DO PHYSICAL BARRIERS AFFECT URBAN CRIME TRIPS?

THE EFFECTS OF A HIGHWAY, A RAILROAD, A PARK OR A CANAL ON THE FLOW OF CRIME IN THE HAGUE[1]

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One way the intensity of criminal traffic between areas has been examined is through gravitational models (e.g. Smith, 1976; Kleemans, 1996; Ratcliffe, 2003; Reynald, Averdijk, Elffers and Bernasco, 2008; Elffers, Reynald, Averdijk, Bernasco and Block, 2008). This is an approach that envisages the origin area as "producing crime trips," the destination area as "attracting crime trips," and takes into account that in between origin and destination areas the would-be criminals may encounter friction. The term gravitational model exploits the parallel with gravitation models in physics, in which the attraction force between two solid bodies, such at the earth and the moon, is modelled proportional to the mass of both bodies and inverse to the distance between them. This is also the case in crime trip models. Here, the distance between origin and destination areas is one of the main friction variables, where the greater the distance the less likely a crime trip will happen. However, more friction variables than just geographical distance may play a role. De Poot, Luykx, Elffers and Dudink (2005) and Reynald and colleagues (2008) showed that social barriers between origin and destination neighbourhoods had such an effect in The Hague (the Netherlands). In that research, the more those areas differed in terms of ethnic composition and level of wealth, the more friction had to be overcome. Inspired by Stouffer (1940, 1960), Elffers and collegues (2008) investigated, again in The Hague, to examine the availability of intervening opportunities that might be acting as a friction variable over and above distance. They found this to not be the case. Greenberg, Rohe, and Williams (1982), Greenberg and Rohe (1984), Ratcliffe (2001, 2003) and Clare, Fernandez, and Morgan (2009) investigated to what extent physical barriers act as friction variable. Physical barriers are obstacles between origin and destination areas, blocking a direct, easy trip, and presenting some difficulty to either cross or circumvent. Examples of this type of barrier are rivers, fences, and main roads crossing the origin-destination line (Rengert, 2004). Van der Wouden (1999) also described railroad lines as physical barriers. Physical barriers require a person undertake more effort to get to a destination. Crossing a barrier like a railroad line, a highway, or a river, at least in a vehicle, is only possible at locations where bridges or tunnels are present, thereby presumably increasing the travel distance.

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[1] This article is based on the master thesis (University of Leiden) of the first author (Peeters, 2007).

These studies often produce conflicting results with respect to the influence of physical barriers. For example, Greenberg, Rohe and Williams (1982) and Greenberg and Rohe (1984) found positive effects of highways and railroad lines in Atlanta, United States on travel to crime; while Ratcliffe (2003) found no effect of vegetation and major roads in Canberra, Australia. Clare, Fernandez, and Morgan (2009) found positive effects of main roads and of the river estuary in Perth, Australia. The present research takes up this issue again, and examines the influence of highways, the railroad lines, parks, and canals as physical barriers in the city of The Hague, the Netherlands.

Physical Barriers within Location Choice Theory

The intensity of crime trips between areas (i.e. the number of trips per unit of time) is an aggregation of target choices made by individual offenders. In the rational choice tradition, Bernasco and Nieuwbeerta (2005) explained the target choice of an individual offender as being governed by a comparison of the attraction level of all potential target areas. This comparison is made in terms of the aggregated value of all targets available for an offender, discounted by the distance to be covered to reach that target area.

The influence of physical barriers in this model may be examined by modifying the effect of distance. Usually, we have no direct information on actual distance covered by an individual offender to a chosen target; and the analyses in the literature cited use approximated distance between the origin and target (often as the distance between the centroids of origin area to destination area). By doing so, researchers implicitly use this distance as an approximation to the actually covered distance. Incorporating whether an offender encounters a physical barrier may improve on this approximation because the existence of a barrier forces the potential offender to circumvent it, hence covering a larger distance than otherwise would have been the case. Alternatively, the offender may have to use a more cumbersome method of passing the barrier (which is then a permeable barrier in the sense of Rengert, 2004), e.g. by using a ferry, climbing a fence, or wait for a traffic sign to show green, which all amount to increasing travel time. We will use the term “facing a barrier” for the two phenomena together: circumventing a barrier or passing through it. In figure 1.1, without a barrier, the upper target would have been closer to the origin than the right hand target (hence, ceteris paribus, being preferable). When the offender has to circumvent the barrier, the upper target becomes less attractive, as the distance to be covered increases.

Figure 1.1 Physical barrier

Of course, the mere indication that a barrier is present is a crude approximation to the additional distance to be covered or to the time it would take. While it may, in principle, be possible to measure the effect of a barrier on time and distance of an actual crime trip in an individual case, this will in practice seldom be feasible; and would require much more detailed data on available roads from origin to destination than usually will be available. We expect, however, that certain types of barriers do present more difficulties to would-be offenders than others. For example, in the Dutch context, an inner city highway will present more difficulties than a canal, as the number of points where one may cross that highway will in general be less than where one can pass a canal. This explanation is not only valid for criminal activity, but will hold for any activity a person from an origin area may consider in choosing a destination area, of course with a different set of attraction indicators. This observation shows that, within the framework of routine activity theory (Cohen and Felson, 1979), we may expect effects of physical barriers. When such a barrier is present, routine activity theory expects less non-criminal traffic from origin to destination, and hence, less crime as well.

Methodology

Research Questions and Hypotheses

By examining data on the intensity of crime trips, it is possible to investigate whether the number of crime trips that include a barrier is significantly different from the number of crime trips that do not cross a barrier. Within a gravitational model of crime trip intensity that has distance as its main friction indicator, we expect that offenders, ceteris paribus, travel less to areas where they have to face a barrier than to neighbourhoods not requiring them to encounter a barrier. As such, the main research question of this article is:

> *Do physical barriers influence the journey-to-crime of offenders, controlling for distance?*

Knowing that distance is a dominant explanatory factor in gravitational models (Elffers et al., 2008; Reynald et al., 2008), we hypothesize that:

> *Physical barriers only have a small amount of additional value next to travel distance.*

As argued above, not all types of barriers are expected to have equal influence, according to the ease with which they may be circumvented. This leads to the next hypothesis:

> *Different types of physical barriers display a different strength of influence on the journey-to-crime of offenders.*

Within the context of the Dutch environment, we expect an urban highway to be a less permeable barrier than a railroad line, a park, or a canal because there are fewer opportunities to cross it.

Finally, the expectation is that having to circumvent a physical barrier will have more influence when the unhampered distance between origin and destination is shorter. This leads to the third hypothesis:

> *Barriers have a larger influence on intensity of crime trips when the trips have shorter travel distances.*

When an offender has to travel only a short distance, the additional travel distance that emerges from facing the barrier is relatively large. The same amount of extra distance is relatively small when the neighbourhoods are far apart and the travel distance is long (Clare et al., 2009).

Data

To test whether physical barriers have an influence on crime trips, information about the origin and destination of crime trips is required. Crime data used here is provided by the regional police force Haaglanden,[2] and is identical to the data used in the research of Reynald and colleagues (2008) on the influence of social barriers. The data is from police records of crimes in the city of The Hague from 1996 till 2004. The data contains 62,871 solved offences committed in The Hague by offenders who lived in The Hague at the time of the offence. We can only use solved crime data, otherwise the origin location of the criminal is unknown. Aggregating the data gives us the total flow of criminal traffic in and between neighbourhoods. Origin-destination trip intensity is defined as the number of crime trips between two neighbourhoods in the time frame considered.

The Hague, Figure 2.1, is a city at the North Sea coast of The Netherlands, with approximately 440,000 inhabitants. The city's current boundaries include the former coastal villages of Scheveningen, Loosduinen, and Kijkduin. The city comprises 94 neighbourhoods, the boundaries being defined by the The Hague municipality on the basis of historical and infrastructural characteristics. For this research, these neighbourhoods are linked to each other to examine the influence of the barriers. This leads to 94 x 94 = 8836 ordered origin-destination combinations. This includes the 94 links where origin and destination neighbourhood are identical. These cases are crime trips where the offender commits a crime in his or her own neighbourhood, which will be referred to as internal crime trips. Since every offender needs to travel to a location where the opportunity to commit a crime is present, every offence can be influenced by physical barriers; therefore, we include all types of offences recorded by the police in the analysis.[3]

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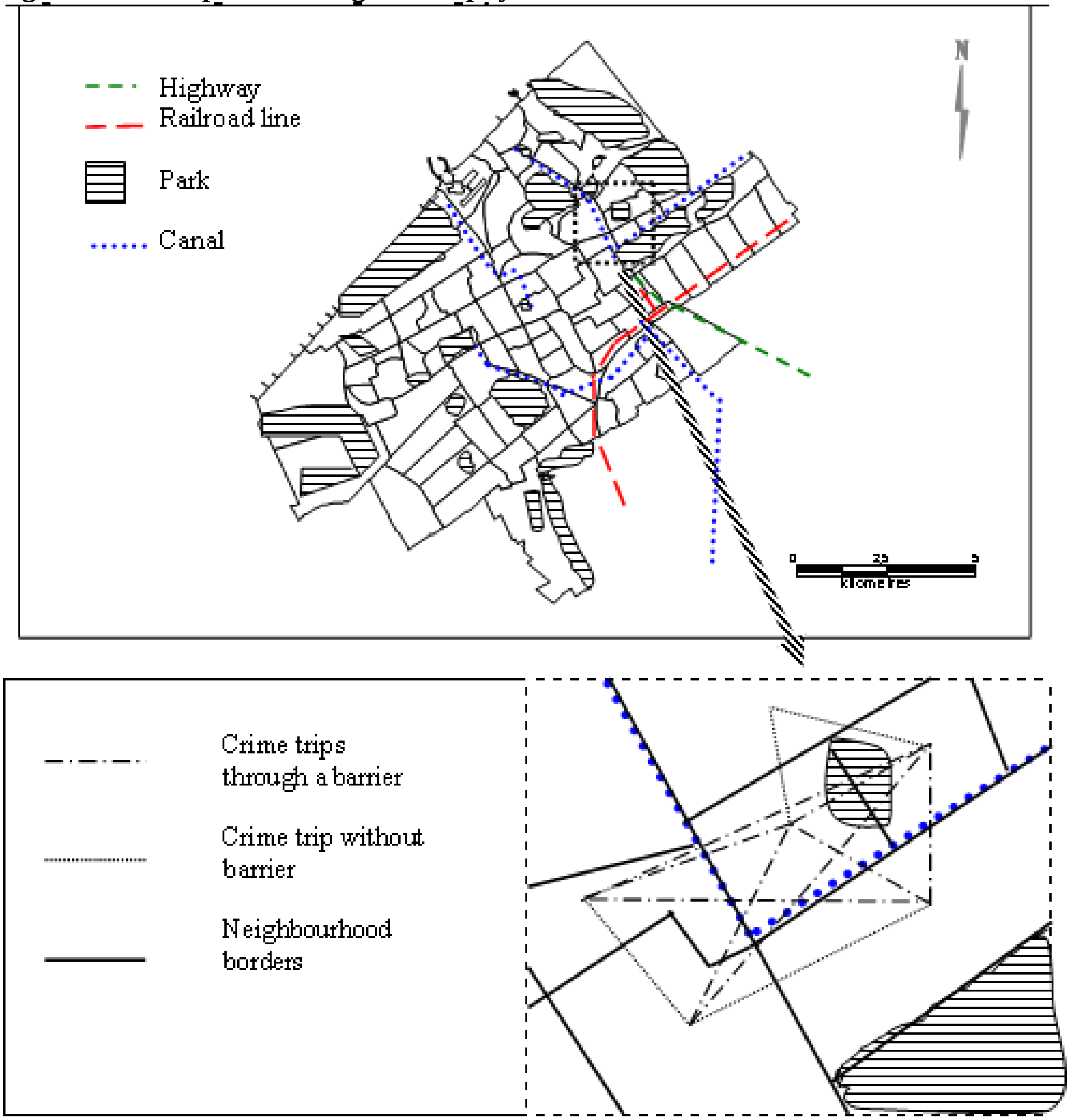
[2] We are grateful to the Regional Police Force Haaglanden for providing access to these data under a covenant with NSCR.

[3] Property offences (37 percent), traffic (23 percent), violent (17 percent), public order (7 percent), vandalism (5 percent), drug related (4 percent) and other offences (7 percent).

Figure 2.1 Map of The Hague with physical barriers



It should be noted that The Hague is a rather small city (ca. 20 x 15 km), and the barriers considered are certainly not insurmountable. The railway line has a number of underpasses, the highway, as well as most of the canals, have a number of viaducts or bridges to cross them, and most of the parks are well kept urban parks with a net of foot paths crossing them. Compared to previous studies (eg. Clare et al., 2009, who studied a very large river as a barrier), barriers in this study are of moderate size, hence we should expect only a small influence of their presence.

Model and operationalisation

For investigating the influence of physical barriers, a gravitational model is used, which models the intensity of crime trips between origin area *o* and destination area *d* in terms of a *push* factor, a *pull* factor, and a *friction* factor.

$$\text{intensity}_{od} \sim \text{push}_o^{\alpha} \cdot \text{pull}_d^{\beta} / \text{friction}_{od}^{\gamma}$$

for some exponents α, β, γ.

Following Reynald and colleagues (2008) and Elffers and colleagues (2008), the push variable is operationalized as the total number of crime trips that originate from the origin neighbourhood to a destination neighbourhood (outflow). The pull variable is operationalized as the total number of crime trips to the destination neighbourhood, originating from whatever neighbourhood (inflow). By taking logs, we linearize such a model (see Smith, 1976).

Friction variables come in two varieties. First is the distance, as is customary in all journey-to-crime studies (we use Euclidian distance between centroids of neighbourhoods). The second is the indicator(s) for the presence of a certain type of physical barrier, i.e. $\text{barrier}_{od}^{(i)} = 1$ if a barrier of type i crosses the line between the centroids of o and d, and $\text{barrier}_{od}^{(i)} = 0$ if that is not the case (for i=any barrier, highway, railroad, park, canal). These barrier indicators were scored manually from a detailed version of map 2.1 . Here, notice that

$$\text{barrier}_{od}^{(\text{any barrier})} = 1 - (1-\text{barrier}_{od}^{(\text{highway})}) \cdot (1-\text{barrier}_{od}^{(\text{railroad})}) \cdot (1-\text{barrier}_{od}^{(\text{park})}) \cdot (1-\text{barrier}_{od}^{(\text{canal}))})$$

When the origin neighbourhood equals the destination neighbourhood (*o*=*d*), the distance_{od} is taken to be half the square root of the neighbourhood surface, which approximates the distance between two random points in the neighbourhood (Ghosh, 1951). By definition, we set $\text{barrier}_{od}^{(i)} = 0$ when o=d, as our data are too crude to distinguish intra area trips in categories that pass or do not pass an intraneighbourhood barrier.

Figure 2.1 shows the location of barriers of the four types (urban highway, railroad line, parks, and canals) as present in The Hague. Notice that urban highway and railroad barriers are rather scarce, while canals and especially parks are quite common. Furthermore, some barriers are located on the borders of the city and the barriers seem to be somewhat clustered.

Analysis

The effects of physical barriers are examined by estimating a regression model for the log of crime trip intensity. The base model, the standard gravitational model, is compared with the base model including physical barrier indicator(s). The physical barrier indicators are added to the model to test whether the physical barrier has an influence on the journey-to-crime when controlling for push, pull, and geographical distance factors. This leads to the following model:

Model with barrier of type i (i = ‘any barrier’, highway, railroad, park, canal)

$$\ln(\#\text{crime trips}_{od}) = \beta_0 + \beta_1 \cdot \ln(\text{inflow}_d) + \beta_2 \cdot \ln(\text{outflow}_o) + \beta_3 \cdot \text{distance}_{od} + \beta_4^{(i)} \cdot \text{barrier}_{od}^{(i)}$$

We also examine whether the influence of physical barrier indicators is different for short and long distance by estimating the model separately for subsets of crime links with small and large o-d-distances.

The research questions then translate into the questions (for i = any barrier, highway, railroad, park, canal)

- are the $\beta_4^{(i)} = 0$ and if not, are these coefficients small (i.e. is explained variance with and without incorporating $\beta_4^{(i)}$ comparable)?
- are the $\beta_4^{(i)}$ different for different i ?
- are the $\beta_4^{(i)}$ larger in a subset of *o-d*-pairs that have small distances only?

Results

Descriptives

The occurrence of barriers is different for the various type of barriers. Canal and park barriers are present as a barrier between 61% of the neighbourhood pairs (i.e. the set of all o-d-links). A railroad is present between 20% of the neighbourhood pairs, followed by a highway which is present as a barrier between 11% of the neighbourhood pairs. In total, a barrier is present in 83% of the links between the neighbourhood pairs.

Correlation analysis between the separate barrier indicators shows a correlation of 0.42 between highway and railroad barriers (over the set of all o-d-links), which is a consequence of them only being present together at the south-east side of the city. This fact should be regarded when interpreting results of those barriers: they largely co-vary in the present dataset. Parks and canal barrier indicators are also rather substantially correlated (0.30). Distance is, as expected, rather highly correlated with the presence of a barrier (0.45 with parks, 0.43 with canals, 0.25 with highway, 0.16 with railroad). Correlation between barriers and push and pull factors is less prominent (all coefficients < 0.10). Descriptives of explanatory variables of the base model are given in table 3.0.

Table 3.0 Descriptives of explanatory variables in the model

	Minimum	Median	Mean	Maximum
Inflow	3.76	6.13	6.02	8.61
Outflow	-2.30	1.39	5.64	7.99
Distance	0.18	3.76	3.96	11.53
Total crime	-2.30	0.69	0.25	6.07

for the definition of variables, see main text

Regression analyses

Table 3.1 shows the results of the analysis for the presence of any barrier (highway, railroad, canal, park, or several of them). When the physical barrier indicator is inserted in the model over and above the push and pull factors and geographical distance, the influence of distance decreases slightly, as could be expected, given their substantive correlation. The barrier indicator takes over a small part of the influence of distance, and in the expected direction (the presence of a barrier mitigates criminal traffic); but the explained variance of the model remains the same as when only push, pull, and distance are included. This means there is no additional influence of the barrier indicator beyond that of distance, though the barrier seems to take over some of the influence of the distance.

Table 3.1 Influence of 'any physical barrier' indicator on the number of crime trips (standardized regression coefficients β)

	Base model	Base model plus 'any' physical barrier term
PUSH AND PULL FACTORS		
Inflow	0.32	0.32
Outflow	0.58	0.58
FRICTION FACTORS		
Geographical distance	-0.29	-0.26
Physical barrier ('any barrier')	-	-0.07
R^2	0.59	0.59
Δ R^2 (compared to the model without barrier term)	-	**0.00**
N	8836	8836

Note 1: all coefficients significant (< .001 two-sided)
Note 2: estimated standard errors of the β estimates are all smaller than 0.01 in both models
Note 3: no collinearity problems occur, all variance inflation factors are smaller than 2

Table 3.2 shows the strengths of various barrier effects in four different models in which the individual barrier indicators are added separately to the base model. In this way, it is possible to see which barrier indicator has the highest influence on crime trips. The results show that the barrier with the highest regression coefficient is the canal barrier, followed by the park and the railroad line. The influence of the highway is not significantly different from zero. Most interesting, however, is that models with barrier indicators do not explain more variance than the base model. It seems that introducing barrier variables only mitigates the influence of distance, which is seen as a reason to look in more depth into the effect of barriers on small and larger distances in the next section.

Table 3.2 Influence of individual physical barrier indicators on the number of crime trips (standardized regression coefficients β)

	Base model	Canal barrier	Railroad barrier	Park barrier	Highway barrier
PUSH AND PULL FACTORS					
Inflow	0.32	0.32	0.32	0.32	0.32
Outflow	0.58	0.58	0.58	0.58	0.58
FRICTION FACTORS					
Geographic distance	-0.29	-0.27	-0.28	-0.28	-0.28
Individual barrier indicator	-	**-0.05**	**-0.02**	**-0.03**	**ns**
R^2	0.59	0.59	0.59	0.59	0.59
Δ R^2 (compared to the model without a barrier term)	-	**0.00**	**0.00**	**0.00**	**0.00**
N	8836	8836	8836	8836	8836

Note 1: all coefficients significant (p < .001 two-sided)
Note 2: estimated standard errors of the β estimates are all smaller than 0.01 in all models
Note 3: no collinearity problems occur, all variance inflation factors are smaller than 2

"Any Barrier" Effect for Shorter and Longer Distances

The next analysis investigates the hypothesis that physical barriers have a stronger impact on short distances than on longer distances. Introduction of an interaction term in the regression equations did not result in considerable differences compared to the previous tables. This is unexpected, seeing that the main effect β-estimates for distance change in table 3.1 and 3.2 when the barrier indicators are incorporated. It may be the case that linear interaction terms do not pick up the relevant variance. For that reason, we also examined interaction by a different method. We selected only those origin-destination links that had a distance smaller than a given constant. We analysed four different cases[4]: very small distances only (< 500 m, N = 107), small distances only (< 1000 m, N = 452), smallest quartile of all distances only (< 2430 m, N = 2202), and smallest half of all distances only (< 3760 m, N = 4424). Of course, later subsets contain the earlier ones. We expect that when two neighbourhoods are far apart, crime flow will be close to zero due to the large distance, irrespective of a physical barrier, hence physical barriers will have a stronger influence (additional to distance) for the subsets with shorter distances only.

Table 3.3 shows the results for the any barrier indicator. It displays a very small amount of extra variance explained by the physical barrier indicator within the very short distance subset, but no effect for the larger distances subsets, compared to the base model. However, this small effect is an intricate composition of taking over (interaction) effects from the other regressors (inflow, outflow and distance itself) – some of them going up, others down – and the barrier coefficient itself is not significantly different from zero. The analyses also show that the models provide a better explained variance in short distances subsets than in the longer distances subsets.

Table 3.3 Influence of a physical barrier on the number of crime trips when adjusted distances are selected (standardized regression coefficients β)

	Distance 0 – 0.5 km (1% of all distances)		Distance 0 – 1 km (5% of all distances)		Distance 0 - 2.43 km (25% of all distances)		Distance 0 – 3.76 km (50% of all distances)	
	No barriers	With barriers	No barriers	With barriers	No barriers	With barriers	No barriers	With barriers
PUSH AND PULL FACTORS								
Inflow	0.24	0.29	0.27	0.29	0.32	0.33	0.31	0.31
Outflow	0.62	0.59	0.64	0.64	0.62	0.63	0.63	0.63
FRICTION FACTORS								
Geographic distance	-0.26	-0.24	-0.30	-0.30	-0.30	-0.29	-0.31	-0.31
Any physical barrier	-	**ns**	-	**ns**	-	**ns**	-	**ns**
R^2	0.76	0.77	0.74	0.74	0.69	0.69	0.64	0.64
ΔR^2 (compared to the model without barrier terms)	-	0.01	-	0.00	-	0.00	-	0.00
N	107	107	452	452	2202	2202	4424	4424

Note 1: all remaining coefficients significant (p < .001 two-sided)
Note 2: estimated standard errors of the β estimates are all smaller than 0.01 in all models
Note 3: no collinearity problems occur, all variance inflation factors are smaller than 2

[4] Peeters (2007) also investigates cases where very short distances are left out, e.g. the links in which o and d are identical, as well as cases where very weak crime links (less than 100 criminal trips between o and d) are left out. These analyses do not produce different results.

We the repeated the previous analysis for the separate barrier variables, adding all individual barrier indicators to the base model together. Table 3.4 shows that the various barriers have different influences on short and longer distances subsets. Additional explained variance of the barrier indicators at the 500 meters subset is a substantial 4% where the railroad and canal barrier have substantial coefficients. Push and pull regression coefficient do increase in the two shorter distance subsets, indicating interaction of these influences with the presence or absence of barriers. In the longer distances subsets, the additional explained variance of the barriers decreases to a 1%. Only the canal barrier is significant in all analyses.

Table 3.4 Influence of various physical barriers on the number of crime trips when adjusted distances are selected (standardized regression coefficients β)

	Distance 0 – 0.5 km (1%)		Distance 0 – 1 km (5%)		Distance 0 - 2.43 km (25%)		Distance 0 – 3.76 km (50%)	
	no barrier	barrier	no barrier	barrier	no barrier	barrier	no barrier	barrier
PUSH AND PULL FACTORS								
Inflow	0.24	0.30	0.27	0.30	0.32	0.33	0.31	0.31
Outflow	0.62	0.64	0.64	0.64	0.62	0.63	0.63	0.63
FRICTION FACTORS								
Geographic distance	-0.26	-0.22	-0.30	-0.29	-0.30	-0.28	-0.31	-0.30
Canal	-	**-0.16**	**-**	**-0.08**	**-**	**-0.05**	**-**	**-0.05**
Park	-	**ns**	**-**	**ns**	**-**	**ns**	**-**	**ns**
Railroad line	-	**-0.19**	**-**	**-0.11**	**-**	**ns**	**-**	**ns**
Highway	-	**ns**	**-**	**ns**	**-**	**-0.08**	**-**	**-0.05**
R^2	0.76	0.80	0.74	0.75	0.69	0.70	0.64	0.65
ΔR^2 (compared to the model without barrier terms)	-	0.04	-	0.01	-	0.01	-	0.01
N	107	107	452	452	2202	2202	4424	4424

Note 1: all remaining coefficients significant ($p < .001$ two-sided)
Note 2: estimated standard errors of the β estimates are all smaller than 0.01 in all models
Note 3: no collinearity problems occur, all variance inflation factors are smaller than 2

Discussion

To examine the influence of physical barriers on the intensity of crime trips between origin and destination neighbourhoods in The Hague, the Netherlands, we estimated gravitational models. Each of the models produced only a small or even absent influence of various barriers on crime trip intensity. Our results are therefore more in line with Ratcliffe (2001) than with Clare and colleagues (2009) and the studies of Greenberg and colleagues (1982, 1984). Small size influences are not unexpected in our study area due to the relative high permeability of the The Hague barriers when compared to the Perth-study of Clare and colleagues (2009), and are also in line with the relative small effects found by Reynald and colleagues (2008) in their study on the influence of social barriers in The Hague.

Barriers of various types have been shown here to have different strength of influence; but the small amount of the total influence makes this result not very helpful. However, the effect as such may be interpreted as an incentive to apply the same method in a city where both formidable barriers and rather permeable barriers are present, such as in Amsterdam. This city has a large river right through the city, with few crossing facilities on the one hand, and a variety of parks, canals, railroads, and highways on the other. This effect makes it understandable that Clare and colleagues (2009) found much stronger effects in Perth with its rather impermeable river barrier. Moreover, as we observed, the distribution of barriers over the study area in The Hague is rather skewed (railroad and highway barriers rather highly concentrated), which may have influenced their impact overall. Future research should try to find a study area in which barriers are rather uniformly distributed over the area.

There is an indication that barriers are slightly more important on short distances, but this has to be qualified. An interesting result here is the regularly observed interaction between barrier effects and the traditional elements in gravity models (especially the pull factor and geographical distance factor) when analyzing origin-destination pairs on short distance only. Introducing a barrier indicator in the model gives, for those short distance cases, a significant barrier effect; while at the same time the effect of inflow, outflow, or distance factors increases or decreases. This result indicates that the influence of barriers is not invariant over a geographical area, and their impact may be different on strong crime links than on weak one. Moreover, we observe that the strength of separate barrier effects is largest on short distances (with strong crime links generally). We may interpret this result as a need for a better understanding of crime links on a micro scale. Looking into crime origins and destinations on a less crude scale than we have done here in terms of neighbourhood centroids may be worthwhile, therefore. It may be advisable to replicate the research with actual coordinates of origin and destination of individual crime trips. Such an improvement, which is within reach in principle with present day GIS methodology, would also make it possible to zoom in on intra origin area crime trips and whether they did have to face a barrier or not. Of course, a better operationalization of barriers in terms of additional distance having to be covered for a given crime would be possible then as well (at least for barriers to be circumvented; for permeable barriers that are passed through, this solution would not work).

Notice that our models work with a rather crude operationalization of the push and pull factors, which are the total outflow and inflow of crime (Elffers et al., 2008). In a sense, we thus have conditioned on overall observed attraction and production of offenders. It could be advisable to introduce more content-oriented submodels for the attraction of an area (such as those of Bernasco and Nieuwbeerta, 2005) as well as for production of motivated offenders in an origin area (in terms of demographics and other socio-economic factors).

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