

# Effectiveness of the Parking Guidance Information system in Frankfurt am Main

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## 1. INTRODUCTION

Advanced traveller information technologies (e.g. dynamic route guidance, pre-trip information systems, radio data systems) are currently the focus of major research and development effort around the world. However, although many field-trials are underway, practical experience in the full-scale implementation and assessment of these systems is still very limited. By contrast, full-scale implementations of somewhat simpler driver information technologies do exist. In particular, information systems based on variable-message signs (VMS) are used extensively in the urban context in parking guidance and information (PGI) systems and in the motorway context in variable direction signing or variable speed control systems<sup>1</sup>. The existence of these simpler but more extensive driver information systems provides an important opportunity to address key questions of user response and aggregate system impact, which are central to the design and evaluation of the more technologically advanced systems. In this paper we report the findings of a study focusing on these issues, in the context of an urban PGI system.

PGI systems are amongst the most long-established and mature of driver information systems. The main objective of most PGI systems is to reduce the amount of time drivers spend searching for a parking place, which can reach up to 40 per cent of total travel time for some groups of drivers — see Table I. Since the first PGI system was installed in Aachen, Germany, over 20 years ago, the idea has spread around the world<sup>4</sup>. A recent review<sup>5</sup> reported 30 systems in German cities alone, of which half had been installed in the last three years. In the U.K. upwards of two dozen systems are now operational.

In spite of the long history of PGI systems few serious attempts have been made to evaluate their impact. For a review of previous studies see Polak *et al*<sup>4</sup> or Körntgen<sup>6</sup>. The results reported here form part of a wider study, undertaken to assess the effectiveness of the new PGI system installed in Frankfurt am Main in 1992<sup>3</sup>. In addition to investigating the effect of the PGI system on drivers' parking search behaviour, the study also looked at wider questions of the redistribution of parking demand in the central area, the effects of

reduced on-street parking and other detailed questions. We believe this study constitutes the most comprehensive assessment so far carried out of the impact of a PGI system.

In this paper we focus in particular on the impact of the PGI system on parking search behaviour, based on a series of surveys performed before and after the installation of the system.

The next section will briefly describe the PGI system and its setting, while the following sections will discuss the surveys performed and will present their results. The final section will highlight the conclusions and policy implications of the results.

## 2. THE FRANKFURT PGI SYSTEM

Frankfurt am Main is best known as the centre of the German financial industry, but is in addition an important industrial centre (e.g. for chemical industry and publishing), and the major regional shopping centre. Roughly one-tenth of the estimated daytime population of 930 000 persons work in the central area of Frankfurt. The central area offers about 1 900 on-street spaces (plus 800 illegal spaces), 8 800 spaces in public off-street facilities and 8 000 private spaces.

The city of Frankfurt decided to install a PGI system to reduce parking search times, to improve the distribution of demand in the parking stock and to support its policy of reducing on-street parking and more intensive parking supply management (higher fees, improved enforcement, better parking for city-centre residents).

The first phase of the PGI system focused on a part of the central area. The PGI system is hierarchical; it first guides the driver to one of the five sub-areas and then, within each sub-area, to a specific off-street facility. The signs indicate the expected number of free spaces in the sub-area or facility at the time of arrival of the driver, i.e. the system provides limited short-term forecasts. The first phase of the system implementation covered three of the five sub-areas (I to III) with a total of 12 facilities and 7 200 spaces and was installed in November 1992. The second phase will cover the remaining sub-areas (end of 1993), while a projected third phase will include signs directing drivers to Park-and-Ride facilities at the city limits of Frankfurt. Figure 1 shows the areas concerned, including the location of the parking facilities and of the variable-message signs, and Fig 2 shows an example of a typical sign. The total investment for the first two phases was DM 14.1M (and estimated annual operating cost of DM500 000), shared between the City and the State of Hessen.

## 3. BEFORE-AND-AFTER SURVEYS

The study consisted of three waves of surveys: one 'before' wave (September 1992) and two 'after' waves (February and July 1993). Each wave comprised the following components<sup>3</sup>:

- interviews with drivers to establish the amount of time they spent searching for a parking place and (in the 'after' waves) their awareness and use of the PGI system;

Table I. Saturday parking search times

Location and year of survey	Interview setting	Year	Mean (min.)	Max. (min.)	St. Dev (min.)	Av. search/Av. travel time (%)
Kingston-upon-Thames	On-street	1985	1.4	30.0	4.1	4.9
Birmingham CBD	On-street	1988	3.1	45.0	4.1	10.3
Birmingham CBD	Hail test	1989	4.6	30.0	5.9	14.1
Frankfurt CBD	On-street	1992	10.9	60.0	10.2	40.3
	Off-street		8.7	80.0	9.7	26.8
Frankfurt CBD	On-street	1993	8.0	40.0	8.1	37.3
	Off-street		5.6	60.0	7.1	21.7
Frankfurt CBD	On-street	1993	7.4	30.0	6.5	32.3
	Off-street		3.4	30.0	4.2	11.6

Sources: Axhausen and Polak<sup>2</sup> and Boltze *et al*<sup>3</sup>

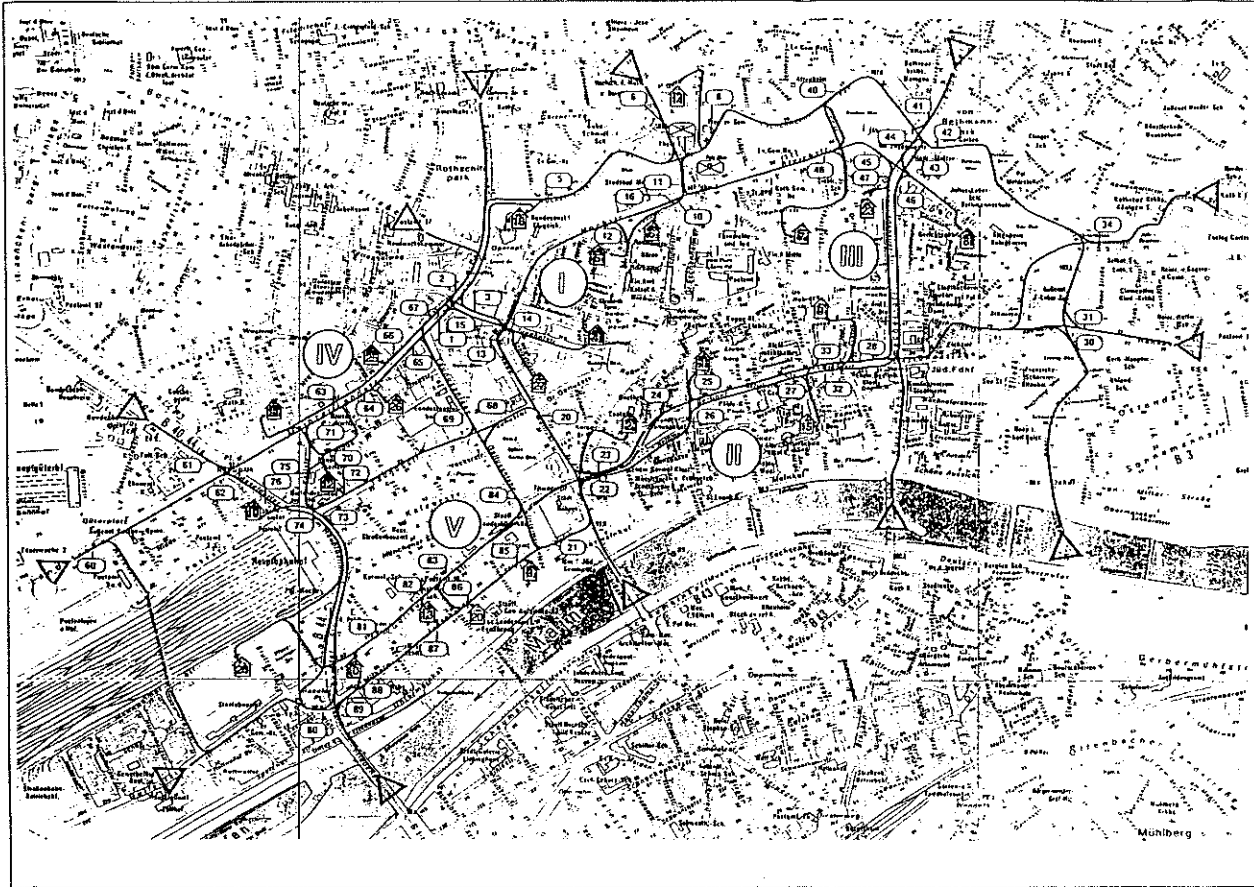


Fig 1. The study area of Frankfurt am Main: the sub-area of the Parking Guidance Information system included in the PGI variable-message signing. (Source: Figure 1 from Boltze et al<sup>3</sup>.)

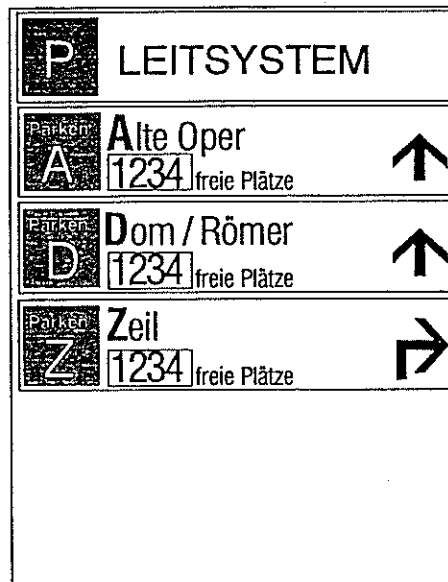
- observation of queue lengths at selected off-street facilities;
- a licence-plate survey at selected off-street facilities to establish any changes in the origin patterns of the drivers parking; and
- observation of arrival and departure profiles, of free spaces and of average durations of stay.

Each wave included counts and surveys on a normal workday (Tuesday) and on a long shopping Saturday (in Germany shops close at 16:00h on Saturdays, except for the first Saturday of each month and the four Saturdays before Christmas, when they close at 18:00h). In addition, special counts and observations were performed on pre-Christmas Saturdays in 1991 and 1992.

The search-time interviews were carried out with drivers parking on-street or off-street. The parking search times collected with such surveys are self-reported values and therefore must be treated with some caution due to the possibility of perceptual errors and differences amongst drivers in separating searching from driving times. However, the data are suitable for comparative purposes across waves. Moreover, although alternative methods of collecting search times, such as car following, are available, these have their own methodological disadvantages<sup>7</sup> and are substantially more expensive per observation.

Each interview lasted for about five minutes. Questioning covered the journey to the centre of Frankfurt, the driver's strategy for finding a parking place<sup>2</sup>, perceived search time, aspects of the journey context (such as

Fig 2. An example of a variable-message sign. (Source: Figure 3 from Boltze et al<sup>3</sup>.)



required punctuality) and the basic socio-economic characteristics. In the 'after' waves, the survey also collected information about the awareness and use of the PGI system and the driver's assessment of different aspects of the PGI system (legibility, reliability, etc.).

The off-street results are weighted by day and time of arrival based on the independent arrival and departure counts performed at 16 of the facilities in the centre.

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Table II. Sample sizes of the three waves

Wave	Day of survey	Type of parking				Total
		Off-street		On-street		
		N	%	N	%	
September 1992	Tuesday	447	85.6	75	14.4	522
	Saturday	649	93.9	42	6.1	691
February 1993	Tuesday	476	88.0	65	12.0	541
	Saturday	513	88.8	65	12.2	578
July 1993	Tuesday	369	75.3	121	24.7	490
	Saturday	571	83.5	113	16.5	684
All waves	Tuesdays	1 292	83.2	261	16.8	1 553
	Saturdays	1 733	88.7	220	11.3	1 953

Table III. Socio-demographic characteristics

Characteristic	Tuesdays		Saturdays	
	Off-street	On-street	Off-street	On-street
[%]				
<i>Gender</i>				
Male	62.2	63.5	69.5	68.2
Female	37.8	36.5	30.5	31.8
<i>Estimated age</i>				
Under 30 years	23.5	29.0	28.6	26.3
30 to 45 years	37.9	39.5	42.6	48.3
45 to 60 years	25.6	24.6	25.1	20.9
Over 60 years	13.0	6.8	3.7	4.5
<i>Work status</i>				
Full-time	65.4	60.6	85.4	75.5
Part-time	8.0	17.6	4.8	10.2
Unemployed	1.2	3.2	0.3	0.3
Non-working	25.4	18.6	9.1	14.0
<i>Car availability</i>				
Always	95.0	91.1	93.2	90.8
When required	4.6	8.9	6.0	8.3
Rarely	0.4	0.0	0.5	0.9
<i>Car registered in</i>				
Frankfurt	31.6	40.4	24.2	47.6
Immediate surroundings	53.8	52.6	60.8	45.9
Elsewhere	14.6	7.0	15.0	8.3
<i>Frequency of visit</i>				
Daily	28.5	25.5	21.0	27.4
Weekly	30.6	32.7	27.9	32.1
Monthly	23.1	30.6	26.1	25.6
Less frequently	17.8	11.2	25.1	14.6
<i>Self-assessed local knowledge</i>				
Very well	30.0	30.4	28.9	32.8
Well	51.6	49.6	46.7	48.7
Less well	11.2	15.0	13.9	12.5
Hardly	4.0	3.1	6.1	3.0
Barely	3.4	1.4	4.2	2.2

N.B.: Values are means of the three underlying daily values

The size of the samples achieved each day of the three waves are shown in Table II, while Table III presents a summary of the socio-economic characteristics of the overall sample. Whereas the Tuesday's and Saturday's samples are comparable in terms of gender, age distribution, car availability and local knowledge, they do show significant differences for the other variables. In particular, on Saturdays there are more full-time working respondents and there are fewer local visitors and a lower level of visiting frequency. This shift reflects an increase in out-of-town working shoppers on Saturdays (see also Table IV).

#### 4. EFFECTIVENESS OF THE PGI

##### 4.1. Awareness and use of the PGI system

In the U.K., a number of surveys have recently been carried out which shed some light on the nature of drivers' awareness and use of PGI systems.

In surveys carried out six months after the introduction of the Leeds PGI system, Smith and Philips<sup>8</sup> found that approximately 70 per cent of drivers were aware of the existence of the system and that around one-sixth of drivers had used the system at least once. In Kingston-upon-Thames, Allen<sup>9</sup> found that only 4 per cent of respondents were completely unaware of the local PGI system after nine months of operation, while 47 per cent were aware of it, but had not used it. About a fifth of the respondents had used the system on the day of the interview. In Nottingham, Polak *et al*<sup>7</sup> found that 63 per cent of drivers were aware of a radio-based parking information system, operating during the Christmas period, when interviewed during the second year of operation. Twenty-five per cent of the respondents were aware of the system, but had not used it.

Local authorities in Germany typically claim that between 50 per cent and 100 per cent of the local users and between 30 per cent and 79 per cent of non-local users are aware of their PGI systems, with a median of about 90 per cent for local users and 30 per cent for non-local users<sup>5</sup>. Use of the systems is reported as 43 per cent in Mainz, 45 per cent in Stuttgart and 59 per cent in Wuppertal<sup>6</sup>.

The two 'after' surveys in Frankfurt allow us to track, to some extent, the development of drivers' awareness and use of the system over time ('use' was here defined as having consulted the system at least once prior to the interview). The main results are shown in Fig 3. Awareness of the system appears to have developed rapidly and stood at about 80 per cent after three months of operation, growing only marginally and slowly thereafter. In fact, it seems unlikely that awareness of the system will grow much further due to the large proportion (about 20 per cent) of infrequent and 'one-off' visitors to Frankfurt. While awareness of the system is similar for those parking on-street and off-street, as expected, the usage of the system is substantially higher amongst those parking off-street. Both awareness and use of the system is a little higher amongst those parking on Saturdays, compared to those parking mid-week.

Table IV. Characteristics of the visit

Characteristic	Tuesdays		Saturdays	
	Off-street	On-street	Off-street	On-street
[ % ]				
<i>Purpose</i>				
Work/Education/Employers' Business	36.1	36.2	6.4	5.9
Shopping	43.8	26.8	79.6	56.6
Private business	13.1	23.5	5.5	26.1
Other	6.9	13.2	8.3	11.6
<i>Duration</i>				
< 30 minutes	2.3	17.8	1.0	19.7
30 - 59 min.	6.9	26.1	2.6	24.8
60 - 119 min.	23.3	27.9	15.5	33.3
120 - 239 min.	46.9	15.0	57.2	14.6
240 - 479 min.	13.6	6.3	20.2	2.5
Over 8 hours	6.9	7.0	3.5	5.2
<i>Appointment</i>				
Yes	35.7	45.0	12.0	20.1
No	64.1	55.0	87.7	79.9
<i>Punctuality for appointments</i>				
Required	61.0	25.6	51.9	14.1
Some leeway	33.4	70.9	37.6	81.3
Not essential	5.8	2.7	10.5	4.6

N.B.: Values are means of the three underlying daily values

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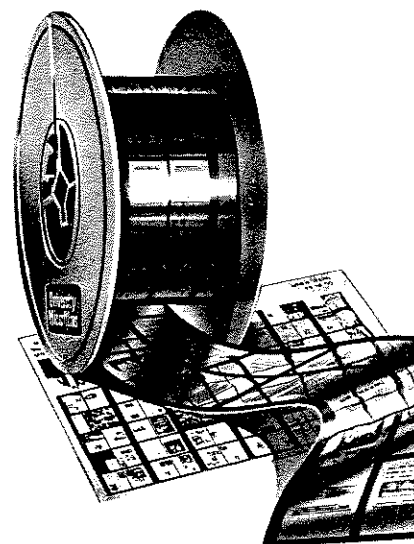
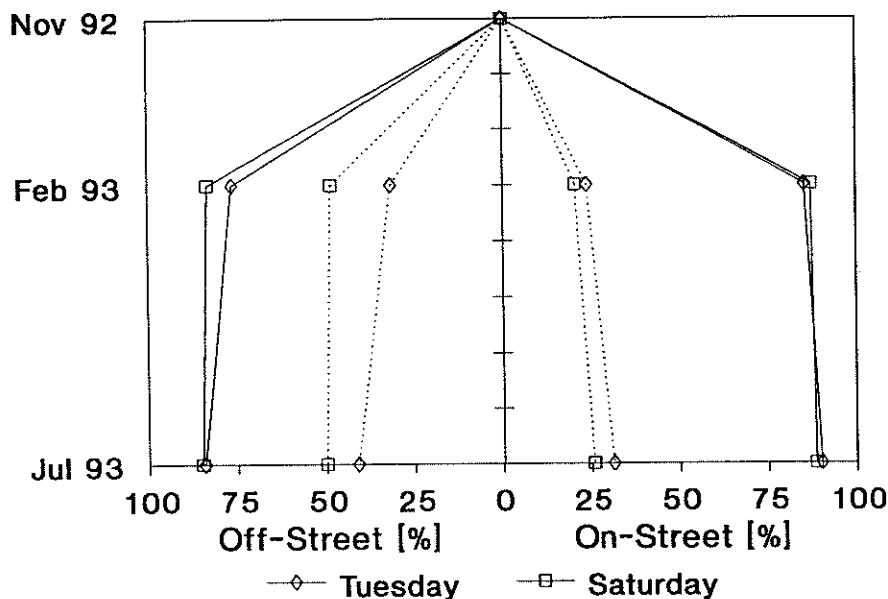


Fig 3. Awareness and use of the PGI system over time (percentage of respondents).



Dashed lines indicate "awareness" - Solid line indicate "use at some point before the interview"

Overall, it appears that around 50 per cent of off-street parkers and 25 per cent of on-street parkers have used the system at some point in time, and on the basis of information from the questionnaires concerning drivers' detailed search behaviour we estimate that on any given day around 20 per cent of those parking off-street will be using the system to

help them find a space. Whilst these figures are comparable to those reported for other PGI systems, in absolute terms they must be judged disappointing. Considerable scope still remains for extending the penetration of the system, particularly amongst those who currently park on-street and may have most to gain from the system.

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**Table V.** Saturdays: Search strategies

Characteristic	September 1992		February 1993		July 1993	
	Off-street	On-street	Off-street	On-street	Off-street	On-street
[%]						
<i>Initial Search strategy</i>						
Direct to parking space	78.1	52.8	75.5	59.2	85.1	56.5
Search near destination	12.3	42.3	11.4	40.2	10.8	43.5
Followed the PGI	—	—	9.6	—	3.2	—
Mixed strategy	9.6	4.9	3.5	—	0.9	—
<i>Replacement strategy</i>						
Other type of parking	62.9	51.4	55.2	66.7	49.7	81.4
Other location	12.7	9.2	4.3	1.7	9.4	—
Park illegal	5.5	14.1	8.7	18.0	5.4	11.5
Next off-street facility	10.5	7.0	6.3	—	14.6	—
Queued	2.0	12.7	—	2.6	1.1	—
Return home	3.7	2.8	1.1	1.7	1.2	0.9
Park-and-Ride	0.1	—	0.3	—	—	—
Now follow the PGI	—	—	20.0	6.8	14.7	—
Other	2.6	2.8	4.1	2.5	3.9	6.2
<i>Type of usage of the PGI</i>						
Choice of a different off-street facility			35.1	52.2	36.9	7.1
Switch to an off-street facility			7.7	—	14.8	60.7
Choice of Park-and-Ride			2.1	4.4	1.1	—
Rely on the PGI			16.9	4.4	15.4	21.4
Checking existing strategy			38.2	39.1	31.9	10.7

**4.2. Impact on search behaviour**

A PGI system can influence parking behaviour both in terms of establishing (or modifying) drivers' desired type and location of parking and by affecting the overall approach used by drivers to finding a place of the desired sort<sup>2</sup>. Table V summarises these impacts for the surveyed Saturdays.

The results indicate that few drivers totally rely on the PGI system in the first instance, even on the crowded 'long Saturdays' when parking congestion is at its worst. Instead, use of the PGI system figures more prominently as a 'replacement' strategy, i.e. a fall-back strategy in the event that the desired type or location of parking cannot be found. However, even in this 'replacement' rôle, the numbers using the PGI are only comparable to those who decide simply to park their car illegally. This indicates that drivers are generally very reluctant to hand over control to an external agent. This impression is reinforced by the type of use which the drivers make of the system. Here only a small share of the users rely completely on the system. Most of them use the system either to check their previous decision or to update it.

**4.3. Aggregate search-time model**

Given the different levels of total demand on the survey days, it is impossible to draw conclusions about the effect of the PGI by a naive comparison of average search times on the different days. In order to identify possible effects of the PGI system on aggregate system performance, it is necessary to model the overall response of the 'parking system' to different levels of demand. Any structural

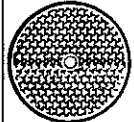
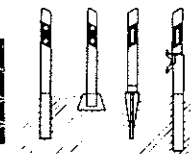
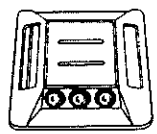



change in these parking performance relations as between the 'before' and 'after' situations may then reasonably be attributed to the effect of the PGI system.

Recent work carried out in London has demonstrated that it is possible to estimate such performance relations using the type of data available in this study, and has suggested appropriate model specifications<sup>10,11</sup>. The approach involves relating the level of parking demand within a given time interval to the average search-time of those drivers who found a parking space during this interval, ideally controlling for the background level of traffic flow in the area. The model was estimated separately for both on- and off-street parking due to the different sample sizes for these two general types of parking. The demand level for off-street parking was approximated by the level of occupancy in the off-street facilities. This is a proxy for the total demand in the study area, especially for the demand for on-street parking. The occupancy was estimated from the search-time survey data. One particular problem with this approach is the possibility of a time-lag between the demand and the search times. It was not possible to include in the model specification a control for the background level of traffic due to technical problems with the detector loops on some of the survey days.

Figure 4 shows a scatter plot of the relationship between mean search times for drivers arriving at off-street facilities and the estimated occupancy of the off-street facilities in the study area, for the surveyed Saturdays. Although there is clearly considerable noise in the data, there is visual evidence of a non-linear trend, especially at high occupancy levels. By contrast, the results for on-street parking on both Tuesdays and Saturdays and for off-street parking on Tuesdays indicated the absence of non-linearities. In fact, average search times for on-street parking seem to be essentially independent of the on-street occupancy (perhaps reflecting the determination of many drivers to find a space in spite of the parking system being at or near capacity throughout most of the day). The off-street demand on the Tuesdays was not high enough to produce the non-linear reactions of the system as a whole.

Since any effects of the PGI system on aggregate system performance were likely to be felt most strongly in the periods of highest parking congestion, it was decided to concentrate the analysis on the data from Saturdays. Accordingly, the functional relationship chosen to represent the parking performance model reflects the non-linearity present in these data:

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Table VI. Saturdays: results of the non-linear regression for off-street parking

Parameter	Value	Std. Error	t-statistic
$\alpha$	3.555	0.396	8.98
$\gamma_2$	-0.605	0.062	9.76
$\gamma_3$	-0.564	0.073	7.73
$K$ [100]	92.219	4.231	21.80
SS Regression	2574.06		
SS Error	232.56		
$R^2$	0.91		

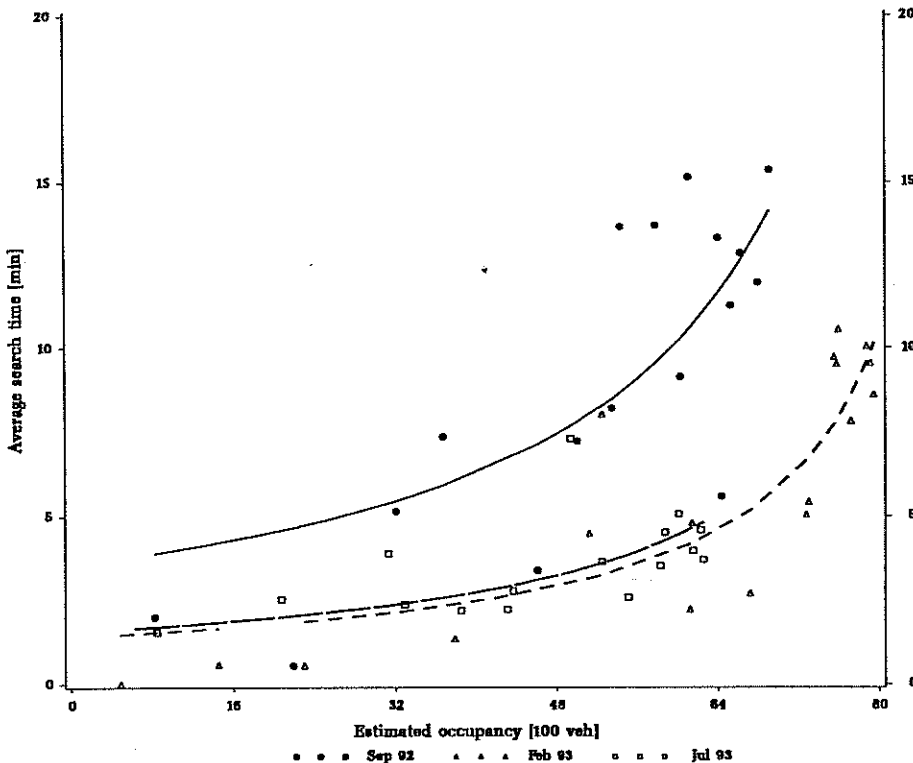


Fig 4. Saturdays: Mean search time for off-street parkers as a function of estimated occupancy of the off-street facilities during the same 30-minute interval.

$$t_i = \frac{\alpha}{(1 - Occ/K)} \quad \dots (1)$$

where:  $t_i$  = Average search time of drivers arriving at off-street facilities in the time interval  $i$

$Occ_i$  = Estimated occupancy of the off-street facilities during interval  $i$

$\alpha$  = Structural parameter of parking performance relation

$K$  = Total capacity of the relevant facilities (including facilities outside the study area and on-street spaces)

This relationship was expanded as follows in order to test for significant structural differences between the three waves:

$$t_i = \frac{\alpha(1 + \gamma_2\delta_2 + \gamma_3\delta_3)}{(1 - Occ/K)} \quad \dots (2)$$

where:  $\gamma_j$  = Change in the structural parameter of the parking performance relation in wave  $j$  ( $j=2,3$ )

$\delta_j$  = Dummy variable equal to 1 for wave  $j$  and 0 otherwise

Table VI gives the estimation results and Fig 4 shows the estimated performance functions. The overall fit of the performance model is satisfactory and all the coefficients are significant and have the expected sign. Both  $\gamma_2$  and  $\gamma_3$  are negative, indicating a downwards shift in the performance function following the introduction of the PGI system. The coefficients  $\gamma_2$  and  $\gamma_3$  are very similar in value (indeed they are not statistically significantly different), indicating that the main system-wide effects of the PGI system were apparent within the first three months of operation. This is consistent with the earlier findings regarding the rapid diffusion of drivers' awareness and use of the system.

We can interpret this shift as representing a change in the technological characteristics of a parking system, such that at all levels of parking demand, parking search times are lower.

## 5. CONCLUSIONS

The series of surveys in Frankfurt allowed a detailed analysis of the effects of a PGI system on driver behaviour. The awareness of the system grew very rapidly to 80 per cent of drivers, but usage remained comparatively low (about 20 per cent of drivers on any one day). This low usage is the result of the drivers' unwillingness to rely on the systems

completely. They use it to supplement their knowledge and to improve their assessment of the traffic situation. However, even this comparatively moderate level of use was sufficient to produce a significant technological improvement in the performance of the parking system, on the heavily-congested 'long' shopping Saturdays. The system had no measurable effect on aggregate system performance either on the normal working Tuesdays or on the on-street parking situation.

To increase the effectiveness of PGI systems further, it is clear that designers will have to find ways of reaching a greater proportion of drivers, and of persuading those drivers already aware of (but not yet using) the system that it does offer them real benefits.

## ACKNOWLEDGMENTS

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