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Effectiveness of the Parking Guidance 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 systems¹. 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 also 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% of total travel time for some groups of drivers — see Table 1. Since the first PGI system was installed in Aachen, Germany over twenty years ago, the idea has spread around the world². A recent review³ reported thirty systems in German cities alone, of which half had been installed in the last three years. In the UK, 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.* (1990)² or Körntgen (1993)⁴. 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 1992⁶. 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.

3 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 day time population of 930,000 persons work in the central area of Frankfurt. The central area offers about 1900 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 part of the central area. The PGI system is hierarchical; first guides the driver to one of five subareas and then within each subarea, to a specific off-street facility. The signs indicate the expected number of free spaces in the subarea 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 subareas (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 subareas (end of 1993), while a projected third phase will include signs directing drivers to Park+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 Figure 2 shows an example of a typical sign. The total investment entailed for the first two phases was DM 14.1 million (just as the estimated operating annual costs of DM 500,000), shared between the City and the State of Hessen

5 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 components⁶:

- interviews with drivers to establish the amount of time they spent search for a parking place and (in the 'after' waves) their awareness and use of the PGI system
- observation of queue lengths at selected off-street facilities

- licence plate survey at selected off-street facilities to establish any changes in the origin patterns of the drivers parking
- observation of arrival and departure profiles, 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 16:00 on Saturdays, but for the first Saturday of each month and the four Saturdays before Christmas, when they close at 18:00). 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 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 to have their own methodological disadvantages⁹ 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 place⁵, perceived search time, aspects of the journey context (such as 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 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 sixteen of the facilities in the centre.

The size of the samples achieved on each day of the three waves are shown in Table 2, while Table 3 presents a summary of the socio-economic characteristics of the overall sample. Whereas the Tuesdays and Saturdays 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 4).

7 EFFECTIVENESS OF THE PGI

8.1 Awareness and Use of the PGI System

In the UK, 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 six months after the introduction of the Leeds PGI system, Smith and Philips (1993)⁷ found that approximately 70% 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 (1993)⁸ found that only 4% of respondents were completely unaware of the local PGI system after nine months of operation, while 47% 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.* (1993)⁹ found that 63% 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 percent of the respondents were aware of the system, but had not used it.

Local authorities in Germany typically claim that between 50% and 100% of the local users and between 30% and 79% of non-local users are aware of their PGI systems, with a median of about 90% for local users and 30% for non-local users³. Use of the systems is reported as 43% in Mainz, 45% in Stuttgart and 59% in Wuppertal⁴.

The two after surveys in Frankfurt allow us to some extent track 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 Figure 3. Awareness of the system appears to have developed rapidly and stood at about 80% 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%) 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.

Overall, it appears that around 50% of off-street parkers and 25% 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% of those parking off-street, will

have 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.

8.3 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 sort⁵. Table 5 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' role, the numbers using the PGI are only comparable to those who decide to simply 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 to check their previous decision or to update it.

8.5 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^{10,11}. 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

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 were 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:

$$t_i = \frac{\alpha}{(1 - Occ_i / K)} \quad [1]$$

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
- α : 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:

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

where:

- γ_j : Change in the structural parameter of the parking performance relation in wave j ($j=2,3$).
- δ_j : Dummy variable equal to 1 for wave j and 0 otherwise.

Table 6 gives the estimation results and Figure 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 γ_2 and γ_3 are negative indicating a downwards shift in the performance function following the introduction of the PGI system. The coefficients γ_2 and γ_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 3 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 parking system, such that at all levels of parking demand, parking search times are lower.

9 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% of the drivers, but usage remained comparatively low (about 20% 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 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 using the the system offers them real benefits.

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Table 1 Saturday parking search times

Location and Year of Survey	Interview Setting	Year	Mean	Max	St.Dev [min]	Av. travel [min]	Av. search/ 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	halltest	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 (1990)⁵ and Boltze *et al.* (1993)⁶

Table 2 Sample sizes of the three waves

Wave	Day of survey	Type of parking				Total	
		Off-street		On-street		N	%
		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	1292	83.2	261	16.8	1553	
	Saturdays	1733	88.7	220	11.3	1953	

Table 3 Socio-demographic characteristics

Characteristic Effectiveness of the PGI system in Frankfurt am Main		Tuesdays		Saturdays	
		Off- street	On- street	Off- street	On- street
[%]					
<hr/>					
Gender					
Male	62.2	63.5	69.5	68.2	
Female			37.8	36.5	30.5 31.8
Estimated age					
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
Work status					
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
Car availability					
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
Car registered in					
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
Frequency of visit					
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
Self-assessed local knowledge					
Very well			30.0	30.4	28.9 32.8
Well			51.6	49.6	46.7 48.7

Table 4 Characteristics of the visit

Characteristic	Tuesdays		Saturdays	
	Off-street	On-street	Off-street	On-street
[%]				
Purpose				
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
Duration				
< 30 min	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
Appointment				
Yes	35.7	45.0	12.0	20.1
No	64.1	55.0	87.7	79.9
Punctuality for appointments				
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

Values are means of the three underlying daily values

Table 5 Saturdays: Search strategies

Characteristic	September 1992		February 1993		July 1993	
	Off-street	On-street	Off-street	On-street	Off-street	On-street
Initial Search strategy						
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	---
Replacement strategy						
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+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
Type of usage of the PGI						
Choice of a different off-street facility			35.1	52.2	36.9	7.1
Switch to a off-street facility			7.7	---	14.8	60.7
Choice of P+R			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

Table 6 Saturdays: results of the non-linear regression for off-street parking

Parameter	Value	Std. Error	t-statistic
α	3.555	0.396	8.98
γ_2	-0.605	0.062	9.76
γ_3	-0.564	0.073	7.73
K	92.219	4.231	21.80
SS Regression	2574.06		
SS Error	232.56		
R^2	0.91		

Figure 1 Study area

Legend: Subarea of the PGI
 Facility included into the PGI
 VMS

Source: Boltze *et al.* (1993), Figure 1

Figure 2 Example variable message sign

Source: Boltze *et al.* (1993), Figure 3

Figure 3 Awareness and use of the system over time [% of respondents]

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

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