicles.
- Sites chosen for surveying which are directly affected and which are potential reroutings.
- Attempt to capture south-east to north-west river crossings.

Fishergate Map



Data pre-processing

Because of the difficult nature of the data, a large amount of pre-processing is necessary.

1. Remove obviously erroneous or problematic data (missing days and site B with low flow).
2. Pick pairs of sites of most interest, those with greatest flow between them and which are on obvious routes of interest.
3. Correct for the problem of false matches — Watling (1994).
4. Trim the times considered to avoid the "early end" problem (is a reduction in flow really a reduction in flow or an increase in travel time).
5. To compare between sites, normalise flows and times so each site is mean zero unit variance.

Initial analysis

- Most analysis is performed as t-tests or fitting general linear models.
- As a result of the closure, sites A, B, C and D had a statistically significant drop in traffic and site K had a statistically significant rise.
- All sites taken together the change in traffic is not statistically significant.
- Results not greatly different if generalised linear models used instead.
- Results not greatly different if 13th July (after day) omitted.
- Results not greatly different if site B (low flow) omitted.

Recurrence rate definition

Given two time periods T_1 and T_2, (eg Mon am peak and Tue am peak) the *recurrence rate* (churn) $R(T_1, T_2)$ is defined below.

Recurrence Rate

$$R(T_1, T_2) = \frac{\#\text{ vehicles seen in } T_1 \text{ and } T_2}{\#\text{ vehicles seen in } T_1}.$$

At 100% all vehicles from T_1 seen in T_2 (but not vice versa). At 0% no vehicles from T_1 seen in T_2.
Note that $0 \leq R(T_1, T_2) \leq 1$ and usually T_1 and T_2 are disjoint (for example, the rush hour on different days). Note also that

$$R(T_1, T_2) \leq R(T_1, T_2') \text{ if } T_2 \subseteq T_2'.$$

That is, the recurrence rate can only remain the same or increase if the second time period examined is made larger.

Model for recurrence rate

Hypothesised model

Recurrence rate data suggests the following model

$$\mathrm{E}[R] = \beta_0 + \beta_1 |d| + \beta_2 I_w + \beta_3 I_d.$$

Where

- R is the corrected recurrence rate between the two days.
- β_i are the model parameters.
- $|d|$ is the number of days (ex. weekends) between the two.
- I_w is one if the days are in different weeks.
- I_d is one if the days are the same day of the week.

Recurrence rates model

Model to fit

$$\mathrm{E}[R] = \beta_0 + \beta_1 |d| + \beta_2 I_w + \beta_3 I_d .$$

Site	β_0	β_1	β_2	β_3	R_a^2	p-value
A	42.2 0.1%	-0.800 0.1%	-3.35 1%	5.41 0.1%	0.545	1.73e-15
B	24.6 0.1%	-0.476 low	-3.40 low	0.0966 low	0.0225	0.198
C	37.6 0.1%	-0.510 0.1%	-3.00 5%	4.39 0.1%	0.386	6.79e-10
Eight other models not shown here.						
All Sites	39.0 0.1%	-0.666 0.1%	-3.71 0.1%	3.72 0.1%	0.222	$<$ 2.2e-16

Match is from 8:20 – 8:40 on day A to entire am peak on day B.

Conclusions on recurrence rate

- Not only does the make up of traffic vary considerably from day to day but the recurrence rate drops off very quickly.
- The combined model shows a recurrence rate of 39% falling off at around 0.7% per day (potential errors mean the absolute figure is probably an underestimate).
- Obviously this model can only be considered as valid for the few weeks being considered.
- Days which are in different weeks differ suffer a reduced recurrence rate (3.7%).
- Days which are on the same day of the week have an increased recurrence rate (3.7%) – "See you next Wednesday" effect.
- Recurrence rate varies between sites.

Flow/travel time response to change

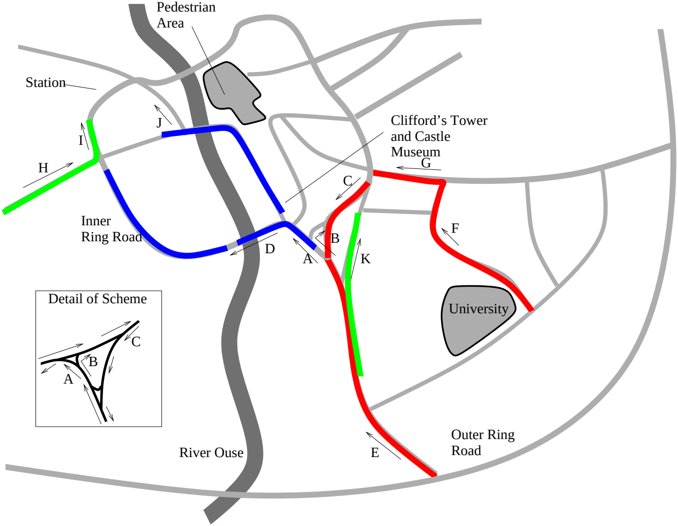
- Want to look at the effect of the closure on flows and travel times (hence site pairs).
- Want to consider a transient effect and fit a model comparing one day with subsequent days.
- Engineering rule of thumb: A new scheme which cases problems on Monday will be "alright by Friday".

Model for closure effect and transient

$$\mathrm{E}[F] = \beta_0 + \beta_1 I_c + \beta_2 D,$$

where F is the normalised flow (or time), I_c is one if the closure is in place and D is zero or the number of days since closure (not weekends).

Flow/time response map



Time response for site pairs

Time model

$$E[T] = \beta_0 + \beta_1 I_c + \beta_2 D.$$

Site Pair	β_0 Intercept	β_1 Closure	β_2 Daily	R_a^2	p-value
E–A (Approach route)	7.19 0.1%	3.72 5%	-0.311 (low)	0.353	0.036
A–D (Exit route)	0.443 0.1%	-0.126 (low)	0.051 10%	0.171	0.175
C–A (Approach route)	1.08 0.1%	2.06 0.1%	-0.162 0.1%	0.861	< 0.001
D–I (Exit route)	5.16 0.1%	-1.57 10%	0.177 (low)	0.156	0.189
H–I (Rerouting? Exit route?)	1.22 0.1%	-0.174 (low)	0.055 10%	0.215	0.136
F–A (Approach route)	3.77 0.1%	1.67 5%	-0.130 (low)	0.339	0.042

Table unit is minutes.

Plus six other models with no sig. parms apart from β_0. Note that random chance will have some models significant.

Flow response for site pairs

Flow model

$$E[F] = \beta_0 + \beta_1 I_c + \beta_2 D,$$

Site Pair	β_0 Intercept	β_1 Closure	β_2 Daily	R_a^2	p-value
E–K (Rerouting?)	216 0.1%	55.4 1%	-3.47 (low)	0.589	0.005
A–D (Exit route)	736 0.1%	-61.4 5%	-1.38 (low)	0.538	0.013
A–J (Exit route)	138 0.1%	-27.2 1%	1.28 (low)	0.504	0.012
D–I (Exit route)	77.9 0.1%	-20.8 5%	2.29 10%	0.305	0.079

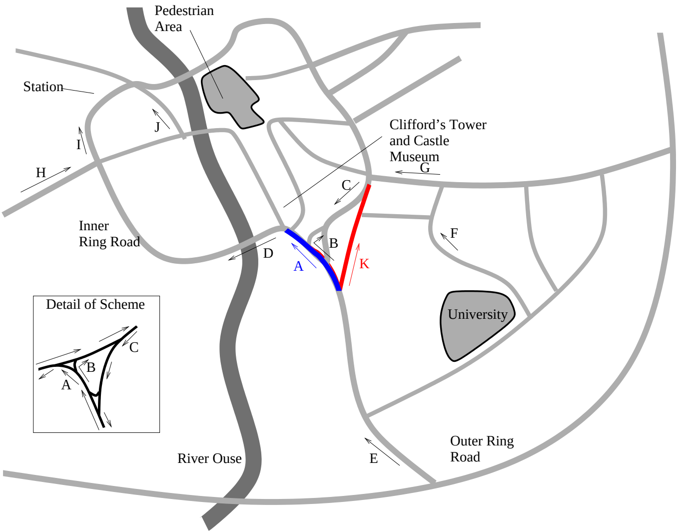
Table unit is vehicles.

Plus eight other models with no sig. parms apart from β_0. Note that random chance will have some models significant.

Discussion of the time/flow response

- Caution: Many models fitted — some will be significant by chance alone.
- All such models but one with significant β_1 or β_2 have a return to normal effect in the right direction.
- An effect on flow does not necessarily imply an effect on travel time.
- Results here can tentatively confirm the "It'll be alright by Friday" effect.
- Both flows and times showed an initial transient effect followed by return to normal (obviously model only valid in short time scale).

Analysis of rerouting – location map



Rerouting model

Consider rerouting from site A (intervention site) to K (potential diversion with stat. sig. increase in flow).

Rerouting model

$$\mathrm{E}[F] = \beta_0 + \beta_1 I_x + \beta_2 D_x + \beta_3 I_y + \beta_4 D_y.$$

Where

- F is the estimated number of travellers at A on day x and K on day y. Ignore $x = y$ case.
- I_x one if day x is a closure day zero otherwise.
- D_x zero if open on day x or no. of days since closure (ex. weekends).
- I_y one if day y is a closure day zero otherwise.
- D_y zero if open on day y or no. of days since closure (ex. weekends).

Rerouting model results

Rerouting model

$$E[F] = \beta_0 + \beta_1 I_x + \beta_2 D_x + \beta_3 I_y + \beta_4 D_y.$$

Quantity	β_0	β_1	β_2	β_3	β_4	R_a^2	p-value
Flow	21.1 0.1%	-6.33 0.1%	0.421 5%	9.90 0.1%	-0.398 5%	0.478	$<$ 1e-15
Recurr. rate	1.15e-4 0.1%	-1.46e-5 1%	3.1e-6 0.1%	2.55e-5 0.1%	-1.73e-6 5%	0.204	1.87e-8

Traffic seen at A on day x and K on day y.
β_1 day x is closure. β_2 days since closure x.
β_3 day y is closure. β_4 days since closure y.

Interpretation: Approximately ten vehicles estimated to switch on first closure day with this falling off by 0.4 vehicles per day. Again evidence of a return to normal effect – though the effects are tiny.

Overall study conclusions

- Data showed strong evidence of rapid fall off in recurrence rates but day of the week effect ("See you next Wednesday" effect).
- Rush hour seems not to be the same traffic every day and replacement is fast over three week time scale.
- Data showed evidence of initial change to flows and travel times at most affected site pairs as a result of change.
- Flows and travel times showed evidence of return to normal as time progressed ("It'll be alright by Friday" effect).
- Data showed statistically significant evidence of small amount of rerouting on days of closure with return to normal effect.

Final conclusions and further work

- Work is result of one survey at one site only — findings may have been predicted in advance.
- Still useful to measure the size of effects we believe will occur.
- Possible use to inform urban transport modelling.
- Could inform "learning" models about churn in demand and rate of learning.
- Could calibrate models for day one and subsequent day effects of road works.
- If we want to understand road traffic as a whole this kind of monitoring study needs to be attempted.
- The necessary data should become more available with better monitoring technology.
- I hope to see more of this type of study.

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