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SUBWAY SLUGS

Tracking Displacement on the London Underground

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Ticket vending machines, installed throughout the London Underground at the end of the 1980s, proved vulnerable to easily-made 50p slugs and had to be modified. Subsequent analysis of the distribution of slug use suggested that, while ordinary passengers and delinquents might have been responsible for the bulk of the problem, several groups of organized offenders had been systematically obtaining large sums of money from the machines at distinct clusters of stations. These offenders therefore seemed to be the likely culprits when £1 slugs, which were much more difficult to make, began to appear soon after the 50p slugs were stopped. Because the same clusters of stations were not affected by the £1 slugs, however, it was concluded that these slugs would have appeared anyway and were not simply the result of displacement. While the remedial measures introduced by the Underground were highly effective, the problem of slug use could have been anticipated at the design stage and might have been prevented by a greater initial investment in the machines.

Soon after new ticket vending machines were introduced on the London Underground in 1987, users discovered that the machines could not distinguish between genuine 50p coins and slugs made by wrapping 10p coins in silver foil. This made it possible to travel for a fraction of the correct fare. Worse from the point of view of the Underground was that users also found that when the coin reject button was pushed, the machines would deliver back, not the foil-wrapped slug, but a genuine 50p coin. It was possible therefore not only to travel on the cheap, but also to milk the machines of cash.

Use of the slugs quickly became widespread throughout the system and, by May 1991, when London Underground Ltd (LUL) decided to modify the ticket machines so that they could no longer accept 50p coins, the slugs were costing the Underground many thousands of £s per month.[1] Apart from the costs of modification (estimated at about £135,000), the remedial measures raised staffing costs because more passengers, who could not use 50p coins in the machines, had to purchase their tickets at booking offices.[2]

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[1] The number of foil-wrapped 10p coins collected in May 1991 was 93,466. It is conservatively estimated in the body of the paper that about one quarter of the slugs collected were deposited by organized groups of offenders systematically milking the machines of 50p coins. On this basis (and subtracting the value of each slug, i.e., 10p), thefts from the machines cost LUL approaching £10,000 in May 1991 alone. Assuming that most of the remaining slug use was by passengers evading payment for journeys they would have taken anyway (rather than taken simply because they could avoid paying the full fare), the cost in lost revenues to LUL in May 1991 may have been as much as a further £30,000.

[2] Analysis of ticket sales for the first complete week of 1991 (beginning Sunday, 5 January 1991) found that 52 per cent of all tickets issued for the system in that week were sold through vending machines; in the corresponding week for 1992 (i.e., after the ticket machines had been modified so that they could no longer accept 50p coins) this proportion had dropped to 45 per cent, indicating a significant additional workload for booking offices.

The measures were also believed by LUL to have displaced, rather than cured, the problem because no sooner was the 50p fraud stopped than a new form of £1 slug began to appear. Thus, an LUL manager was quoted in a local newspaper story entitled, 'Crooks keep a step ahead', as claiming that, 'no sooner had he stalled the smaller scam than the bigger rip-off took over' (*The South London Press*, 18 June 1991).

There might seem little reason to resist the implication that the preventive measures were a waste of effort, but it is possible that, despite the timing of their introduction, the £1 slugs might have appeared independently of any measures directed at the 50p slugs. The empirical literature has shown that crime is rather easily prevented by increasing its attendant risks and difficulties and that displacement is not inevitable (Barr and Pease 1990; Gabor 1990; Clarke 1992). Consistent with this, the only previous study of slug use showed that when parking meters in certain parts of New York were modified to prevent use of slugs, there was little displacement to nearby areas (Decker 1972). Differences in the nature of the 50p and £1 slug make it all the more unlikely that the present case would prove an exception. The 50p slugs could be made by any schoolchild since all that was needed was a 10p coin and some aluminium foil. The £1 slugs, of which there were two main kinds, were a different matter. These had to be made either by casting lead counterfeits in crude moulds, or by filling metal piping of the same diameter as the £1 coin with solder and then cutting the pipes into coin-sized slices. In neither case were the £1 slugs particularly sophisticated, but they required more skill and equipment than most adults, let alone schoolchildren, could readily muster.

With the agreement of LUL, a study was therefore undertaken to examine the nature and extent of displacement following the modifications made to the ticket machines. The study made use of monthly counts of 50p slugs collected at 243[3] stations of the London Underground from April 1990 until July 1991 (by which time all of the 900 ticket machines had been modified), and counts of £1 slugs from April 1991 until February 1992.

Procedure

Two main assumptions governed the conduct of the study. First, it was assumed that, in principle, two distinct forms of displacement ought to be detectable as a result of modifying the machines to prevent the use of the 50p slugs:

1. some geographical displacement of the 50p slugs from stations where machines were modified earlier in the programme of modifications to those modified later and,
2. a shift from 50p to £1 slugs following the completion of the modifications.

Secondly, it was assumed that the slugs were used by distinct groups of offenders who would differ in the strength of their motivation and, therefore, in the degree to which their fraudulent activities might either be stopped or displaced. Following discussion with LUL officials, four such groups were identified:

[3] The number of stations served by the London Underground is 271 (see Fig. 1 for a plan of the system). For 24 of these stations managed by British Rail no counts were available of slugs collected and these stations were excluded from the study. A further three stations (Edgware Road, Hammersmith, and Shepherd's Bush) serving the Metropolitan line as well as other lines are treated by LUL as consisting of two stations each, but were combined for the purpose of this study. Finally, Mansion House, which for much of the period was closed for renovations, was not included.

1. schoolchildren and other regular travellers occasionally 'saving' themselves travel money;
2. delinquents and vagrants milking machines in their localities for cash;
3. thefts by 'organized' groups of offenders;
4. thefts by booking office clerks by substituting slugs for 50p coins when servicing the automatic ticket machines.

These characterizations of the groups involved suggest that most were responding to the tempting and easy opportunities presented by the ticket machines and that only the third group, the organized offenders, would be motivated enough to find a way round LUL's preventive measures and might thus be principally responsible for both kinds of displacement identified above. Of the other groups, few regular travellers would be likely to seek out stations where they could continue to use the 50p slugs because of the additional delay to their journeys. They would also be unlikely to manufacture more elaborate counterfeits, since this is a much more serious offence than simply wrapping low-value coins in foil. Vagrants and delinquents milking the machines for ready cash might exhibit more displacement, but empirical studies have shown that most offenders do not generally travel far (Brantingham and Brantingham 1984). In addition, because of the difficulties involved, these groups of offenders would be unlikely to make more elaborate slugs of the £1 variety. Booking office clerks would be most unlikely to attempt a transfer to stations where the machines still accepted 50p coins because of the comparatively small financial rewards involved. Nor would they be likely to risk bringing themselves under suspicion by using a new kind of slug until these had already become commonplace.

This line of reasoning suggested that, unless organized offenders were accounting for a large proportion of the 50p frauds, displacement following modification of the ticket machines is unlikely to have been extensive. The first step in the analysis therefore consisted of an analysis of the 50p slug use prior to preventive action being taken, with the purpose of establishing what proportion of the 50p slug use represented the activities of organized offenders, and where these activities were concentrated in the system. In the second stage of the analysis, evidence of displacement was sought by examining the patterns of 50p and £1 slug use that existed after the vending machines had been modified. Before presenting these two stages of analysis, however, the general features of slug use are discussed.

General Features of Slug Use

The rapid growth in the use of 50p slugs is apparent from Table 1: between May 1990 and May 1991 slugs increased more than fivefold from 17,066 to 93,404.[4] All lines were affected to a greater or lesser degree and by May 1991, only five stations in the system (all small ones in the outer suburbs) had reported no slug use. The five stations with the largest numbers of 50p slugs reported between May 1990 and May 1991 were: Victoria (35,499), Oxford Circus (26,098), Piccadilly Circus (22,432), South Kensington (14,389) and Plaistow (12,998). With the exception of the last, these are some of the largest and busiest stations on the system.

[4] While unusually detailed, the data set has the important limitation that counts of slugs at individual stations were not made until the 50p slugs had become a significant problem for LUL. This made it impossible to study the development and spread of the problem.

TABLE 1 *Slugs collected*[a] *at 243 London Underground Stations, May 1990–February 1992*

Month[b]	50p	£1
May 1990	17,066	
June	28,929	
July	30,868	
August	38,230	
September	48,402	
October	50,092	
November	50,396	
December	63,074	
January 1991	56,791	
February	66,566	
March	70,983	
April	75,463	73
May	93,404	135
June	67,232	525
July	11,289	246
August	741	1,258
September		2,248
October		910
November		1,031
December 1991/January 1992[c]		3,256
February 1992		1,616
Totals	769,526	11,298

[a] In some cases, slugs were handed over to the police for investigation and were included in station counts only when returned.
[b] Counting periods did not coincide exactly with calendar months nor cover an identical number of days for each period.
[c] Slug counts for these months were combined.

Following modification of the machines which took about a month beginning in the early part of June 1991, there was a rapid decline in the use of 50p slugs. No more of these were turned into the central collection agency after August. The £1 slugs began to appear in small numbers a few months before the ticket machines were modified to prevent use of the 50p slugs. When records began in April 1991, 73 £1 slugs were collected from machines at 13 stations scattered throughout the system. This dispersion, together with the fact that the slugs were not of a uniform pattern, suggests that they were not introduced by a particular criminal gang, but by a number of individuals who had separately made or acquired slugs. Following modification of the machines to prevent the use of the 50p slugs, the use of £1 slugs expanded quite rapidly. However, even nine months after their first appearance, they still constituted only a small fraction of the numbers of 50p slugs at their height.

Patterns of 50p Slug Use Prior to Preventive Action

That £1 slugs appeared in large numbers only after the machines were modified is indicative of displacement, but the fact that they were used on a much smaller scale than the 50p slugs also suggests that displacement was at best modest. More precise conclusions concerning displacement required information about the proportionate

contribution to the problem of each of the four groups of likely slug users. For reasons explained below, this in turn required information about: (i) the correlation between station counts of passengers and slugs; (ii) the fit between station counts of slug usage and concentrations of delinquent and homeless populations; (iii) the existence of clusters of adjacent stations with high rates of slug use (indicating the activities of organized offenders); and (iv) the existence of isolated stations with high rates of slug use (possibly indicating thefts by booking office clerks).

Correlation between slug use and passengers per station

If regular travellers were responsible for a significant proportion of the 50p slugs, there ought to be a correlation between the number of slugs collected and the number of passengers using each station. Some stations, such as those serving more affluent commuters likely to be using season tickets, and those serving large numbers of visitors to the capital (e.g., Heathrow) would be less likely to be affected.

Regression analysis showed a strong relationship between counts of 50p slugs collected at each station between May 1990 and May 1991 and the numbers of passengers served[5] ($R^2=0.68$), suggesting that the use of 50p slugs was quite widespread among London Underground passengers and not simply confined to a 'criminal' few. A further implication was that, in identifying high risk stations, it would be important to control for passenger use. With this aim, the results of the regression analysis were used to predict the numbers of 50p slugs at each station on the basis of the estimated numbers of passengers using each station. 'Residuals' were then calculated by subtracting predicted from actual slug counts, and station rankings for the extent of slug usage were determined by calculating the residual as a percentage of these predicted values. The procedure is illustrated by the figures in Table 2 which show the five most affected stations as determined by this procedure.

TABLE 2 *Five London Underground Stations Most Severely Affected by 50p Slug Use, May 1990–May 1991*

Station	Actual number of slugs	Predicted number of slugs	Residual	Residual as percentage of predicted	Rank[a] for slug use
Plaistow	12,998	2,594	10,404	401	243
Dollis Hill	5,743	1,347	4,396	326	242
Willesden Green	10,109	2,411	7,698	319	241
Becontree	4,594	1,237	3,357	271	240
West Ham	4,085	1,200	2,885	240	239

[a] The least affected station in the study ranked 1; the most affected ranked 243.

A longer list of the most affected stations was established by inspecting the size and distribution of the residuals. Fifty-eight stations, or just under one quarter of the 243 studied, had *residuals which were more than 25 per cent greater than their predicted slug use* and this group was defined as those most severely affected by slug use. These stations, which

[5] LUL estimates (in millions) for spring 1990 of the annual two-way passenger throughput (i.e., passengers entering and leaving) for each station.

included many of the smaller ones, accounted between them for 394,876 slugs, or 51.3 per cent of those collected on the system.

The analyses below concentrate upon the 58 most severely affected stations (ranked 186th to 243rd), but it should be noted that, as predicted, stations in the outer suburbs (particularly those in the West and North-West of London) were heavily clustered in the least affected quartile of stations. Also as predicted, Heathrow 123 and Heathrow 4, with many tourists and other visitors to London, fell into the least affected quartile (respectively ranked 38th and 53rd).

Slug use in delinquent areas and at stations frequented by the homeless

If delinquents and vagrants requiring ready cash were heavily involved in milking the machines, stations in 'delinquent areas' or frequented by homeless people should have higher rates of 50p slug usage. While it might have been possible to use police arrest statistics to develop measures of the delinquency of areas surrounding each station, the effort involved seemed disproportionate to the likely value of results. Instead, it was hypothesized that, if delinquents were major contributors to the problem, the distribution of slug use on the Underground should follow the familiar 'concentric zone' pattern of delinquency in large cities first observed by Shaw and McKay (1942) in Chicago.[6] In other words, slug use should be greatest in the zone surrounding the central part of the city and should decrease with increasing distance from the centre. The central zone should show intermediate levels of slug use.

The fact that the London Underground is divided into concentric fare zones (with zone 1 constituting the stations in the inner city and zone 5 constituting the stations of the outlying suburbs) greatly facilitated testing of this hypothesis. It can be seen from Table 3, which shows the number of 50p slugs collected per 100,000 passengers for

TABLE 3 *50p Slug Use on London Underground Fare Zones, May 1990–May 1991*

Fare zone	No. of stations	No. of 50p slugs per 100,000 passengers
1	61	40.5
2	59	70.8
3	33	55.0
4	33	38.2
5	57	29.8

zones 1–5, that the pattern of slug use conforms to prediction. Thus, zone 2 had the highest rate of slug use (70.8 per 100,000 passengers) and zone 5 the lowest (29.8 per 100,000). These results are consistent with the hypothesis that delinquents made a substantial contribution to the problem of 50p slug use on the London Underground.

Counts of homeless people frequenting London Underground stations are not available and other means had to be employed of identifying the stations most used by

[6] Less evidence has been found in British cities of concentric zones of delinquency, largely because post-World War II slum clearance schemes have had a profound effect on the distribution of delinquency (Baldwin 1979).

the homeless. Information was sought from a Westminster Hospital team studying 'persons under trains' on the London Underground (Farmer *et al.* 1991) about the proportion of such incidents at each station involving persons 'of no fixed abode'. In seeking this information it was assumed that stations with a significant number of such reports would be among those with the largest numbers of homeless people. The list of these stations was augmented through discussions with the British Transport Police (London Underground Division), who have considerable experience in dealing with homeless people, to produce a list of ten stations (Camden Town, Embankment, Euston, King's Cross/St Pancras, Leicester Square, Paddington, Tottenham Court Road, Tooting Broadway, Victoria, and Waterloo) judged by the Westminster Hospital team and the British Transport Police to have the greatest concentrations of homeless people.[7]

Though many of these stations show relatively high levels of slug use, only two (Camden Town and Victoria) fell within the top quartile of 58 stations defined as the most severely affected—a result no different from chance. Moreover, one of these two, Victoria, belonged to a cluster of stations on the Victoria line that appeared to have been prey to a group of offenders centred on Brixton (see below), while the other, Camden Town, was found to be one of the stations most affected by the £1 slugs (see below), which were thought to be beyond the resources of most homeless people to manufacture or acquire. On the basis of this analysis, therefore, it seems unlikely that homeless people as a group contributed significantly to the 50p slug problem.

Concentration of slug use at clusters of stations

If organized offenders were systematically stealing large sums of cash from the machines, they are likely to have operated at not just one station, but at a cluster of adjacent stations. On any one day, having emptied a particular station's machines of 50p coins they are likely to have moved on to do the same at a nearby station. In addition, by dispersing their activities over a number of stations, sometimes operating at one and sometimes at another, they are likely to have reduced the risk of attracting attention from station staff and the consequent risk of apprehension.

That many of the severely affected stations might indeed fall into such clusters is suggested by the list of the five most severely affected stations in Table 2. Thus, Plaistow, West Ham, and Becontree are stations on the same part of the District line in the East End of London and might form part of a larger cluster; similarly, Dollis Hill and Willesden Green are adjacent stations on the Jubilee line in North-West London and might also belong to a larger cluster (see Fig. 1).

In order to identify any such clusters, the positions on the London Underground route map were plotted of the 58 most severely affected stations. Inspection of the resulting plot suggested that there were several clusters (defined as a minimum of three adjacent 'severely affected' stations, either on a single line or on two lines served by a single interchange station). There also seemed to be some larger clusters which included one or two stations falling outside the severely affected group. Presumably

[7] Embankment and Waterloo are close to 'Cardboard City' (so-called because of the cardboard shelters constructed by the homeless) which is under Waterloo Bridge, while many of the stations (Euston, King's Cross/St Pancras, Paddington, Victoria, and Waterloo) are also major British Rail termini. This means there are large station concourses at ground level with snack bars and off-licences and plenty of room for vagrants to wander and congregate.

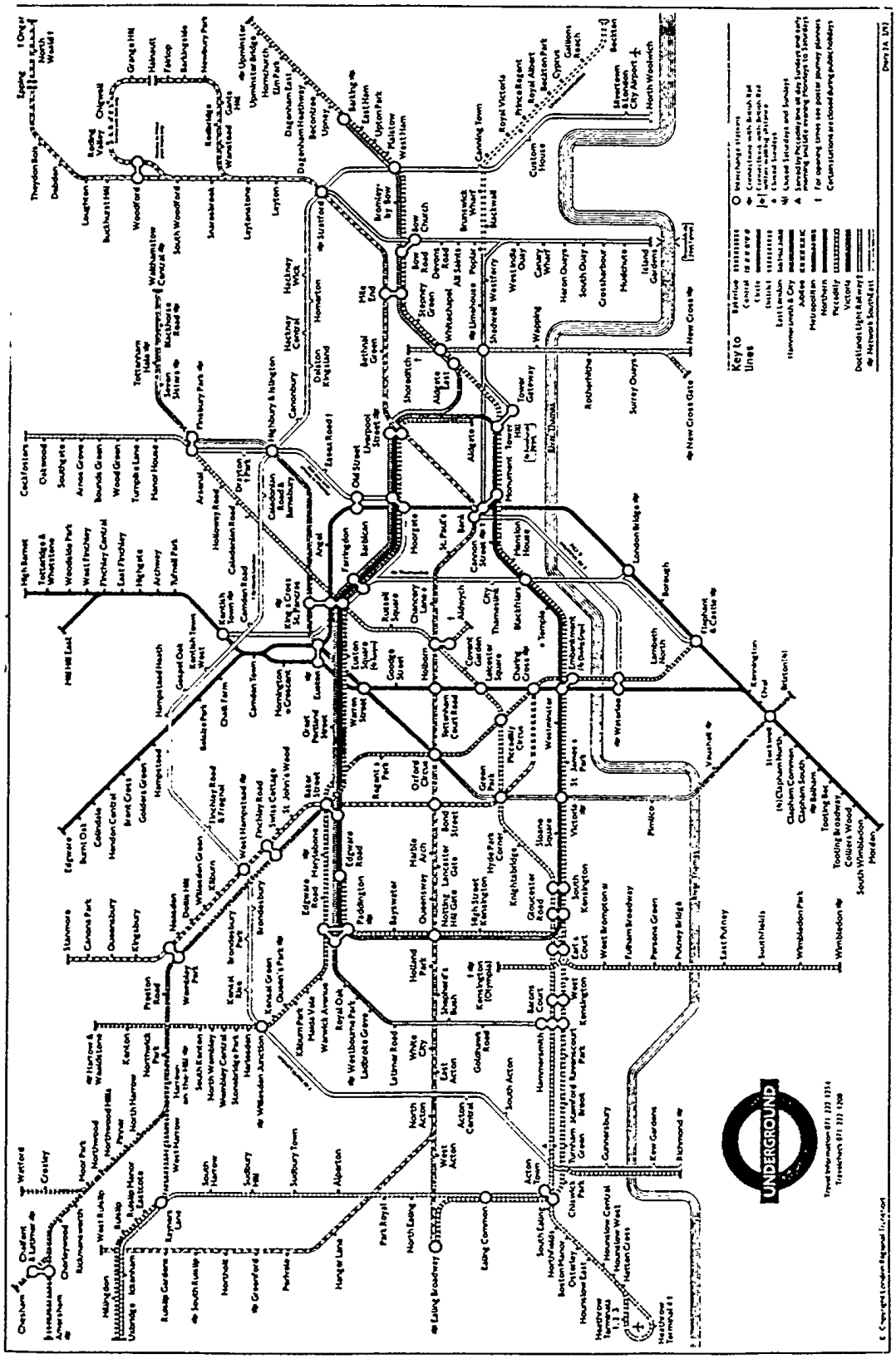

FIG. 1 Plan of the London Underground system

these unaffected stations, due to their design or vigilant staff, did not afford the same opportunities to feed the ticket machines with slugs.

The main danger of identifying clusters by inspection of the plots of stations on the London Underground route map is that stations at the extremes of clusters might have been included in that cluster when they should not have been. Further analysis designed to exclude this possibility was therefore undertaken of the clusters identified by inspection. Stations at the extremities of clusters were included only if they met one of two conditions: (1) they fell within the top 58 severely affected stations, or (2) their monthly counts of slugs were highly correlated with those of the other stations in the cluster. Whether a station met the latter criterion for inclusion involved some judgement and depended on the actual value of the Spearman correlation (it had to be greater than 0.22, which was the mean intercorrelation for all stations in the sample) and also had to be close to the average intercorrelation for the stations in the cluster under consideration.

On the basis of this procedure (see data for the illustrative cluster in Table 4) seven clusters were identified (see Table 5), which between them accounted for 47 of the 58 severely affected stations.[8]

TABLE 4 *Possible Cluster of Stations in East End of London Severely Affected by 50p Slug Use*

Station	Rank for slug use	Residual	Total 50p slugs	Mean Spearman coefficient	Included in final cluster
Dagenham Heathway	221	1,528	3,242	0.35	Yes
Becontree	240	3,357	4,594	0.43	Yes
Upney	216	868	1,958	0.30	Yes
East Ham	215	2,882	6,540	0.29	Yes
Upton Park	210	1,980	4,611	0.47	Yes
Plaistow	243	10,404	12,998	0.52	Yes
West Ham	239	2,885	4,085	0.43	Yes
Bromley-By-Bow	190	480	1,937	0.41	Yes
Bow Road	231	2,298	3,718	0.52	Yes
Mile End	159	−315	3,050	0.33	No
Stepney Green	204	849	2,196	0.19	No
Whitechapel	167	−65	2,896	0.12	No
Aldgate East	186	987	4,792	0.14	No
Shoreditch	225	591	1,094	−0.23	No

High slug use at individual stations

Thefts by booking office clerks would be likely to occur only at stations already affected by routine use of slugs, because individual clerks (unless they were in league with their colleagues) would otherwise run a risk in reporting such 'discoveries'. Thefts by clerks

[8] The probable centre of each cluster was identified by examining three factors relating to each station: the rank for slug use, the size of the residual (i.e., actual minus predicted slug use) and the mean Spearman correlation of that station's monthly slug counts with the remaining stations in the cluster. These factors were subjectively weighted to produce a judgement about the probable centre of the cluster. For example, Plaistow was selected as the probable centre of Cluster 1, because it had the highest rank, the largest residual and the joint largest mean Spearman of the nine stations included in the final cluster (see Table 4).

TABLE 5 *Clusters of London Underground Stations Severely Affected by 50p Slug Use, May 1990–May 1991*

Cluster	No. of stations	Severely affected stations	Mean intercorrelation	Mean rank	Total 50p slugs	Total minus predicted	Geographical area	Line	Probable centre
Bow Road to Dagenham Heathway	9	9	0.61	222.8	43,683	26,682	E. London	District	Plaistow
Baker Street to Kingsbury	11	11	0.42	217.1	58,975	30,622	N.W. London	Jubilee	Willesden Green/ Dollis Hill
South Kensington to Barons Court and Fulham Broadway	7	7	0.35	211.0	50,375	23,229	W. London	District	West Kensington
Victoria to Brixton (+Oval)	6	5	0.58	199.7	65,681	20,072	S.E. London	Victoria	Brixton
Hammersmith to Euston Square	12	9	0.51	199.6	79,273	31,821	W. London	Metropolitan	Shepherd's Bush
Baker Street to Kilburn Park and Notting Hill Gate	9	7	0.33	198.6	54,808	19,905	W. London	Bakerloo/Circle	Edgware Road
Arsenal to Turnpike Lane (+Seven Sisters)	5	4	0.80	190.2	26,180	7,340	N.E. London	Piccadilly	Manor House

are therefore likely to have been masked by those committed by the public and it was thought that the best chance of detecting such thefts would be to concentrate on the ten out of the 58 severely affected stations that did not form part of a larger cluster and which might, therefore, have been stations where booking clerks were exchanging slugs for coins on emptying the ticket machines.

Two tests were undertaken on these ten stations (Northfields, Golders Green, Camden Town, Marble Arch, Oxford Circus, Piccadilly Circus, Covent Garden, Shoreditch, Stepney Green, and Aldgate East), both of which would need to be satisfied before this speculation could be seriously entertained: (1) unusually large increases in the use of 50p slugs should be observed at the station in the month (May 1991) immediately preceding the modifications as a result of clerks learning that ticket machines were scheduled for modification; and (2) no evidence should be found of displacement of 50p slug use to immediately adjacent stations in the month (June 1991) following modification of the ticket machines.

Only one of the ten stations met both these tests. So as not to reveal its identity, event data are shown in Table 6 for this station (A) and the three[9] immediately adjacent stations (B–D). It will be seen that there was a substantial increase in slugs collected in May 1991 at station A, with no evidence of compensatory displacement to the adjacent stations in June. While this pattern is consistent with fraud by booking office clerks at

TABLE 6 *An Isolated Station Severely Affected by 50p Slug use (Station A) and Immediately Adjacent Stations (Stations B–D)*

1991	Number of slugs			
	Station A	*Station B*	*Station C*	*Station D*
January	219	174	54	45
February	754	120	59	0
March	708	0	1	242
April	925	325	0	213
May	1,584	160	95	160
June	545	100	70	84

station A, it is by no means proof of such fraud. It could be a chance effect and it could also reflect organized theft of a less usual pattern (not only booking clerks might learn of modifications to machines elsewhere in the system).

In none of the other nine cases was the pattern of slug use consistent with fraud by booking office clerks and it must be concluded that little evidence was found in this study that fraud by booking office clerks contributed to the scale of the 50p slug problem.

Conclusion to the first stage of analysis

The main purpose of the analysis reported above was to establish the contribution to the overall problem of slug use made by organized groups of offenders, systematically plundering the machines. These would be the people most motivated to find ways of

[9] Station A serves an intersection.

circumventing the preventive measures. Such an estimate (admittedly crude) can be derived by summing the figures in column 6 of Table 5, which gives the total number of slugs collected in the seven clusters of severely affected stations, minus the number expected on the basis of total passenger throughput. This produces a figure of 159,671, or just over 23 per cent of the 690,264 slugs collected on the entire system between May 1990 and May 1991.

Extent of Displacement

In six of the clusters in Table 5, the groups operating were feeding the machines with an average of about 2,000 slugs per month, more in later months. Assuming that the vast majority of these slugs were being used to obtain cash rather than to travel, and subtracting the value of the 10p coins needed to make the slugs, it can be calculated that each group was netting about £200 per week. There would be considerable incentive to safeguard this amount of income and therefore a considerable likelihood of displacement.

Following modification of the ticket machines at the severely affected clusters of stations, two patterns of displacement should therefore result:[10] (1) some temporary geographical displacement of 50p slug use to nearby stations where ticket machines had not yet been modified, and (2) the substitution of £1 slugs at the original clusters of stations.

Geographical displacement of 50p slugs to other stations

A combination of circumstances made it difficult to track displacement of the use of the 50p slugs as the ticket machines were modified. First, it was not known precisely when a particular station's machines were altered. According to LUL, most of the machines were modified during June, although ones at a handful of the most severely affected stations seem to have been modified earlier (at the end of April/beginning of May) and those at some other stations do not seem to have been modified until July. Secondly, there were often large monthly variations in station slug counts (some of which were due to the need for police to keep slugs temporarily for investigation), which means that a recorded increase in slugs at a particular station following the modification of ticket machines at a nearby station would not necessarily be evidence of displacement. This problem of interpretation was exacerbated by the fact that slug counts were generally increasing at the time of the intervention.

Even so, there seems little doubt that some geographical displacement of 50p slug use occurred. Though numbers of slugs collected at the majority of stations declined in June, there were 96 stations where they increased. Only 11 of these stations were among the most severely affected group of 58, suggesting that the ticket machines at many of the most severely affected group of stations had been targeted for early modification. In general, stations showing increases in June were more likely to be the more distant suburban ones of zones 4 and 5, rather than those of zones 1–3: 47 per cent of zone 4 and 5 stations showed an increase in June compared with 35 per cent of the rest.

[10] The authors do not know whether the 50p slugs could be used in other vending machines not belonging to LUL; if so, there might have been some displacement to these other machines.

Some of these outer zone stations fell into clusters that were quite close to some of the severely affected clusters in Table 5, suggesting that the increases might be due directly to displacement from these clusters. The clearest example of this[11] was found in East London, where a cluster of 19 stations on the Central line (Leyton to Epping) showed large increases in slug counts immediately following modification of ticket machines at Upton Park, Plaistow, West Ham and Bromley-by-Bow. The machines at these four stations, which formed part of Cluster 1, appear to have been modified at the end of April. This was some weeks before the remaining stations in the cluster, but there is little evidence of displacement to these five stations in May or June (see Table 7). However, there was a very substantial increase in May and June in slugs collected in the Central line cluster of 19 stations, with a total of about 6,600 slugs collected at these stations, compared with less than a third of that number in March/April. Timing suggests that this increase was due to displacement and was not the result of a new criminal group coming on the scene. Though substantial, the increase is only about 60 per cent of that which would have occurred had displacement from Cluster 1 been complete (in April and May, a total of 7,200 slugs was collected at Upton Park, Plaistow, West Ham, and Bromley-by-Bow).

TABLE 7 *50p Slug Use at Three Nearby Groups of Stations in the East End of London, January 1991–August 1991*

Stations	No. of stations	Jan.	Feb.	March	April	May	June	July	Aug.
Upton Park to Bromley-by-Bow (District Line)	4	2,915	2,916	3,300	3,900	116	22	0	0
Other stations in severely affected District Line cluster	5	3,148	2,405	2,637	1,956	2,028	2,690	139	0
'Displacement' stations on Central Line (Leyton to Theydon Bois)	19	542	1,310	917	1,226	3,209	3,408	1,153	153

Clusters of stations affected by £1 slugs

Even if the organized offenders would be those most likely to switch to the £1 slugs, not all of them would find ways of obtaining or making the new slugs at the same rate and it might be some time before they could resume their fraudulent activities. Indeed, it is apparent from Table 1 that even nine months after the first appearance of the £1 slugs these were still being used at a small fraction of the rate of use of 50p slugs at their height.

This fact is reflected in the numbers of stations that met the criterion for being severely affected by the use of £1 slugs, i.e., whose residuals were more than 25 per cent greater than their predicted use of slugs.[12] Only 29 stations, or just under one eighth of

[11] Another example is that seven out of a group of nine stations on the Metropolitan line (Northwick Park to Rickmansworth) just north of the cluster of severely affected stations on the Jubilee line centred on Willesden and Dollis Hill (Cluster 2) registered gains in June, whereas there was a decline in Cluster 2. A similar pattern was observed for a group of stations on the Central and Piccadilly lines north-west of Cluster 5, centred on Shepherds Bush.

[12] Residuals were calculated as before on the basis of a simple regression analysis.

the 243 studied (accounting between them for 5,681 slugs, or 50.3 per cent of the £1 slugs collected on the system), met this criterion compared with the 58 stations that met the same criterion for the 50p problem.

A plot of these 29 stations on the London Underground route map revealed that only 12 of them (Camden Town, Edgware Road, Earl's Court, Euston Square, Fulham Broadway, Kilburn, Kilburn Park, Manor House, South Kensington, West Ham, West Hampstead, and Upton Park) were stations also severely affected by the 50p slugs. All but one of these 12 fell into one of the seven clusters identified in Table 1. All but one of the remaining stations severely affected by the £1 slug constitute what seems to be an extended cluster of 16 stations on the Northern line, beginning at East Finchley and continuing down the line's east and west branches until, respectively, London Bridge and Leicester Square. (This cluster appears to include two stations not on the Northern Line, Highbury and Islington and Liverpool Street). Only one of these 16 stations, Camden Town, fell into the group of the 58 stations most affected by the 50p slugs.

Spearman correlations could not be reliably computed in an attempt to establish the boundaries of the cluster because there were so many months for many of the stations when no £1 slugs were collected. However, detailed examination of the pattern of slug use suggested (but did not establish) that the one large cluster might in fact be comprised of two distinct poles—a northern one (consisting of East Finchley, Highgate, Archway, and Tufnell Park) and a southern one (consisting of Liverpool Street, Moorgate, Bank, and London Bridge)—prey to two separate groups of offenders, who might both stray into the in-between stations on the Northern line. The £1 slugs first began to appear in large numbers in the northern pole during August 1991, which was about a month earlier than in the southern pole. The northern pole was also more severely affected. The mean rank of its four stations was 239.5 and the number of slugs collected in excess of predicted was 2,155. For the four stations of the southern pole the comparable figures were 221 and 432.

In sum, many fewer stations were severely affected by the £1 slugs and there was only limited overlap between these stations and those severely affected by the 50p slugs. Moreover, the £1 slugs were concentrated (whether in one large or in two smaller clusters) on a part of the system, the Northern line, which had been relatively unaffected by 50p slugs. These facts suggests that, even though the £1 slugs began to appear at around the time the 50p slugs were eliminated, their appearance was not due simply to displacement. The £1 slugs might have been brought into use even had the 50p slugs not been stopped.

Summary and Conclusions

The main purpose of this study was to establish the extent of displacement following modification of the Underground's new ticket vending machines to prevent the use of 50p slugs. These slugs were costing LUL many thousands of pounds per month and were affecting stations throughout the system. Soon after the modifications to prevent use of the 50p slugs were complete, significant numbers of £1 slugs began to appear though, even some nine months later, these had by no means reached the scale of the problem formerly due to the 50p slugs.

In seeking to establish whether or not the appearance of the £1 slugs was due to

displacement, it was necessary to make some assumptions about the possible groups of offenders involved since these would vary in their determination to find ways round preventive measures. The analysis undertaken, which, incidentally, further supports arguments about the need for crime-specificity in criminological explanation (Clarke and Cornish 1985; Cornish and Clarke 1986), suggested that perhaps a quarter of the 50p slugs had been deposited by organized groups of offenders. There appeared to be about seven of these groups, operating in different parts of the system, who were systematically plundering the ticket machines of cash. (The travelling public and delinquents seemed to be responsible for most of the remaining slug use, with apparently little contribution by the homeless or by ticket office staff).

Since it appeared that each of the groups of organized offenders was netting large amounts of cash from use of the slugs, there was a powerful incentive for displacement and, indeed, evidence consistent with substantial geographical displacement of 50p slug use by these groups was found. In the month or two after machines began to be modified these groups appear to have shifted their operations from their usual stations to nearby ones where machines had not yet been modified. However, this geographical displacement was soon brought to a halt when modifications were complete.

Moreover, there was little evidence that the appearance of the £1 slugs was the result of displacement, since few of the stations most severely affected by the £1 slugs were the same as those formerly preyed upon by the organized groups. Instead, it seems more likely that this more valuable (though more difficult) form of fraud would have developed in time anyway, and that its appearance when the 50p fraud was stopped was coincidental. Indeed, the possibility cannot be ruled out that the development of the £1 slugs was given some impetus by the success enjoyed by the 50p slugs. The knowledge that it was possible to defraud the ticket machines through the use of low value slugs might have encouraged some people (not necessarily those milking the machines of 50ps) to develop a higher value slug. Rather than constituting an example of displacement, the appearance of the £1 slugs might, therefore, furnish an example of 'crime breeds crime'.

The fact that some geographical displacement of the 50p slugs occurred as a result of the preventive measures is not inconsistent with the conclusion that these same measures did not result in displacement to the use of £1 slugs. The rational choice theoretical underpinnings of situational prevention suggest that displacement will occur whenever a similar reward can be obtained with comparatively little additional risk or effort, but not otherwise (Cornish and Clarke 1986). This proposition is supported by the present results: while it was not difficult for the organized groups of offenders to move to other stations in order to continue using the 50p slugs, it would have been much harder for them to find ways of obtaining or making £1 slugs.[13]

Such is the power of the 'dispositional' bias (Clarke 1980) in criminology that even the LUL managers dealing with the slug problem, seemed all too ready to believe that 'criminals will always find a way'. In fact, even though it was expensive to modify the ticket vending machines (about £135,000), LUL stopped a problem that at its height was costing the Underground about one third of that amount per month. Their action

[13] According to a newspaper story, 'Police Launch National Hunt for Coin Forgers', the situation may have subsequently changed. Counterfeit £1 coins began to appear in large numbers in London during July and August 1992 as a result of being 'mass produced and distributed throughout the country by several gangs of forgers' (*Independent*, 6 September 1992).

therefore safeguarded a considerable amount of revenue as well as constituting yet one more case study of successful situational crime prevention (Clarke 1992). They did this with a straightforward mechanical change after extensive surveillance efforts by revenue protection officers and police had netted but a few offenders and had failed to stem the problem.

While LUL can take some satisfaction from stopping the 50p frauds, they must bear some responsibility for the design flaw that permitted the problem in the first place. A decision was taken on cost saving grounds that the ticket machines should be supplied without complex coin-verifying technology and, more important, without the so-called 'lifo' coin shute (i.e., 'last in, first out'). This made possible the fraud involving depression of the coin reject button. With 'lifo' installed, the offender would have had his slug returned, not a genuine 50p coin. LUL is now embarked on an extensive programme of modifying the vending machines, budgeted at some £5.5 million, which, apart from enhancing change-giving capacity, will improve coin recognition and provide the 'lifo' coin shute.

Criticizing the original specification for the machines is not merely being wise after the event, since it could have been expected that, with the millions of daily users, it would not be long before somebody would stumble on the way of defrauding the machines or would bring experience to bear from dealing with other machines.[14] Indeed, it is not inconceivable that the first to commit the frauds were technicians and others with detailed knowledge of the workings of vending machines. Even if this were not the case, the history of invention suggests that a number of people may have independently discovered how to defraud the machines with foil-wrapped coins. The fact that the £1 slugs appeared in different forms, at a variety of locations, supports this speculation.

With the exception of some ethnographic descriptions and important statistical studies by Tremblay (1986) and Mueller (1971), respectively, of a wave of credit card frauds in Canada and a fad of stealing Volkswagen badges in the United States, there is a dearth of research on the way that new forms of crime develop and spread. If criminologists are to provide practical advice on ways of stopping such epidemics, more research of this kind is urgently needed. In particular, it is important to understand how information spreads about new criminal opportunities and ways of exploiting these. Little is known about the role in these processes of criminal entrepreneurs, of insiders with special knowledge and even of the media. Current examples of possible subjects for such research include robberies at automatic teller machines (ATMs), 'ramraiding'—in which vehicles are used to smash a way into shops carrying high-value merchandise—and so-called 'carjackings', in which owners of generally expensive automobiles are deprived of their vehicles at gun point.

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[14] This lesson should not be overlooked by other transit authorities, such as that of New York City (Sims 1991), which are planning to introduce similar ticket machines.

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