Investigating Paper Ticket Usage on London Underground's Network

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Abstract

Whilst smartcard ticketing systems are increasingly available, traditional paper tickets are still in use on many public transport systems. As metro stations are becoming more crowded than ever, usage of station spaces for paper ticket facilities and services could be reviewed. To inform station planning and operations, this study examined the paper ticket usage on London Underground. It was found that a 18% of station entries across the London Underground Network were made using paper tickets. Stations connected to mainline railway termini or near to sightseeing locations in Central London had high percentages of overall paper ticket entries with Marylebone's 44% being the highest. Stations adjacent to London Heathrow Airport had high percentages of Adult Single paper ticket entries. This paper then classified the stations according to their proportions of paper ticket entries, and recommendations were made for each group regarding the facilities and services required for paper tickets. The results would be useful for station planning and management.

Key words:
Paper ticket, London Underground, Station Planning, Ticket barrier throughputs, Entry/exit counts

1 Introduction

In recent years there has been major evolution in ticketing methods available to passengers on public transport networks across the globe and electronic tickets and payment systems are increasingly popular (EC Smartcards Study Consortium, 2011). Different ticket types impose different requirements for station operations and facilities. Whilst there are many reasons why electronic tickets can be cost effective for operators (for example, see Ferreira et al 2013), provision of facilities and services for paper ticket users can be cost ineffective in various ways. Some paper ticket users purchase tickets at stations where they start their journeys, which means that at stations there need to be ticket bending machines and ticket offices which can issue paper tickets. This issue is important because, while many metros face increasing passenger demand, available space at metro stations is often limited and there is constant pressure to accommodate commercial facilities (e.g. shops, cafes) to raise non-transport revenue. In addition, there has been a growing body of research that uses smart card data (e.g. Pelletier et al 2011, Kurauchi and Schmöcker 2016, Li et al 2018, Cao and Fujiyama, 2016), but such datasets usually do not cover

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paper ticket users. It would be useful to understand the passengers and their journeys which are not covered by such datasets.

As for the existing literature about paper ticket usage on public transport systems, whilst there has been a growing number of research on e-ticketing (e.g. Puhe 2014), limited is evidence on the types of people who do not use electric ticketing. There have been reports that senior citizens (Gerathy, 2015), infrequent users and people with low income (Transit, 2012) are identified as contributors to use of paper tickets. There has been research on customer attitudes towards electronic ticketing for public transport systems, which can reversely explain why and in what circumstances paper tickets were preferred. Apanasevic et al (2013) showed that customers preferred paper tickets because they are 'understandable', 'easy to use' and could be 'used by several people or a group travelling together', while the electronic ticketing solutions are thought to be too complicated and inconvenient for tourists and people living outside the main city where there is no opportunity to 'top-up' smart cards. Graham and Mulley (2011), which investigated the ticket usage on Sydney's public transport systems before and after the introduction of its multimodal prepay ticketing system, suggested that there are significant differences in the characteristics of passengers using 'multi-modal' and 'pay-as-you-go' tickets and that this difference is driven largely by age, income and interchange, and concluded that passengers who continued to pay cash after the fare and ticket reform showed 'high sensitivity to public transport cost and are those passengers with the lowest incomes'. Whilst these existing studies have identified the types of passengers who would use paper tickets, little research has been conducted on paper ticket usage at operational levels: for example, paper ticket usage by station or by day. As described in the introduction section, provision of facilities for paper tickets have implications on operational resource usage and requirements, and therefore it is important to understand how paper ticket is used on public transport systems. Using London Underground's network as a case study, this research investigates the paper-ticket usage on public transport.

2 Method

This study used two datasets: Entry/Exit Count dataset and Rolling Origin and Destination Survey (RODS). The Entry/Exit Count dataset gathers data from the ticket barriers of the stations on London Underground. Each ticket barrier can count the numbers of passengers entered (and exited) and their ticket types for each day, and report them to the system. RODS is an annual questionnaire survey that is distributed to passengers at stations of London Underground in November every year and asks about their journey as well as their personal characteristics. In its 2014 survey, 34 stations were selected, with 127,000 forms handed out and 16,982 valid forms returned. This dataset included 458 records where the ticket type is not identifiable, resulting in 16,524 records for the analysis. 786 records used paper tickets.

The first part of this paper analyses the patterns of journeys with paper tickets, followed by analysis on paper-ticket usage by stations. The Entry/Exit Count dataset was used for this purpose. Then, using 2014 RODS data, the characteristics of passengers with paper tickets are investigated.

Note that currently in London, the following types of paper tickets are available.

- **Adult tickets**: Single, Return, One-day travelcard (unlimited rides within the day), One-day Off-peak travelcard (unlimited rides within the day after 9.30am on weekdays and all day at weekends), Season tickets (Weekly, Monthly and Yearly; Unlimited rides when the ticket is valid).
- **Child tickets**: Single, Return, One-day travelcard, One-day Off-peak travelcard, Season tickets.
- **Other tickets**: Freedom pass (travelcard for elderly and disabled people), Veteran pass, some privilege tickets, staff pass.

London adapts a zonal system for fares and currently there are nine zones with one being the central London. Different prices are set for travelcards valid in different zones. Since the introduction of Oystercards, the strategy for fares has been that the fares for cards should always be cheaper (or at least the same). For example, a single ride fare within zone 1 is £2.40 for cards, but £4.90 for paper tickets (at the 2017 price). It should be noted that Oystercards or any other Train Company-issued smartcards were not usable on stations on the mainline railway network outside London's Fare Zones in the South East of England in 2014. Mainline railway stations outside London Fare Zones can sell tickets that include travelcards (e.g. Return tickets: Southampton to London Zones), but these had to be paper-based. This means that the entries of commuters who travel from mainline railway stations outside London's fare zones to underground stations in Central London using season tickets to London Zones, were included in 'Adult Season' in the Entry/Exit Counts.

3 Results

3.1. Overall ticket usage by types

London Underground serves 270 stations and the total line length is 402 km. Since their introduction in the 1950's, paper tickets had been the principal form of tickets on the London Underground (LU) network (Wanless and Hart, 1989) until the introduction of Oystercards (a smartcard ticketing system) launched in 2003. Since 2014, Oystercards have been supplemented by a Contactless ticketing system (in which passengers can touch their credit and debit cards on card readers in the same way as Oystercards, and the fares are the same between Oystercard and contactless systems with a minor exception (i.e. there are a week-based cap on the sum of fare spending for the contactless, but not for payment by Oystercards). Figure 1 shows the sums of station entries made by paper tickets and the total entries including cards by year since 2001. There was a steep decline in usage of paper tickets between 2003 and 2006, which corresponds to the introduction of Oystercards. From 2006 onwards the rate of decline appears to have slowed considerably. The figure suggests that since their introduction Oystercards have become the main way for the payment, but there have been still some paper ticket usages. In 2014, around a 18% of the entries at the stations were made using paper tickets.

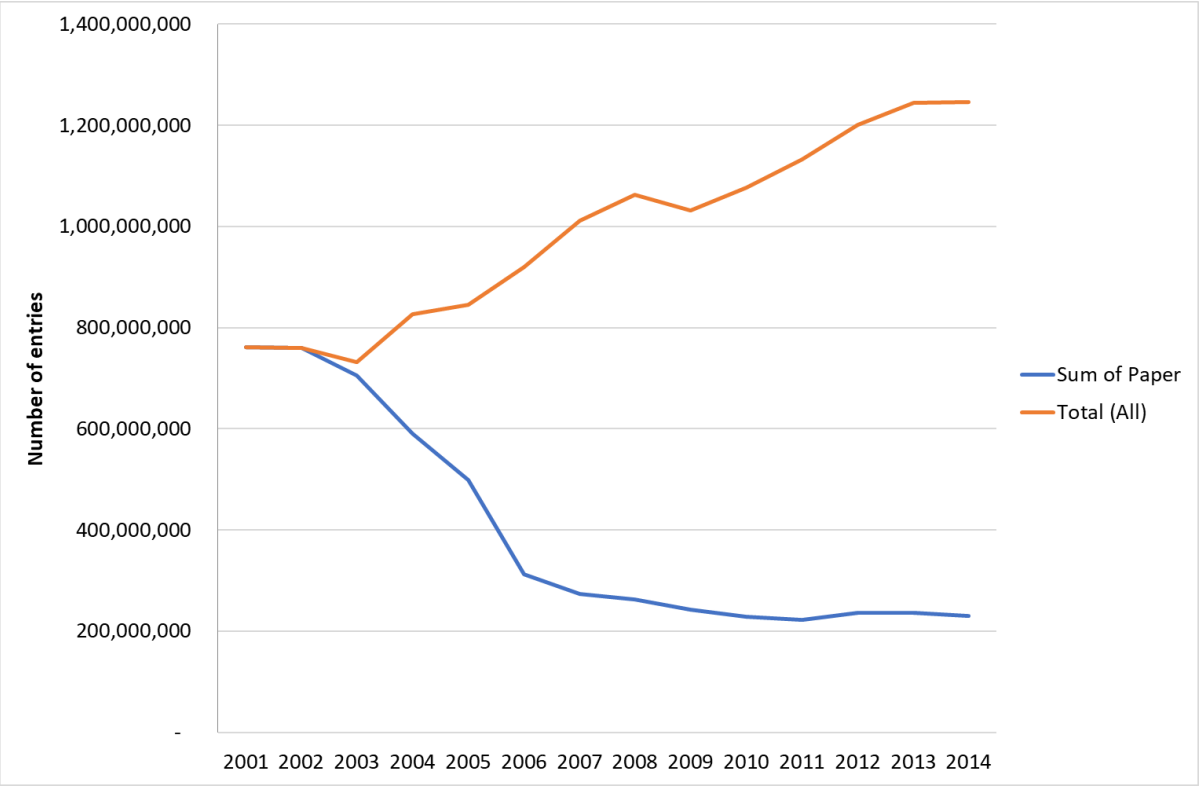

Figure 1. Historical trends of the numbers of station entries by ticket types

Figure 2 shows the entries each paper ticket type by year. In the dataset, One-day (peak) travelcards as well as Travelcards attached to tickets issued at National Rail stations are included in the 'Season' categories. It can be seen that Adult Single, Adult Season, Adult Off-peak Travelcard has large entries, although they have been gradually decreasing. Their shares within paper ticket entries were 5.9%, 26.3% and 22.5% respectively. Note that the increase of 'Other' is mainly due to increase of entries with Veteran passes.

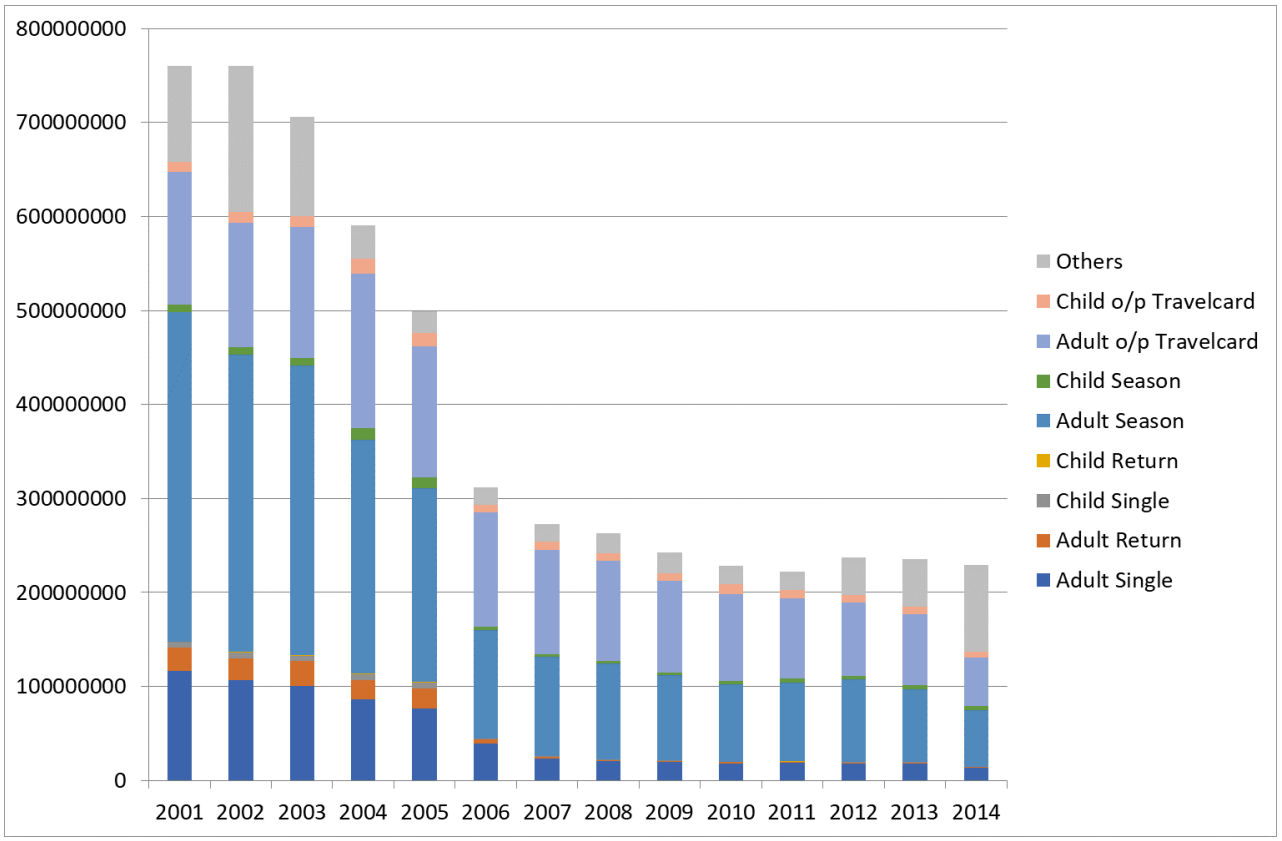

Figure 2. Breakdowns of paper ticket entries

3.2 Paper ticket usage by month and by day:

The detailed paper ticket usage was analysed using the Entry-Exit Count dataset for the calendar year of 2014. In this and the following analyses, we focused on adult paper tickets only as the proportions of child tickets are small. Figure 3 provides the number of entries by paper ticket type by month. Adult Season had peaks in January, March and October. Off-peak travel cards have different peaks: January, March, August and October/November.

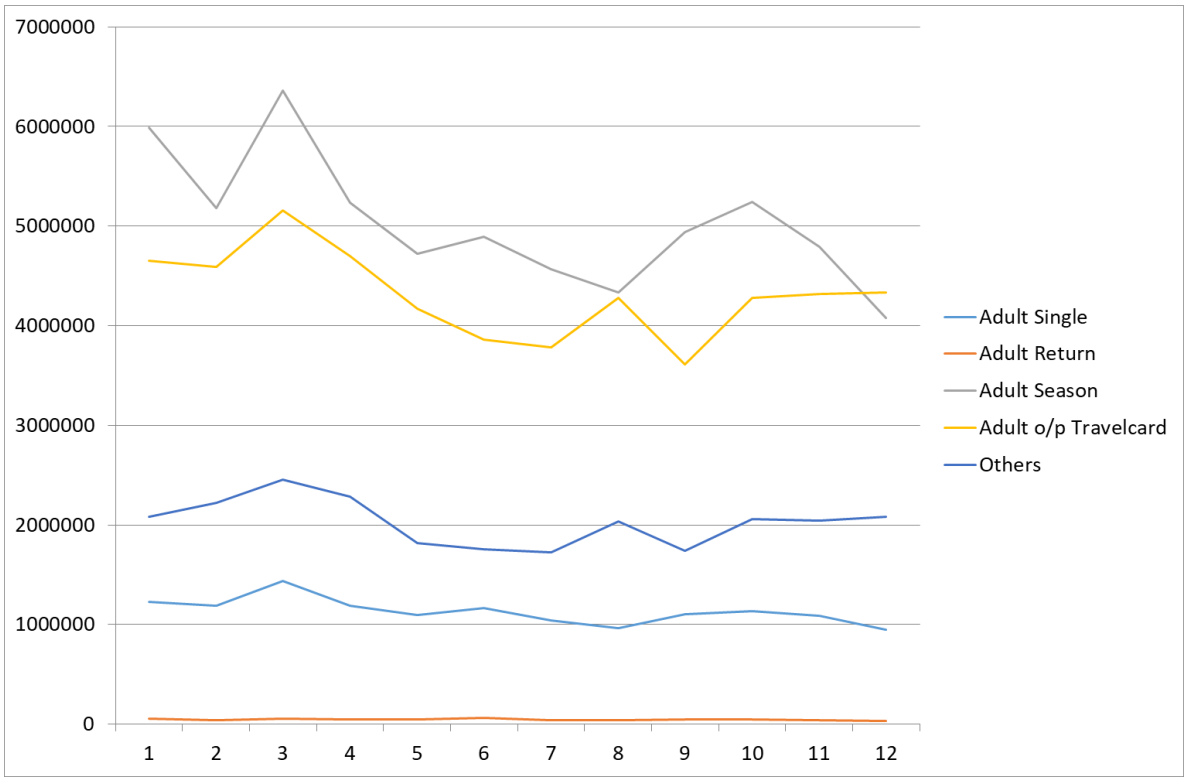

Figure 3. Number of entries by paper ticket type by month

Figure 4 shows the number of entries by paper ticket type by day. Adult Season had peaks on weekdays, while off-peak travel cards had a peak on Saturday. The reason why Monday saw fewer entries may be because that in the UK, there are several holidays on Mondays when companies are closed.

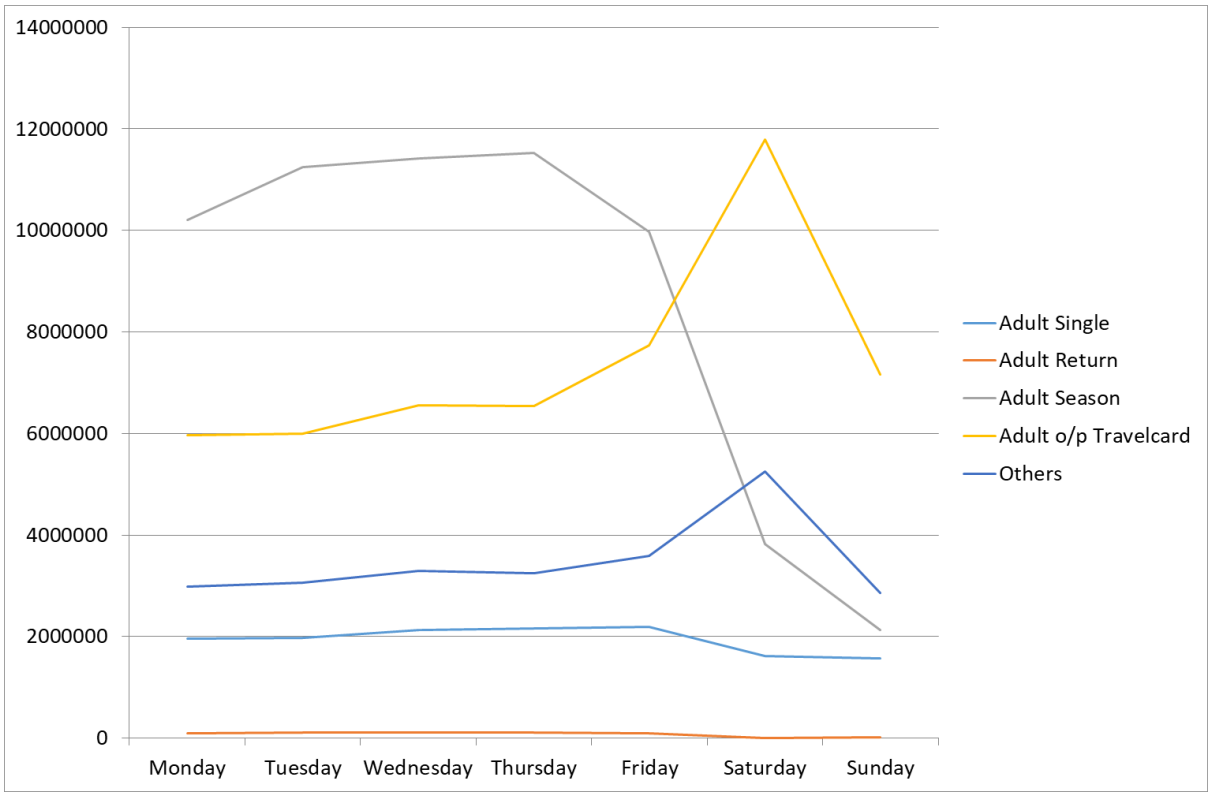

Figure 4. Number of entries by paper ticket type by day

3.3 Paper ticket usage by station

The detailed paper ticket usage was analysed using the Entry-Exit Count dataset for the calendar year of 2014. Table 1 shows the highest 10 stations in the percentages of the entries of each type of Adult paper tickets, to the total entries (including card entries). The numbers are sums over the whole year. The stations with high numbers of entries and percentages of Adult Single included stations connected to Heathrow Airport (London's largest airport) as well as the stations in Zone 1 (Central London) connected to mainline railway termini with intercity services (including Euston, Paddington, Kings cross). Adult Return showed a different picture. The stations with the highest proportions included stations towards the end of underground lines and the edges of the London fare zone. Adult Season included stations not only stations connected to mainline railway termini but also stations in central business districts. For example, Bank and Moorgate are in a central financial area of London. In contrast, many stations with high Adult Off-peak paper ticket proportions were close to sightseeing destinations in Central London, such as Covent Garden, Westminster.

Table 1. The top 10 stations with the high proportions of each type of Adult paper tickets

Rank	Adult Single			Adult Return			Adult Season			Adult o/p Travelcard			Paper ticket total		
	Staion	Fare Zone	% to the total entries	Staion	Fare Zone	% to the total entries	Staion	Fare Zone	% to the total entries	Staion	Fare Zone	% to the total entries	Staion	Fare Zone	% to the total entries
1	Heathrow Term. 4	6	11.8%	West Ham	2/3	1.4%	Marylebone	1	19.1%	Covent Garden	1	15.6%	Marylebone	1	43.5%
2	Heathrow Term. 123	6	10.8%	Amersham	9	1.1%	Waterloo	1	14.4%	Westminster	1	14.3%	Paddington	1	37.0%
3	Euston	1	5.9%	Chesham	9	1.0%	Bank & Monument	1	13.7%	Hyde Park Corner	1	13.5%	Euston	1	36.0%
4	Paddington	1	5.3%	South Ruislip	5	0.9%	Cannon Street	1	12.6%	Knightsbridge	1	13.2%	Westminster	1	35.5%
5	King's Cross St. Panc	1	4.1%	Watford	7	0.9%	Euston Square	1	12.4%	Piccadilly Circus	1	12.0%	Waterloo	1	34.0%
6	Tottenham Hale	3	3.9%	Hillingdon	6	0.9%	Moorgate	2	12.0%	Bayswater	1	10.6%	Covent Garden	1	31.9%
7	Marylebone	1	3.2%	Rickmansworth	7	0.9%	Aldgate	1	11.9%	Cockfosters	5	9.6%	Hyde Park Corner	1	31.3%
8	Euston Square	1	3.2%	Chalfont & Latimer	8	0.8%	Euston	1	10.8%	Camden Town	2	9.5%	Embankment	1	31.1%
9	Ealing Broadway	3	2.2%	Croxley	7	0.8%	Blackfriars	1	10.4%	Marble Arch	1	9.5%	King's Cross St. Panc	1	30.9%
10	Waterloo	1	2.1%	Cockfosters	5	0.7%	Embankment	1	9.8%	Paddington	1	9.4%	Euston Square	1	29.3%

Proportion: The percentage of the number of entries with the specified type of paper tickets, to the total entries of the station including card entries

A correlation analyse was performed between the proportion of each paper ticket type (Adult Single, Adult Return, Adult Season, Adult Off-peak Travelcard) and that of each card type (Pay-As-You-Go(PAYG) and Prepay (season tickets on cards). Table 2 shows the results. Relatively high correlation coefficients were observed between Adult Return and Oyster Prepay and Adult Season and Adult off-peak Travelcards.

Table 2. Correlation coefficients between ticket types

	Adult Single	*Adult Return*	*Adult Season*	*Adult o/p Travelcard*	*OysterNonPrepay*	*OysterPrepay*
Adult Single	1.00					
Adult Return	0.07	1.00				
Adult Season	0.35	-0.18	1.00			
Adult o/p Travelcard	0.41	0.04	0.56	1.00		
OysterNonPrepay	-0.36	-0.53	-0.01	-0.31	1.00	
OysterPrepay	0.09	0.58	-0.42	-0.11	-0.78	1.00

In order to classify stations by ticket usage characteristics, a principal component analysis was performed using SPSS version 23. Two components were identified with their Eigenvalues more than 1.0. The first component had an eigenvalue of 2.40 covering 40.0% of the variance, and the second 2.01, 33.5%. Figure 5 plots ticket types on the identified components according to their loadings, while Figure 6 plots the stations based on loadings on the components. It can be seen that stations at Heathrow are distinct from the rest. Stations connected to mainline termini had high values on the component 2, while stations at the ends of the lines had high values on the component 1.

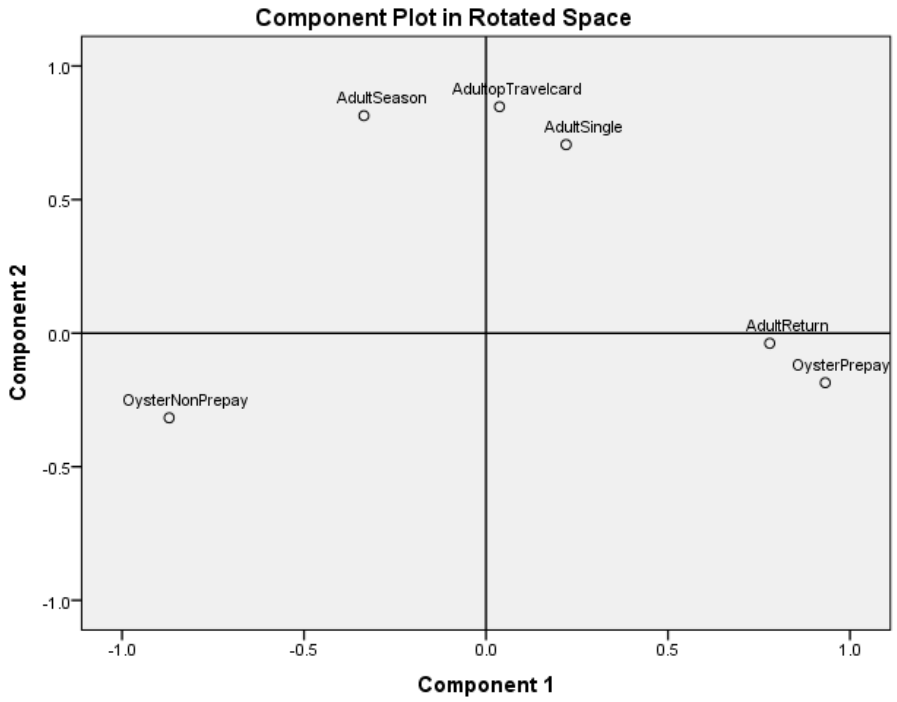

Figure 5. Component plots of the ticket types

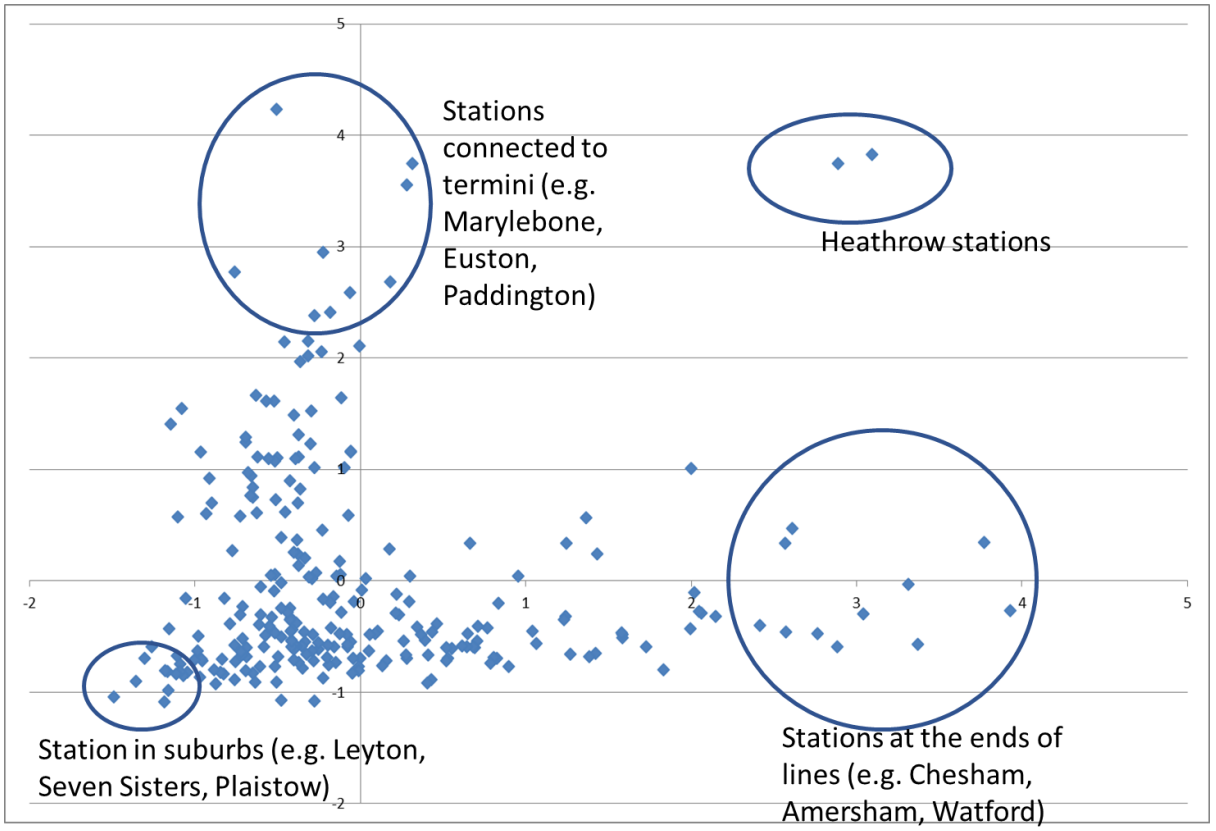

Figure 6. Distribution of stations according to the loadings on the components

3.4 Characteristics of trips with paper tickets

Using the datasets of RODS 2014, the characteristics of paper ticket users and their travel patterns were analysed. Figure 7 shows the percentage of each age sector of paper ticket users, to the total paper ticket users within the RODS respondents. The figure provides the percentages for each gender, and for comparison purposes, the percentages of the total RODS respondents, which include card users. The figure shows that among the male RODS respondents who used paper tickets for underground journeys, a 41% of them were aged 45-59. The percentage for females were 37%. These are higher than those of the total RODS respondents (i.e. 31% for the whole male RODS respondents, and 25% for females). It can be said that this age sector has more tendency of use of paper tickets than the other age sectors for both males and females.

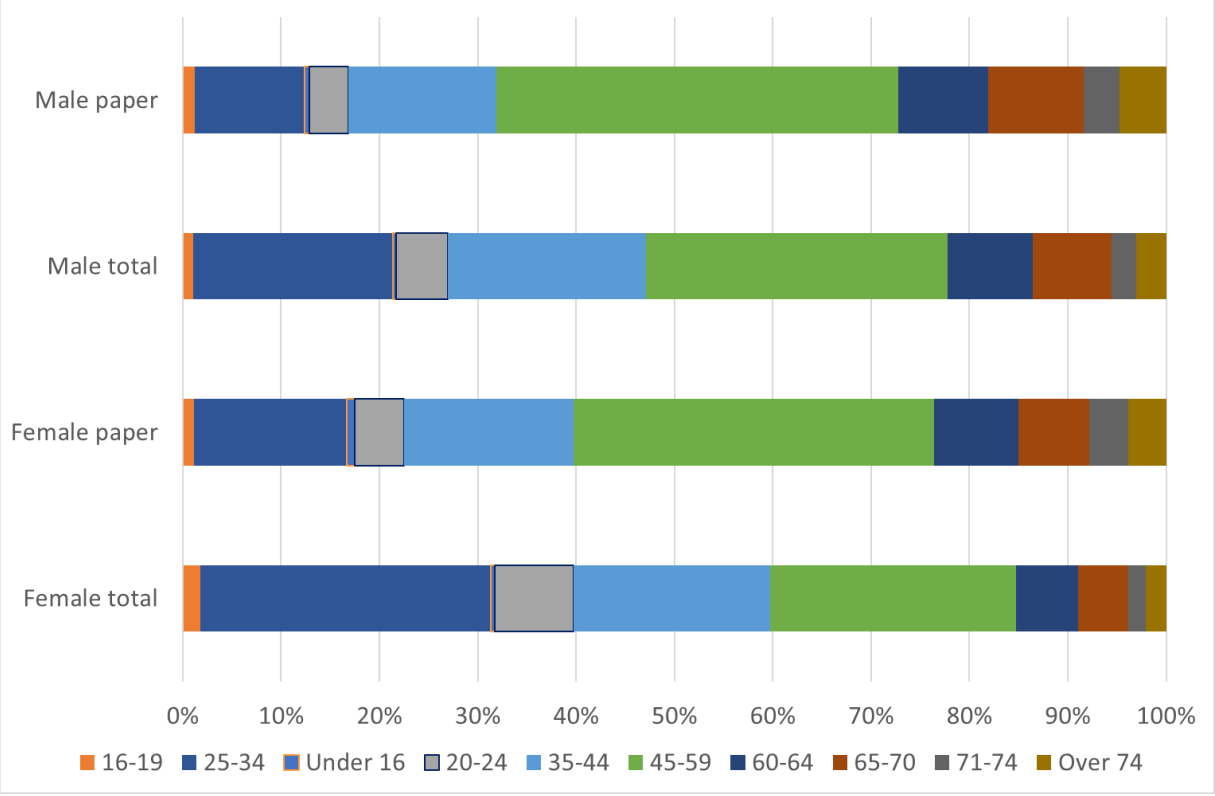

Figure 7. Percentage of each age sector by gender. Male/female total include male/female respondents who used cards for their journeys.

Figure 8 shows the percentage of each travel frequency category of RODS paper ticket respondents, to the total paper-ticket respondents. For comparison purposes, those of the total RODS respondents which included card users are shown as well. It can be seen that paper tickets were used by those with less journey frequencies.

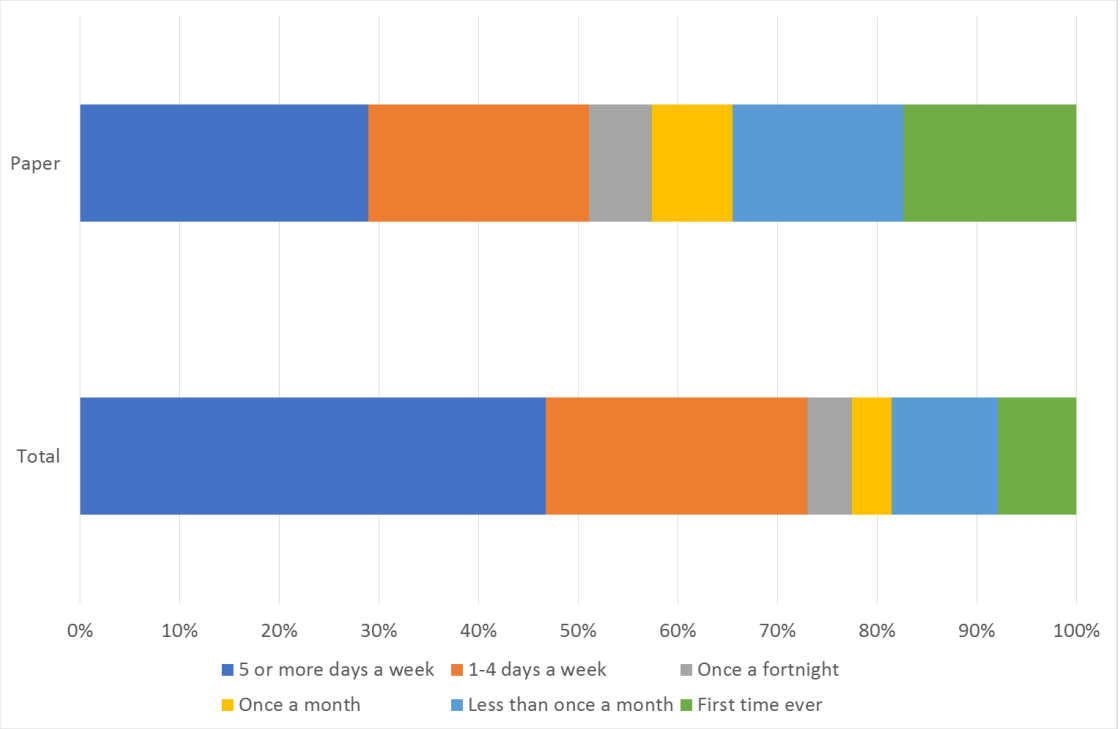

Figure 8. Percentage of survey respondents of each travel frequencies to the total respondents of each ticket category: Paper or Card

Within 786 records which used paper tickets, there were 16 records in which we could not identify the exact paper ticket types, resulting in 770 records available for further analysis. Figure 9 shows the proportion of each destination purpose (the purpose of the respondent's travel to the destination) by paper ticket type. Note that we have removed 'Home' (i.e. going home) and 'Not stated' from the analysis, resulting in 465 records for analysis. These included 91 records of 'Single or Return', 227 'Day Travel Card' and 147 'Travelcard (season)'. It can be seen that 'Travelcard (season)' had higher proportion of journeys to work-related destinations, while more than half of respondents with Day Travelcard had non-work-related journeys.

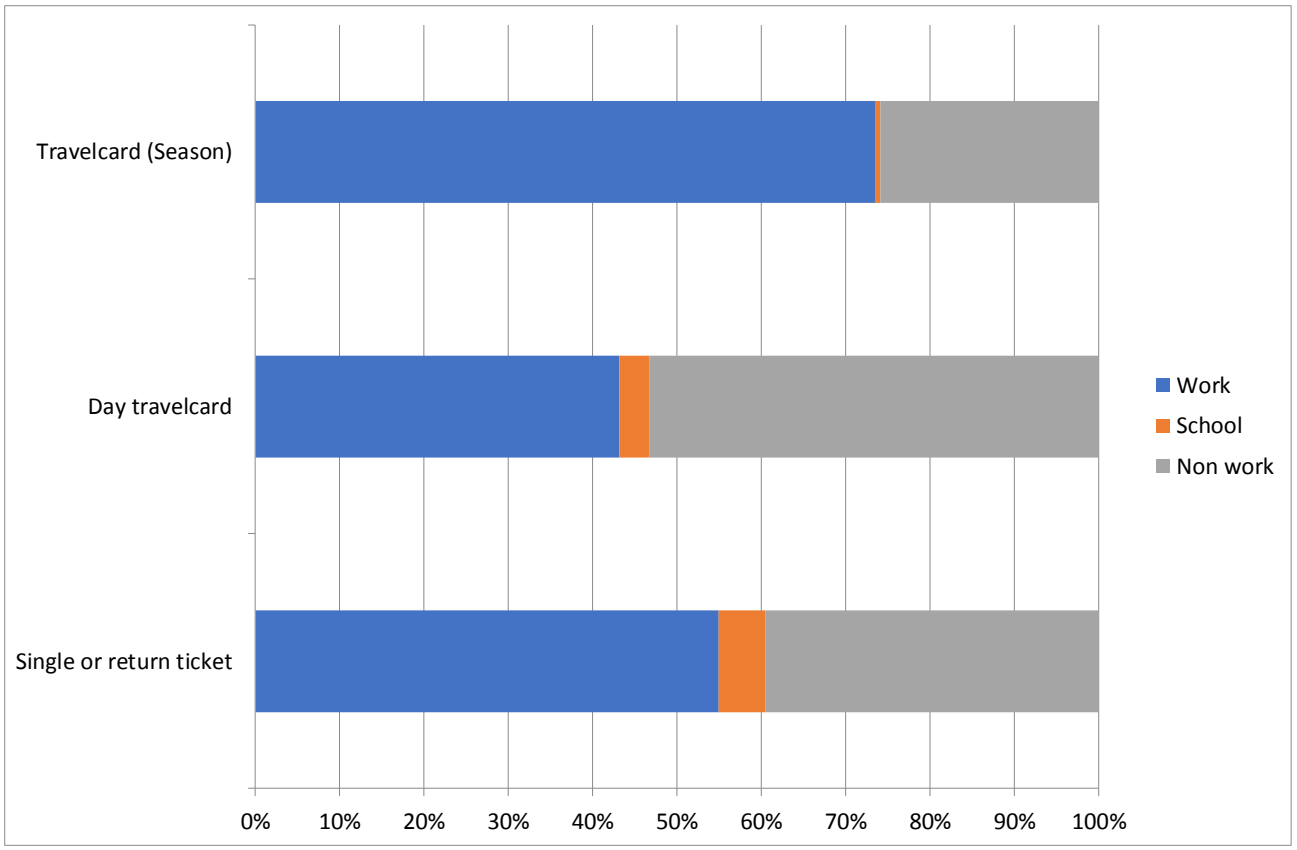

Figure 9. Proportion of each destination purpose by paper ticket type

Figure 10 shows the proportion of paper ticket usage by time of the day. The time recorded here corresponded to the survey question about the time the respondent started their London Underground journey. The time categories correspond to the ones used for peak/off-peak fare calculation. It can be seen that the usage in the mid-day off-peak (9.30-15.59) had a large proportion (62%) within paper: Day Travelcard.

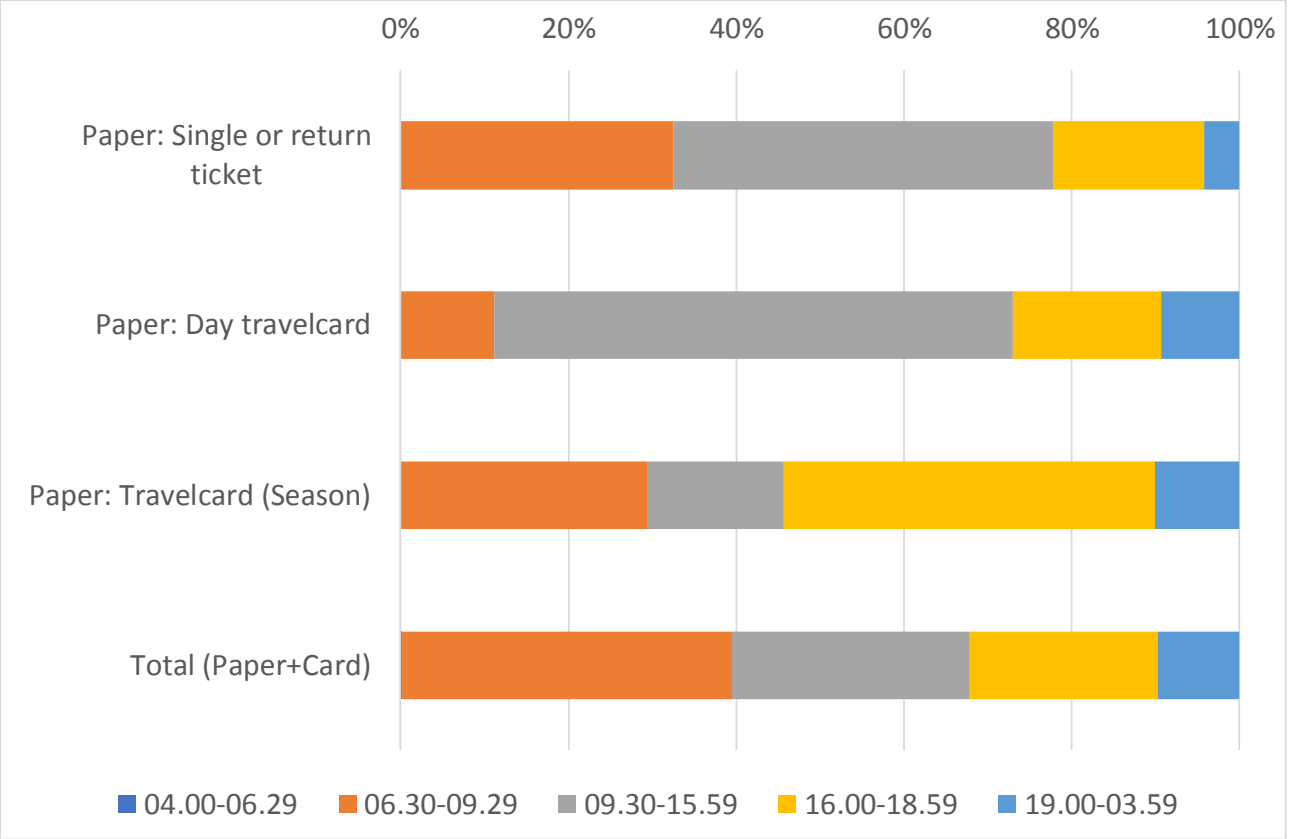

Figure 10. proportion of paper ticket usage by time of the day

4 Discussion

This paper analysed the paper ticket usage on London Underground. While card payment has been becoming dominant since the introduction of Oystercards in 2003, there has been still some paper usage and Figure 1 shows that around 18% of entries were made using paper tickets.

Figure 2 shows that Adult Single, Adult Season and Adult Off-peak Travelcards had the largest entries within paper tickets, but their usage patterns were not the same. Figure 9 shows that Adult Season had the highest share of destination purpose of work and Figure 4 shows that it was used mainly on weekdays. In contrast, usage of Adult Off-peak Travelcards was peaked on Saturday (Figure 4) and in August (Figure 3), and it has the highest proportion of non-work destination purpose (Figure 9). These findings can lead to an assumption that Adult seasons are mainly used by commuters and Adult off-peak travelcards are used by non-work and occasional travellers including sightseeing passengers. In addition, Figure 3 found that Adult Season had peaks in January, March and October and this may be because season tickets are usually used by commuters (and those who attend schools) and they may use season tickets after festive and vacation periods when they may started new jobs but do not know the detailed attendance requirements associated with the jobs. These assumptions can be supported by the findings of Table 1 as well; the stations with highest proportion of Adult Seasons included stations connected to suburban railway termini or in the central financial business area, while the stations with

highest proportion of Adult off-peak travelcard included major sightseeing destinations. As for Adult Single, it did not have as much variation as Adult Season or Adult Off-peak Travelcards by day or by month. Table 1 shows that stations connected to Heathrow Airport had high proportions of this ticket type, while stations connected to mainline railway termini with intercity or/and airport services (including Euston, Paddington, Kings cross). This suggests that Adult Single is used by non-London residents who may not have a plan of making many trips within London.

Figure 7 suggests that paper tickets were used by the age sector of 45-59 than the others. Graham and Mulley (2012) suggest that young people (e.g. the age sector of 25-34) can accept card payments and this finding matches theirs. Figure 8 suggests that the proportions of paper ticket users who travel once a fortnight or less are higher than those of Total (including card payment passengers). This is understandable because 1) paper tickets are traditional, universal and intuitive ticketing, and 2) in order to use the card payment system, it is necessary to understand how it works, but frequent or young users tend to overcome such initial difficulty.

As mentioned in the introduction section, paper ticket usage has implications in station planning and operations. Table 1 shows that stations connected to mainline railway termini have high percentages of paper ticket entries (e.g. Marylebone 44%. Paddington 37%). Throughputs at ticket barriers may vary according to ticket types, and TfL (2014) suggested that paper ticket users spend twice a longer time to go through barriers than those with smartcards. In calculation of the number of ticket barriers required and in simulation of passenger movements within stations, this ratio of paper ticket entries may need to be considered. Whilst some transport operators (including some Japanese operators) mix barriers which can accept paper tickets and those which can handle cards only at station gate lines for cost-saving purposes (because ones that can accept paper tickets are more expensive), stations with high proportions of paper ticket users may not be able to adapt this strategy. In addition, it has been found that the stations with the smallest proportions of paper ticket entries still have a 6% to 7% of paper ticket entries to the total entries (e.g. Chigwell 6%, Leyton 7%), which means that there still needs to be provision of paper ticket facilities at all the stations.

Adult Single, which needs to be purchased at stations before journeys, requires ticket bending machines or in some cases ticket offices at stations. Table 1 suggests that stations with high proportions of Adult Single travel cards include stations connected to mainline railway termini with intercity services or Heathrow airport. Whilst enhanced numbers of ticket bending machines need to be installed at these stations, there is an opportunity for paper ticket reduction as well: because those who use Adult Single may include many non-London residents, who may be not familiar with card payment systems (which offer cheaper fares), key would be to inform them about card payment systems. London Underground could work with intercity service operators and the airport authority to inform such passengers before they come to London Underground stations since passengers could have some moments to be exposed to such information while they are on intercity services or at the airport. While some public transport systems are going paperless (e.g. Gerathy 2015), this highlights the issue of the importance of informing those who come from outside the city or abroad.

To inform station planning, a principal component analysis was performed to group stations. The results of Figure 5 show that Oyster Prepay (including season tickets) and Adult Return had high scores on the first component and while Non-prepay card had a lower score. This implies that the first component showed the level of regular trips (including commuting). Adult Single, Adult Season and Adult off-peak Travelcard, which had high shares in the total of paper tickets, had high scores on the second component. This implies that the second component shows the level of the paper ticket usage. Figure 6 plots stations according to their scores on the first and second components. In the figure, there are two stations (Heathrow Terminals 123 and Heathrow Terminal 4) on the top right of the figure, and they are distinct from the rest. Stations in the bottom right region include those at or near the ends of lines (including Chesham, Amersham), which have a relatively high proportion of Adult Return and Oyster-prepay. While the number of paper ticket entries are small at these stations, as passengers would purchase Adult Return tickets, there still need to be some facilities for paper tickets. Stations on the top left include those connected to mainline railway termini (including Marylebone, Euston). These stations have high proportions of paper ticket users including Adult Single, which should be considered in calculation of the throughputs of ticket barriers as well as of the number of paper ticket bending machines. Stations on the bottom right include those in suburbs (Zone 3-4. Including Leyton, Seven Sisters) but not towards the ends of lines. The proportion of Oyster non-prepay entries is high at these stations, which means that they would need Oyster top-up facilities. When a new station is planned, it is possible to consider a possible group the new station would belong to and plan the station's facilities for paper tickets accordingly.

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This work is based on Tolulope Mohammed's MSc thesis at University College London. The comments and opinions made in the paper are not of London Underground.

Conflict of Interest: The authors declare that they have no conflict of interest.

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