# Social Norms as a Cost-Effective Measure of Managing Transport Demand:

## Evidence from an Experiment on the London Underground

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**Abstract**

In an effort to cope with increasing passenger demand on its network, Transport for London (TfL) implemented in the second half of 2017 an experiment on one of its busiest metro train platforms. The platform surface was painted to highlight the exact location of the train doors once it comes to a full stop and to direct passengers to wait in parts of the platform that would not obstruct passengers from alighting from the train and leaving the platform. We estimate the effect of this intervention to change passenger behaviour on the platform on train waiting and delay times. We use different sets of assumptions about what the counterfactual change in waiting and delay times would have been in the absence of the intervention. Depending on the assumptions, we find that the intervention has reduced train waiting times between 0 and 8.7%. We also find that this reduction came about mainly through reducing delay times of trains once they are delayed, which were cut by 4.7% to 12.6%. The reductions are not evenly distributed throughout the day, but tend to occur during peak traffic hours. The value of the implied time savings are £3,000,000, at a cost of £25,000, amounting to a return of £125 per £1 investment.

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## 1. Introduction

Transport is a key factor in any modern economy and its cost-effective management and supply are crucial if the ever-growing demand is to be met and development sustained (Duarte *et al.*, 2010). Many modern local and national authorities now implement policies to encourage people to patronise more environmentally friendly modes of transportation which mainly involves the use of public transport (Karekla and Tyler, 2012). Therefore the occurrence of delays to transport services would have economic and social costs on the stakeholders. Any delay to a high frequency metro network like London Underground can have far reaching and knock-on effects, as delays to a train service quickly cascade to other trains on the same line. One major source of the occurrence of delay to a transport network is the sheer increase in the demand for the network's services, which in turn puts pressure on the capacity. The demand for transport has been increasing over time in many urban and rural economies. A study published by the Office of Rail and Road between 2009 and 2010 shows that UK rail passenger trips (national rail and London Underground) increased by 45% in the preceding 10years. To support this report, Atkins (2006) predicts that the demand for some inter-urban rail lines would increase by between 70% and 104% by 2026. Increases in demand inevitably impact on the reliability of a transport network (Melo *et al.*, 2011; Barron *et al*., 2013) and increases transport costs in general. How can transport networks cope with these increases in demand in the face of capacity constraint?

Overcrowding on platforms increases dwell times – the length of time trains remain at the platform from wheel stop to wheel start - which then translates to increased delay and costs for both providers and passengers. Many metros now invest in acquiring more capacity for their networks through different means like technical and structural solutions to manage travel demand (Barron, 2016). However non-effective control of platform dwell times may truncate the utility expected from the investments to increase network capacity (Barron, 2016). To effectively manage dwell times at platforms one can resort to hard and soft measures (Bamberg *et al*., 2011). Hard measures include investments in structures and infrastructures; for an old network like London Underground it entails retrofitting structural adjustments to existing infrastructures which are usually very expensive and can sometimes pose an engineering challenge. Soft measures on the other hand broadly represent measures which cause conscious or subconscious behavioural change. Traditional methods involve campaigns, sign posts, audio-visual cues on the platforms, fare structure manipulation and others (Bamberg *et al*., 2011; Loukopoulos, 2007; Fujii and Taniguchi, 2006). Therefore, where there exist capacity constraints, it is imperative that the providers of the transport network seek smarter and cost-effective ways of managing passenger flow and demand. Many researchers now question the efficacy of using only traditional economic methods in controlling transport demand. For instance, economists and transport policy makers have hitherto focused on the Pigouvian method of using prices to control passenger demand (eg charging more to travel in the peak than off-peak), but the efficacy of price in the demand and supply functions of any public transport network depends critically on its price elasticity, transport policy and passengers' behavioural norms. In addition, there is now evidence that non-price interventions can be very effective and relatively inexpensive in some scenarios (Allcott, 2011; Bertrand *et al.*, 2010).

There is limited quantitative evidence based on experimental settings in transport management showing causal effects from norms to behaviour (Metcalfe and Dolan, 2012). To contribute to the growing appreciation of the efficacy of non-price interventions in transport management this paper uses empirical evidence from a London Underground experiment to show that a psychologically realistic depiction of human behaviour is important in making economic and transport policy decisions; while aiding in the understanding of the link between behavioural economics and transport (Metcalfe and Dolan, 2012).

This *evidence-based economics* (Thaler, 2016) is important in formulating transport policies in the context of cost and capacity constraint. In this paper, we address the question of using social norms to nudge passengers into conformity to facilitate the reduction in dwell times. The aim is to analyse whether a causal relationship between the implementation of the intervention and dwell time changes through nudging human behaviour to conformity exits. We employ data from London Underground's Green Lane policy experiment at King's Cross station. The experiment was aimed at influencing passenger behaviour by laying green vinyl on the platform supported by audio and visual cues that encourage customers to pass along the platform until they find a non-green space to stand and wait for a train. The green vinyl was laid only on the Southbound Victoria line platform at King's Cross (providing the treated group), owing to its vantage position as a pinch point location and a central hub on the network created by persistent increase in demand and connections to other inter-urban lines. The vinyl on the platform also shows where the doors would open when the arriving train completely stops at the platform thereby helping passengers know exactly where the doors would be. Data were collected over four months starting from the 24$^{th}$ of July 2017 for every London Underground train through King's Cross and adjacent stations using specialist software.

We begin by estimating double difference (DD) regression equations in a bid to examining the possible treatment effects of the policy. The intuition is to capture the effects of the intervention on dwell times at the treated platform relative to the dwell times at the control platforms. Four sets of controls were used to estimate four different DD regression estimates which all control for 15-minute time slots to account for varying demand levels during different times of the day. To relax the common trend assumption of DD equations we expand our regression models to triple difference (DDD) equations under different assumptions since there are three different potential sources of dwell time variations; seasonal, station specific and line specific variations.

Now there might be objections to the identifying assumptions of the triple difference equations. For instance, the difference in dwell time changes between King's Cross and adjacent stations may be different for the Victoria line than for others. If, however, these differences between the Victoria line and other lines are the same across years, then we can add yet another difference in time to obtain the quadruple difference estimate of the Green Lane intervention. We thus further expand our model to a quadruple equation which then becomes our model of choice; we find that dwell times at the treated platform reduced compared to the control (untreated) platforms. Our empirical strategy thus amounts to estimating the effect of the Green Lane policy intervention on dwell times under a set of different assumptions, and we demonstrate that each of those assumptions yields a statistically and economically significant effect. We controlled for seasonality, station and line specific effects in our quadruple model to ensure that the variation in dwell times during the study period could not be attributable to anything else but the Green Lane policy intervention. The resulting estimates show that while the correctness of any of those assumptions cannot be known, it seems very improbable that all our estimated treatment effects should be attributable to a factor other than the Green Lane policy intervention. We observe a significant reduction in dwell time of just over 3 seconds, which is a profound result for London Underground by its own standard. London Underground values one second savings in dwell time at a pinch point location on the network at £1M worth of customer benefits (Goodwin, 2017). Therefore, our research indicates that the Green Lane intervention generated customer benefits of £3,000,000 for London Underground at a cost of £25,000 (total costs of materials and labour for installing and decommissioning the Green Lanes at one platform). Aside from this introduction (section 1) the rest of this paper is divided into three further sections. Section 2 reviews the existing literature, exploring the concepts and importance of nudge and social norms and their implementation in the parlance of economics and transport policy. Section 3 presents the methodology, data and experiment description as well as the identification technique used for this empirical research. Section 4 finally contains the empirical results summary and explanatory notes.

## 2. Review of Extant Literature

2.1 Social Norms.

There is a wealth of research and literature on social norms. It is widely accepted that social norms are important in influencing human behavior in social sciences (Sherif, 1936; Cialdini *et al*., 1991; Merton, 1957; Coleman, 1990). Economics is no different – after all it is "…a science which studies human behaviour as a relationship…" (Lionel Robbins, 1935 pp 16). The way humans (both *homo economicus* and *homo sociologicus*) interact in a society and the acceptability of norms and values in the society are dynamic; which itself can be modelled using game theory which can predict the longevity of some norms over others (Young, 2007). In a nutshell, norms are unwritten rules that govern individual behaviours in a society in any given situation. Once a particular way or method of doing something or behaving in an environment becomes established as a rule (a norm) it is rational to conform to them with the expectation that all others, or at least many others, would conform as well. In his *Treatise of Human Nature,* 1738, David Hume observes that it will be in one's interest to leave another in the possession of their goods (Bell, 1967). But the caveat is that they in turn have to act in the same manner, because they are sensible (rational) and of a like interest in the regulation of their conduct, such that so long as this common sense of interest is mutually expressed and known to all parties, it produces a suitable resolution and behaviour for present and future interactions (Young, 2015). Formally, define social norms as the "rules and standards that are understood by members of a group or society, which guide morally relevant social behaviour by way of social sanctions, instead of the force of laws" (Nolan, 2015). It then follows that for a norm to be considered "social", it must be acceptable to and shared by the other members of the society and its sustainability is a function of both the approval and disapproval of the members of the society (Elster, 1989). The dichotomising feature of a social norm is that it does not benefit any one individual but the whole society in its broadest sense, and the punishment for non-conformity cannot be enforced legally (although can be constrained by rationality – a key assumption in economics and many legal texts are annexed from existing norms to make them legally enforceable) but through some sort of social sanctions imposed by others, or self-imposed sanctions such as the feelings of embarrassment, shame, guilt and uneasiness that the offenders suffer when they violate any existing norms (Sugden, 1987; Elster, 1989; Coleman, 1990; Young, 2007). For instance, it is not generally acceptable to unilaterally question or indeed challenge the pastor or priest during a Sunday service, such behaviour would attract some sort of social sanctions from the other members of the congregation or church. It may result in the individual being excommunicated from the church or they may become so uncomfortable that they leave the church by themselves. Other examples include not jumping queues, not picking one's nose in public, standing on the 'right' side of an escalator, giving up one's seat for a pregnant or elderly person, etc. Social norms differ from other norms; there are as many norms as there are human endeavours! Norms can emanate from personal goals (e.g. self-imposed sanctions or codes of conduct) or from inter-personal agreements (e.g. "a gentleman's agreement" or legal norms to govern a society). In short social norms inform the way people behave and interact in a society so conforming or not to social norms is a matter of utility. A fair utilitarian may conform if doing so increases the average utility of the members of the society, while a rational agent may err if the personal utility of doing so outweighs the social sanctions they will suffer afterwards. In this paper we analyse the usefulness and effectiveness of using social norms to influence passenger behaviour in a bid to reduce the generalised cost of travel.

In economics social norms have been employed mainly as a tool for explaining human behaviour. It pertains to several economic phenomena like unemployment, game theory, consumption function and other micro and macro-economic topics (see Akerlof 1980; Bernheim, 1994; Fehr and Gächter 2000; Conlin *et al*, 2003; Akerlof 2007; Krupka and Weber, 2013) and an integral content of behavioural economics (Thaler, 2016; Oliver, 2013; Heap, 2013). Of course, there are some reservations among economics scholars on the appropriateness of the title *behavioural economics* - because the study of economics as a whole is the study of human *behaviour* - it has however become a toolbox for empirical work in economics and transport studies, as it offers the opportunity to develop better models by incorporating insights from other social science disciplines (Thaler, 2016; Oliver, 2013). Economics assumes rationality in the study of human behaviour, which in turn is influenced by both economic incentives and social norms. Lindbeck *et al* (1999) show how economic incentives or the pursuit of individual goals influence and are influenced by social norms in a welfare state. Based on the assumption that individuals would generally rather live off their wages or income, which is seen as the norm in a social milieu, Lindbeck *et al* (1999) state that the more the number of individuals that adhere to the same norm the stronger the norm would become. In this sense social norms become an equilibrating scenario in a repeated game where individuals derive utility from economic incentives and the disutility arising from unilaterally deviating from the norm caused by sanctions from the other members of the society.

In game theory the concept of social norms has been used in solving several equilibrium situations (see Schelling, 1981; Bicchieri, 1993; Young, 1993b; Sugden, 1987; Lewis, 1969). Thibaut and Kelley (1959) show that in repeated game situation individual players tend to avoid costs by agreeing on terms of reference beforehand. This is because engaging in any bargaining in a bid to influence the preferred outcome can be costly; therefore it is rational to agree on the terms from the outset which then become the norm. It has also been argued that social norms yield pareto-efficient scenarios (Coleman, 1990; Ullman-Margalit, 1977) and are quite efficient and effective in the equitable regulation of social welfare (Akerlof, 1976; Bicchieri et al, 2018; Nolan, 2015). In a situation where a norm leads to a pareto-inefficient situation it is expected to disappear with time. This is the case with most, if not all gender, race, or sexual orientation bias norms (Bicchieri *et al*, 2018). It is worthy to note however, that inefficiency is only a necessary condition for the disappearance of a social norm; it is by no means a sufficient condition as is evident in situations where corruption results in huge social costs to many and benefits a few (Bicchieri and Chavev, 2010).

2.2 Service Reliability in Transport Networks

Train service reliability is an important objective to any metro operator. A good transport system is important in bringing together product and factor markets, thereby promoting inter and intra-regional trade as well as reallocation of economic activities (Lakshmanan, 2011, Levinson and Zhang, 2008; Landex, 2013). It is perhaps useful to distinguish between forms of transport reliability. Bell and Iida (1997) identify two forms of reliability; connectivity and travel time reliability. Connectivity is defined as the probability that the traffic on a transport network will arrive at a predetermined destination in the first. Travel time reliability is the probability that a transport service will arrive at a scheduled destination in a given time. Passengers generally focus on the time difference to their journeys; the major concern here is more with variability in travel time than with total journey time *per se* (Preston *et al*, 2009; Bates *et al*, 2001; De Jong *et al*, 2004; Tseng *et al*, 2008). If there is no variation in travel time on a train service it would be considered as reliable, even when there is a variation in travel time, it could still be considered as reliable if the variability is predictable (Bates *et al*,

2001) because passengers can be expected to be rational enough to foresee and plan their journeys accordingly. Other forms of reliability abound depending on perception. Some passengers consider accessibility, comfortability and quality of service as indicators of reliability. Operators share similar views with passengers in terms of reliability, but they worry more about the ability to provide services that are robust and resilient to all kinds of failures and the ability to return to normal service following any system shock, in a safe, efficient and cost-effective manner (OECD and ITF, 2010). Therefore, operators are particularly concerned with dwell time management which ensures service and headway regularity as well as generalised cost minimisation (Trompet *et al*., 2009; Rudnicki, 1997). While local authorities on the other hand, are concerned with the safe and timely movement of labour and materials to ensure a smooth running of the local economy.

There is a positive correlation, *inter alia*, between reliability and metro investment levels; many economies invest in their systems in a bid to increase reliability. China for instance, is investing about $127billion on its metros (http://www.thetransportpolitic.com) and the United Kingdom has commenced a £16billion expenditure on another high speed rail (HS2), while London Underground has earmarked some £9billion on metro upgrades, renewals and maintenance in a  bid to improve reliability (DfT, 2013). The importance of a city' transport links and network can indeed be further appreciated when there is a disruption, which in turn causes delays that lead to unreliability to both customers and operators alike. For example, the 1995 Kobe earthquake disaster in Japan, or the massive snow disruption to London's network in January 2010. Aside from notable natural or seasonal causes, there are numerous potential sources of disruption to a transport network that could have severe impact on the functioning of the local economy, this range from technical and mechanical sources like equipment failures, trackside failures to delays caused by congestion. Where there is evidence of physical capacity constraint, managing congestion on the platforms is a real and viable method of improving or maintaining reliability. Congestion translates to increase in dwell time and passenger discomfort, which leads to increased generalised cost.

Managing congestion and capacity through the control of train platform dwell time is now receiving increased attention among scholars and operators. Dwell time is and important variable that changes service level and reliability, so its extension or inconsistency can be detrimental to a network's capacity and hence ability to provide reliable service irrespective the level of investment (Thoreau et al., 2016; Barron, 2016). This can be achieved with hard or soft measures. Hard measures represent heavy investments which include capital expenditure on structural adjustments like platform expansion, installation of platform edge doors (PEDs), station restructuring, line re-signalling and even procurement of new rolling stock to meet to demand. Soft measures on the other hand represent non-intrusive interventions such as communication campaigns and other techniques that support and encourage behavioural change (Brog *et al*., 2009; Cairns *et al*., 2008; Taylor, 2007; Avineri and Goodwin, 2010; Bamberg *et al*., 2011).

This paper argues that soft measures can be very effective if implemented properly in controlling the generalised cost through platform dwell time management. Dwell time depends, *inter alia*, on system constraints such as station layout, signalling capacity, train design, demand, as well as human behaviour in traffic flow context (Wright, 2015; Buchmueller, Wiedmann and Nash, 2008; TfL, 2014). Dwell time management has become the future in terms of managing existing capacity in a transport network through information dissemination which benefits both passengers and operators alike (Avineri, 2011), as well as implementing policies that nudge passengers to conformity.

### 2.3 Dwell Time Reduction Strategies.

As stated earlier platform dwell time can be managed through hard and soft measures. Examining passenger movement in a laboratory setting at the University College London, Fujiyama *et al*. (2014) find that adjusting train width and platform step height improved boarding/alighting. This hard measure is a useful consideration in the construction of new metro stations or procurement of new rolling stock but would be a very expensive investment for an existing network to retrofit platforms or adjust train doors. Karekla and Tyler (2012) analysed the Victoria line in London to determine the possibility of reducing dwell time by making specific changes to train system hardware which entails both trains and platform. Using data from London Underground and on-site observation they test different models with 4 different scenarios which are: only platform step height reduction, possibility of holding train dwell time at 20seconds, only train door width reduction and a combination of platform step height and door width reduction.

Not surprisingly Karekla and Tyler (2012) conclude that adjusting the width of train doors and platform step height are most effective in reducing dwell time, which is quite like the conclusion arrived at by Thoreau *et al*. (2016) who opine that the optimum train door width should be somewhere between 1.7 and 1.8 metres. Again, this is an expensive hard measure especially for an existing network. Even when the cost of adjusting train door width can be deferred until new stock are due to be purchased anyway, it would still cost London Underground approximately £1.5m per platform to adjust the height (Karekla and Tyler, 2012). Platform edge doors (PEDs) are installed on platforms to reduce platform train interface issues thereby reducing delays and speeding up train service. PEDs have been installed in many modern metros and normally work *pari passu* with the train doors as barriers between the train and the passengers on the platform. Installing PEDs at existing and curved platforms can be expensive and prove to be an engineering challenge.

De Ana Rodriguez *et al*. (2016) find that PEDs have negligible effect on passenger boarding and alighting time while Thoreau *et al*. (2016) conclude that effect of PEDs is mixed. It can however be argued that PEDs affect dwell time through the control of passenger behaviour that may affect train on-time departure. *Ceteris paribus*, PEDs help passengers queue at the right place and eliminate the guess work in determining where the train doors would be. This can be important in controlling dwell time, but not enough to warrant the huge investment cost.

Soft measures can be very cost effective and as efficient in controlling dwell time. A major variable in the dwell time management equation is passenger behaviour (Oliveira *et al*., 2019; Barron, 2016; De Ana Rodriguez et al., 2016; Harris, 2006; Wiggenraad, 2001). Therefore, platform communication systems that encourage passengers to pass along platforms to get on less crowded carriages of an arriving train have been proposed by the likes of Olaverri-Monreal *et al*. (2018) and Moncrieff (2015). Although already in use in some newer metros like Singapore, it can become counter intuitive as it may encourage 'bunching up' of passengers around the doors of the supposedly emptier carriage. In a field experiment carried out at Schiphol Airport station in Amsterdam Van den Heuvel (2016) finds that adjusting train stopping positions decreased dwell time by 30seconds during the peak, however Oliveira *et al*. (2019) opine that the method does not help with crowd control and is only effective in facilitating the boarding of less busy train carriages. The use of price structure to control demand and therefore platform dwell time can be effective (Douglas *et al*., 2011; Liu and Charles, 2013; Currie, 2011; Qu *et al*., 2018). But it comes at a cost, especially to the transport consumer, and it may encourage modal switch to less energy efficient modes which the costs us all!

Perhaps the closest interventions to the Green Lane experiment are platform communications and markings encouraging passengers to pass along the platform or not to hold train doors. These are traditional demand control methods and are quite common at metro stations, but operators should focus more on using these methods to effect positive behavioural change Barron (2016). This paper seeks to analyse of the implementation of such intervention can actually lead to a reduction in dwell time. To the best of our knowledge there is a gap in literature linking cause and effects between behavioural change intervention and dwell time reduction (Oliveira *et al*., 2018), this paper attempts to fill that gap; no less than by scientific methodology.

2.4 The Nudge Concept

We proceed by presenting the nudge concept which has become quite popular in economics, psychology and sociology in recent times. In their book, *Nudge*, Thaler and Sunstein (2008) advocate the use, or subtle manipulation, of an individual's choice architecture or choice environment to influence behavioural change by 'nudging' them into conformity. The idea is a relatively gentle paradigm shift that is aimed at encouraging people to make decisions that are in their best interest, without incurring any financial or legal penalty for non-conformance. Many governments now implement the nudge concept when enacting policies, we identify just two here. The United States under Barack Obama employed the services of Cass Sunstein as the Administrator of the Office of Information and Regulatory Affairs, a post that comes with enormous power and the responsibility of overseeing federal regulation. In 2010 a former British prime minister, David Cameron, set up what is considered as a 'nudge unit' (The Behavioural Insight Team) in the Cabinet Office. The team is tasked with using behavioural economics and market signals to enact government policies geared towards softly influencing behaviour and attitude to achieve government long term goals. Since inception the team has produced reports on methods and applications of theoretical economic concepts with application to areas such as taxation, health and energy (Behavioural Insight Team UK, 2010, 2011, 2012; Oliver, 2013; Dolan *et al*., 2012). The idea has been shown to work in practice. The organ donation opt-out policy already in use in Spain is an apt example of the implementation of the nudge concept, citizens are assumed to consent to donating their vital organs when they die unless they opt-out themselves while alive. It must be recognised however, that the organ donation policy has cultural and religious implications. But the individual has the right to opt-out at any time which makes it difficult for the libertarians to criticise this policy as it does not remove from the individual's ability to make rational choice that is self 'satisficing', it can however be argued that presenting the choice in the first place to the individual to make presents a level of paternalism (see Thaler and Sunstein, 2003; Sunstein and Thaler, 2008; Heap, 2013; Camerer *et al*., 2003). Another example is the 2012 government policy on UK pension scheme. To increase the pension saving rates among the private sector workers the government mandated employers to implement an automatic enrolment scheme on their pension funds. This meant that staff would be automatically enrolled for the firm's pension scheme and the appropriate contributions deducted from the employee's paycheck unless and until they make a deliberate effort to opt out, quite simply the nudge concept is an anti-regulatory approach to influencing behavioural change. Some behavioural economists opine nudge must serve as a complement to regulation and never a substitute (Loewenstein *et al*, 2012) while others like Marteau *et al* (2011) have criticised it for undermining the potentials of effective regulation when need be. Nudge is widely used in many spheres of human existence and we now highlight just a few of those instances in the transport sector.

### 2.5 Some Transport Sector Nudges.

While it is common to attribute the introduction of the concept of nudging to Richard Thaler and Cass Sunstein, the idea predates them and has been in operation for many years. London Underground has used the nudge idea in many of their campaigns dating back to 1926 as can be seen in Figures (1 and 2) below. This is some sort of renaissance of the social proof idea which simply asserts that people tend to follow the popular paths, that is, following the herd syndrome (Cialdini, 1984; Harris, 2006; De Ana Rodriguez *et al*., 2016).


1926 LU Behavioural change poster    1944 LU Behavioural change poster

*Figure 1: London Underground behavioural change posters.*

The idea was to cause a behavioural change in commuters to facilitate a reduction in dwell times and delays to the train services; the concept remains the same in this decade. A deviating passenger may get a social sanction in the form of a 'look' or even a 'telling off' by other transport users. The 1975 poster is closely related to the Green Lane experiment used in this paper. Again, any commuter standing at the door way or seen as obstructing the door way may receive a sanction from the other commuters or even station staff.


1975 LU Behavioural change poster.    2015 LU Behavioural change poster.

*Figure 2: London Underground behavioural change posters.*

Another example is seen below (Fig. 3), where the local council of Tonbridge and Malling in Kent, United Kingdom use a roadside sign to encourage people to change their behaviour and attitude towards littering.


*Figure 3: A roadside litter campaign in Kent (Adapted from Tim Harford, 2014)*

Figure 4 shows pictures of speed bumps drown on a London street which makes drivers slow down as they pass the bumps. It should be mentioned however, that the effects of some of these signs diminish with continuous us; that is, once people realise they are just pictures they tend not to conform, but non-frequent users are still expected to obey instinctively. On the other hand, a catastrophic negative externality of these innovations is the real possibility of a collision between a pedestrian thinks it is real and a driver that knows it is not real.

*Figure 4: Optical illusion speed bumps on a London road (BBC, 2016).*

These are just a few of the instances where the nudge concept has been used in achieving transport goals. To the best of our knowledge, literature and research establishing cause and effects of the use of nudge concepts and social norms in the transport sector is scare or even non-existent.  The goal of this paper therefore, is to attempt to analyse, if existing, the cause and effects of the use of nudge concepts as a transport policy tool. Can social norms be used as cost effect tools in reducing dwell times? Today many modern railways and metro systems are investing in additional capacity; these include new trains (Like the London Underground S-stock which has walk through cars) and signalling systems. If network or line capacity can be defined as the equivalent of train frequency multiplied by train capacity, it then follows that capacity could be constrained by network or line train design, train operations, management structure and network infrastructure and capabilities, signalling systems, and station dwell times (Barron, 2016; Karekla & Tyler, 2012; Wright, 2015). Dwell times management is mostly about passenger movement management. It focuses particularly on the human factors side of the railway management equation and encompasses both passengers and operational staff alike and particularly important if the benefits of the investments in the other parts of the network would be realised (Barron, 2016). As Bray (2017) puts it "spending on transport programmes that focus on influencing the brains of travellers, rather than infrastructure, can be effective."

## 3. Methodology

3.1 The London Underground (LU) Network.

London Underground is the oldest network in the world, which ran its first train service in 1863. With this title come capacity and structural challenges as many of the modernisation works to the network are either impossible or very expensive to retrofit. The network consists of 17 different lines connecting some 270 stations and extends to 250 miles of track with about 45 per cent of it in tunnels making it the 7$^{th}$ largest and 3$^{rd}$ longest (in kilometres) network in the world. Figure 2 is a section of the London Underground network (Tube map). In 2017 the network served about 4 million passenger journeys per day making it one of the busiest metros in Europe in terms of passenger demand, just after Moscow and Paris respectively. The central zones are the busiest and connect passengers to many of London's landmarks and financial hubs.

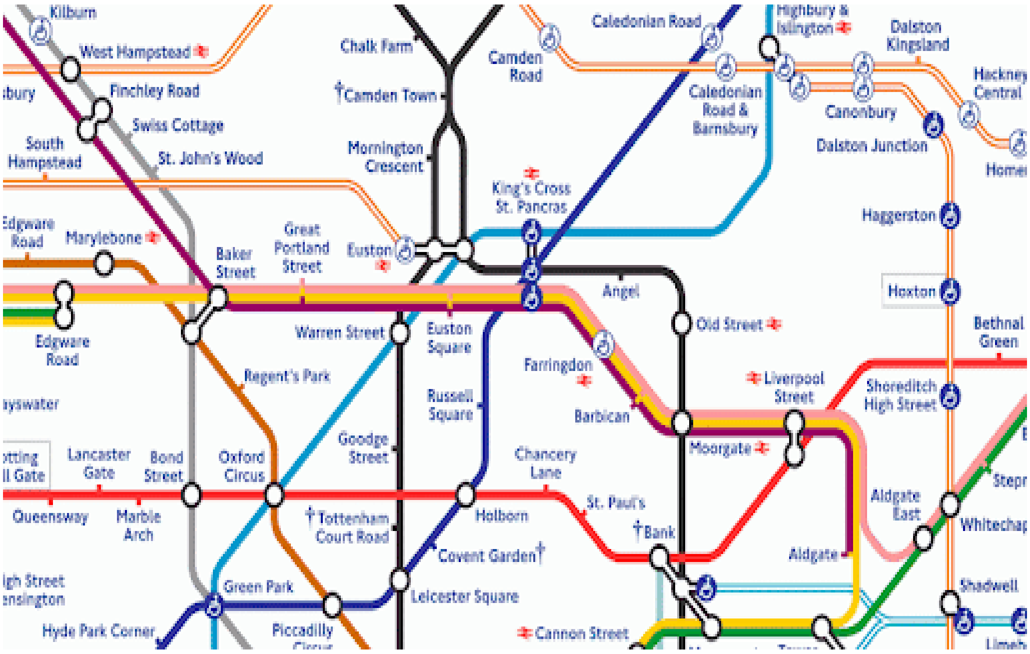

*Figure 5: Section of the Tube Map.* *Source: http://content.tfl.gov.uk/standard-tube-map.pdf*

It is important to note that the users of this network face overcrowding on the platforms in the peak times (0700 – 1000 hours and 1600 – 1900 hours). Critical congestion occurs particularly in the 'peak of the peak' (0800 – 0900 hours and 1645 – 1730 hours) when the network is busiest and operating close to its maximum capacity. At these times passengers face delays as they may be unable to board the first available train and even the subsequent ones depending on their position on the platform and level of congestion on both the platform and the arriving train. Consequently, London Underground is constantly seeking for innovative and cost-effective methods of improving customer experience and reducing the generalised cost of travel. One of such ways is the Green Lane project designed to influence passenger travel in a certain way to aid the reduction of dwell times, travel time and costs.

### 3.2 The Experiment

The Green Lanes project was aimed at influencing passenger behaviour in a transport setting. It was an experiment performed at the platform level in a bid to aid the reduction of the generalised cost of travel for customers by decreasing dwell and journey times which would, in effect, increase the capacity for more service frequency at the treated station. This could be achieved through 'nudging' passenger behaviour using majorly visual and audio cues, but without incurring high costs or imposing physical or financial impediments. The project commenced on the 17th of July 2017, and the lanes remained in place till early 2018 but the data for this paper were from inception of the Green Lane to the end of November 2017.

To perform the experiment the Victoria line at London King's Cross station was chosen because of its central location and the persistent increases in dwell times in recent years. King's Cross station is a major hub and terminal with connections to many parts of London, England and Scotland even. The Victoria line serves several central and very important stations linking many of London's landmarks, central and suburban districts. It was completed in 1968 as a new line on London Underground network and was designed to reduce congestion on other lines like the Piccadilly line. However, dwell times have increased due to congestion brought about by persistent rise in travel demand over the years. King's Cross station constitutes a pinch point location and a bottle neck on the Victoria line, but only the southbound Victoria line was chosen for treatment because the dwell times on this platform increased significantly from 35 seconds to 47 seconds between 2015/16 working timetables (Goodwin 2017).

*Figure 6: Green lanes at London King's Cross station. Adapted from Goodwin, 2015.*

The attractiveness of this experiment is in its simplicity. As can be seen in Figure 3, Green vinyl was laid on the platform in such a way that encourages customers to pass along the platform until they find a non-green space to stand and wait for a train. The green vinyl also showed where the doors would open when the arriving service train comes to a complete stop at the platform edge. The choice for the green colour is in accordance with international convention for green indicating ‘clearance to proceed’. The passengers are expected, or at least encouraged, to keeping moving on any green section of the platform and not to stop until they get to any non-green section. When a train arrives at the platform, the alighting passengers use the space on the Green Lanes spurs to exit the platform so that passengers waiting in the non-green sections could board quicker. In theory, this should eliminate or at least reduce the pushing, bumping and shoving that happens at peak times when the platforms are crowded. It would also help control the frequency of the occurrence of platform train interface (PTI) issues. This consists of injuries to passengers or staff including getting caught in the closing doors or having items caught between the doors at the platform edge. At all times during the experiment there were visual cues like posters and direction markers encouraging passengers not to stand or wait on any green section but to keep moving while on it, at peak times however, there would be a member of station staff on the platform performing what London Underground termed SATS duties. This entails giving audio messages, managing overcrowding on the platforms and assisting the train driver in ensuring safety on the platform during train arrival and departure. A close alternative to the Green Lanes is the platform edge doors (PEDS) which can be found on the new sections of the Jubilee line in London and in many new metro networks in the world. As the London network is old and extensive, updating them by retrofitting platform edge doors on old and curved platforms would be an engineering challenge and significantly more expensive than the Green Lanes vinyl.

3.3 Operating Procedure.

The Victoria line is a deep-level line and runs an automatic train operation process, but all the trains have train operators (drivers) in the front cab. The driver can intervene when automation breaks down as well as assist with doors opening and closing to minimise PTI issues resulting in injuries. There are 16 stations on the route and King's Cross station is somewhat in the middle in Zone1 providing interchanges with other London Underground lines and National Rail services. The Victoria line is used by around 200 million passengers each year, making it the sixth-most heavily used line on the network (TfL, 2014). When the train arrives at the platform, the driver opens the doors for alighting and boarding to commence. The driver monitors this process through the in-cab and platform CCTVs depending on location. Provided the station starting signal is clear (clear signals are usually green and indicate to the driver that they can proceed), the driver then pushes the doors close button which in turn triggers a process that effectively brings boarding and alighting to completion. This usually begins with an audible sound that only lasts for a couple of seconds or so before the doors begin to shut. The trains are fitted with sensitive edge technology; this is a safety device which ensures the doors are completely shut without which the train would be unable to proceed. A clear signal indicates that the route ahead is clear of any train, secure, and safe for the train to proceed. As soon as the doors close the train departs, once it clears the platform and section of track, it is then safe for the next train to arrive. The process is repeated at the arrival of the next train with the driver on-board.

The station starting signal is automatically controlled by a computer preloaded with a predetermined running timetable which has the scheduled arrival and departure times of every train going through every platform on a line. If a train arrives before the scheduled arrival time, the starting signal remains at danger (red) and would only clear at the scheduled departure time. This always remains the case safe for when a failure occurs, at which point the signalling process would be controlled by a duty Signalling Operator and the service itself regulated by a duty Service Controller. The passengers are encouraged to stand at the non-green areas so as not to obstruct the flow of traffic especially at peak times. At both the AM and PM peak times there is usually a station staff member on the platform assisting with platform duties as mentioned before. They were tasked with encouraging passengers to acknowledge the Green Lane and to conform to the rule of not standing or waiting anywhere on the Lane. The Green Lane keeps the walkways clear for alighting passengers to easily disembark from the train so that boarding can commence quicker.

3.4 Data

The Green Lane intervention officially commenced on the 17th of July 2017 with the lanes laid only on the southbound Victoria line platform which conveniently provided the treated platform or group as it were. The dwell time data were supplied by TfL using specific software that records detailed real time train movements to the second. The data includes dwell time counts for London Underground services from 5am to 1.30am from Monday to Friday (weekdays), but we restrict our sample to trains departing between 6am and 11pm, since platform crowding does not occur outside this time interval. The weekend data have been excluded owing to lower weekend service frequency, prevalence of engineering works leading to platform or station closures and decreased weekend demand. Furthermore, any abnormally long or short dwell time is disregarded, as rule of thumb any dwell time <10 or > 70 seconds is excluded as this is an indication of service disruption, retaining 96% of dwell time observations. All trains arriving at the study platforms have an arrival time and a departure time, the time difference between these variables gives the dwell time (Dwell) in seconds. The dwell times extracted are from 21st of May to 30th of November for both 2016 and 2017, which in effect creates two pre-treatment periods. For the control platforms, all other platforms (both directions) at LU King's Cross station, as well as stations before and after King's Cross station on all lines passing through King's Cross have been included. These constitute: Angel, Caledonian Road, Euston, Euston Square, Farringdon, Highbury and Islington, and Russell Square.

### 3.5 Identification

We identify the effect of the green lanes on dwell times by comparing the change in dwell times at the treated platform with changes in dwell times at different sets of control platforms. Our data is unique and present us with different choices as control observations. Any change in dwell times that we observe between post and pre-treatment dwell times on the treated platform could be due to any of the following effects:

- Dwell times are longer after July 17th (regardless of the year).
- Dwell times have decreased on the Victoria line (regardless of station).
- Dwell times have decreased at King's Cross station (regardless of service line).
- Dwell times have decreased because of the Green Lanes intervention.

Our estimation strategy is to estimate the effect of the Green Lanes based on different combinations of control observations – and correspondingly different assumptions regarding the counterfactual trend in dwell times on the treated platform. We start with the Difference-in-differences (DD) estimator where the change in dwell times over time on the control platforms is subtracted from the difference on the treated platform. This removes biases in second period comparisons between the treatment and control platforms that could be the result from permanent differences between those platforms, as well as biases from comparisons over time in the treatment platform that could be the result of trends (Imbens and Wooldridge, 2007).

Let $Y_{tsld}$ represent the natural logarithm of dwell time[3] of a train at time *t*, at station *s,* on service line *l*, and travelling in direction *d.* Here, *t* is any moment in time from 6am on May the 21st to 11pm on November 30th in 2016 and 2017, and *d* can be inbound (towards central London) or outbound (away from central London). We further define the following variables:

$Post_t$ = 1 if *t* is later than 6am, July 17th, in either year (2016, or 2017), and 0 otherwise.

$D2017_t$ = 1 if *t* is in 2017, and 0 if *t* is in 2016.

$Kings_s$ = 1 if *s* is King's Cross station, and 0 otherwise.

$Victoria_l$ = 1 if *l* is the Victoria line, and 0 otherwise.

$In_d$ = 1 if the *d* is inbound, and 0 otherwise.

An observation is identified as subject to the Green Lane treatment, if (and only if) all those indicator variables are equal to 1.

Where applicable, we also include the following control variables: *Demand* is the sum of daily station entries and exits. We include it as a control variable since higher demand is likely to increase dwell times. Since the demand variable is a total

[3] Residuals from a dwell time regression exhibit a log-normal distribution. We therefore use the natural logarithm of dwell times as the dependent variable, which also results in a better model fit in terms of $R^2$.

daily count of the number of passengers through the gates it is difficult to apportion the passengers to individual platforms at the stations of entry or exit. We thus assume demand to be constant throughout the day and across station platforms, but include *Interchange*, a variable counting the number service lines through a station. It is typical that stations with high interchange options tend to have higher demand. In addition, *DemandPerLine* has been added to account for demand level at each platform in a station. This is just a simple arithmetic division of the total station demand by the number of lines at the station. *ServiceLevel* as the variable name suggests, is the service level or headway variable which represents train service frequency measured in seconds. This is effectively the time interval between two scheduled train arrivals and is expected to be negatively correlated to dwell time; higher service frequency reduces station dwell times. *ServiceLevelDemand* is a variable interacting demand and the level of train service on a line. We also include dummies for each 15-minute interval of a day (from 6am to 23pm), for each weekday, and for each month. Finally, we allow for different trends in dwell times by year as well as by treatment period (e.g. before and after the 17$^{th}$ of July). The error term $\varepsilon_{tsld}$ is assumed to be independent of either the treated and untreated groups or platforms and have identical distribution over time. In addition, robust standard errors are used to account for heteroscedasticity. The sample data used consist of weekday data of both inbound and outbound trains from the city centre.

The intuition behind the standard DD is to capture the effects of the Green Lane policy intervention on dwell times at the treated platform relative to dwell times at the control platforms, so four sets of controls were used to estimate four different DD estimates. The interpretation given to the standard DD estimate is a function of the assumptions made about how the policy intervention affects the outcome of interest (see Athey and Imbens, 2006). Here it is assumed that the treatment effect is constant across individual dwell time observations, depending on the period of observation (e.g. peak or off-peak). The estimates obtained by these DD methods depend on the key identifying assumption that the paths of dwell time changes, if any, for both the treated and control platforms would not be systematically different in the absence of the Green Lane intervention, so that only the intervention itself induces a deviation from this so-called *common trend* assumption. Put differently, the pre-treatment gap is zero so the response of both the treated and control platforms are the same before the intervention (Lee, 2016).

To estimate the effects of the Green Lane project on dwell times, we compare the change in dwell times at the treated platform – southbound Victoria line at King's Cross station – before and after the implementation of the policy in 2017 and then compare this change with the corresponding changes to dwell times at:

- The same station, line and year but the opposite platform at King's Cross (Northbound platform) where no Green Lanes were registered.
- The same station, line and direction in the previous year where no Green Lanes were registered.
- The same line, year, and direction of travel but in adjacent stations where no Green Lanes were registered.
- The same station, year, and direction but for other service lines.

We estimate the following equations;

$$Y_{ts} = \alpha + \beta Post_t + \gamma Kings_s + \delta(Post_t \cdot Kings_s) + \rho X_{ts} + \varepsilon_{ts} \qquad (1)$$

Where the sample is restricted to inbound trains on the Victoria line in 2017. The parameter of interest here is δ, which is the estimated treatment effect of the implementation of the Green Lane policy on dwell times at the treated station. A negative δ represents a decrease in dwell times at King's Cross Victoria line platform compared to the dwell times at the control stations on this line (Euston and Highbury & Islington) in the same direction of travel.

$$Y_t = \alpha + \beta Post_t + \gamma D2017_t + \delta(Post_t \cdot D2017_t) + \rho X_t + \varepsilon_t \quad (2)$$

Where the sample is restricted to inbound trains on the Victoria line at King's Cross station. Equation (2) controls for effects which are specific to the time of the year (seasonality effects). A negative δ indicates a decrease in dwell times at the southbound Victoria line at Kings Cross in 2017 compared to the same time period in the preceding year (2016) when no Green Lanes were in effect.

$$Y_{tl} = \alpha + \beta Post_t + \gamma Victoria_l + \delta(Post_t \cdot Victoria_l) + \rho X_{tl} + \varepsilon_{tl} \quad (3)$$

Where the sample is restricted to inbound trains at King's Cross station in 2017. We look at dwell times at all the other lines running through King's Cross station and compare them to those of Victoria line before and after the intervention and in the same direction as stated earlier. If δ is negative, then Green lanes caused the decrease on the Victoria line platform compared to the other lines at King's Cross.

$$Y_{td} = \alpha + \beta Post_t + \gamma In_d + \delta(Post_t \cdot In_d) + \rho X_{td} + \varepsilon_{td} \quad (4)$$

Only equation (4) uses dwell time data from both directions of travel. We compare dwell times at the untreated outbound (northbound) platform with those at the treated inbound (southbound) platform in 2017. Our a priori expectation is that there would be no treatment effect on the opposite platform since no intervention was registered there.

3.6 Triple (DDD) and Quadruple Difference Methods.

In our setting, the common trend assumption of the DD estimator for any of the above models might not hold. To see this, consider the following example. Assume that dwell times decreased by three seconds at the treated platform, and that dwell times at other stations on the Victoria line also decreased by two seconds. If we estimate the treatment effect with equation (1) we would obtain a treatment effect equal to 1 second – and assuming that the common trend was a decrease by 2 seconds. But what if, during the same time period, dwell times for other service lines at King's Cross station also decreased by 1 second compared to dwell times at other stations? Then, the estimated treatment effect is likely to be spurious and fully explained by some effect specific to King's Cross station. Therefore, we expand our estimation to triple and quadruple difference estimators. The triple difference in a given year can be calculated as follows:

$$Y_{tsl} = \alpha + \beta Post_t + \gamma Kings_s + \varsigma Victoria_l + \delta(Post_t \cdot Kings_s) + \vartheta(Post_t \cdot Victoria_l)$$

$$+ \eta(Victoria_l \cdot Kings_s) + \iota(Post_t \cdot Victoria_l \cdot Kings_s) + \rho X_{tsl} + \varepsilon_{tsl} \qquad (5)$$

The difference in dwell time changes between King's Cross station and adjacent stations is calculated for service lines other than the Victoria line giving us the change in dwell times specific to King's Cross station. Under the assumption that this effect is the same across service lines, we can subtract this difference from the difference in dwell time changes between King's Cross station and adjacent stations for the Victoria line and obtain the effect of the green lanes on dwell times. In a regression as in equation (5), this effect can be estimated by a model with a full set of interactions of the variables $Post_t$, $Kings_s$, and $Victoria_l$. The green lane effect will be given by the coefficient on the triple interaction term $Post_t \cdot Kings_s \cdot Victoria_l$.

Since there are three potential sources of dwell time changes alternative to the Green Lane intervention (season, station, and service line), we can estimate three different triple difference effects, each based on a different assumption. Other than the triple difference described above (based on station and service line), we thus estimate two further triple difference treatment effects. One under the assumption that the difference in dwell time changes between King's Cross and adjacent stations on the Victoria line would be the same in 2016 and 2017 in the absence of the green lane intervention, and another one under the assumption that the difference in dwell time changes between the Victoria and other service lines at King's Cross station would be the same in 2016 and 2017 in the absence of the Green Lane intervention. Finally, one might object to the identifying assumption of any of the triple difference in equation (5). The difference in dwell time changes between King's Cross and adjacent stations might be different for the Victoria line than for others (e.g. because the Victoria line might carry more passengers through King's Cross station than other service lines). If, however, these differences between the Victoria and other lines are the same across years, then we can add yet another difference in time to obtain the quadruple difference estimate of the Green Lane intervention. In a regression, this effect can be estimated by a model with a full set of interactions of the variables $Post_t$, $Kings_s$, $Victoria_l$, and $D2017_t$. The Green Lane effect will be given by the coefficient on the quadruple interaction term $Post_t \cdot Kings_s \cdot Victoria_l \cdot D2017_t$.

Our empirical strategy thus amounts to the estimation of the effect of the Green Lane intervention on dwell times under a set of different assumptions, and to demonstrate that each of those assumptions yield a statistically and economically significant effect. While the correctness of any of the assumptions cannot be known, it seems very improbable that all our estimated treatment effects should be attributable to a factor other than the Green Lane intervention.

3.7 Delay Time Analysis

Given scheduled departure times of trains, any intervention to speed up alighting and boarding times of passengers would have an effect on dwell times only if the train exceeds or is close to exceeding its scheduled departure time. Otherwise, even if alighting and boarding completes faster, the train would have to wait on the platform until its scheduled departure time, thus only prolonging the time where it is idle. We therefore extend the analysis to an investigation of whether the green lanes had a stronger effect on reducing delay times rather than dwell times in general. To do this, we have to take into account that 1) we observe delay times only once a train exceeds its scheduled departure time, and 2) we do not observe the train's regular dwell time once it is delayed (rather, the delay time is censored). Consider the following empirical model. A train is scheduled to stay on the platform for $\bar{t}$ seconds. A latent dwell time variable $Y^*_{tsld}$ and a latent delay time variable $Z^*_{tsld}$ are given by

$$Y^*_{tsld} = \beta X_{tsld} + \epsilon^y_{tsld} \qquad (6)$$

$$Z^*_{tsld} = \gamma X_{tsld} + \epsilon^z_{tsld} \qquad (7)$$

The actual dwell time $Y_{tsld}$ is observed only if $Y^*_{tsld} \leq \bar{t}$ , in which case

$Y_{tsld} = Y^*_{tsld}$, and the delay time is unobserved. If, on the other hand $Y^*_{tsld} > \bar{t}$, then the actual delay time is given by $Z_{tsld} = Z^*_{tsld}$, and we know that the latent dwell time exceeds the schedule $\bar{t}$: $Y^*_{tsld} > \bar{t}$ .

We assume that the errors are jointly normally distributed:

$$\begin{pmatrix}\epsilon^y \\ \epsilon^z\end{pmatrix} \sim N\left(\begin{pmatrix}0 \\ 0\end{pmatrix}, \begin{pmatrix}1 & \sigma_{yz} \\ \sigma_{yz} & \sigma_z^2\end{pmatrix}\right)$$

The contribution of a train on schedule and with observed dwell time $y$ to the likelihood function is given by;

$$\phi(Y^* = y) = \int \phi(Y^* = y, Z^*)\mathrm{d}Z^* \qquad (8)$$

and the contribution of a train delayed by $z$ (seconds in natural logs) is given by;

$$\int_{\bar{t}}^{\infty} \phi(Y^*, Z^* = z)\mathrm{d}Y^* \qquad (9)$$

Amemiya (1985) derives closed form solutions of the likelihood of this class of models (p. 386). We estimate the above model with maximum likelihood. Both latent variables are modelled as a quadruple difference (see previous section), and no restrictions are placed on the parameters within or across the latent variable equations. We thus allow the green lanes to have differential effects on regular dwell and delay times.

One constraint that we face is that we do not observe the scheduled arrival and departure times of all trains. However, from trains for which we do observe these data, we can impute a train's scheduled dwell time. Our delay time is thus based on the difference between scheduled and actual *dwell* times, rather than the scheduled and actual departure times. For example, if a train arrives 5 seconds behind schedule, and departs 5 seconds behind schedule, it would be classified as departing just on time according to our imputation. Because the service frequency is high (on the Victoria line a train runs every 2-3 minutes), this misclassification should not be of concern, as passengers do not arrive at the platform with the intention of catching a particular scheduled train, but rather to get on the next available train regardless its scheduled departure (actual timetables for the Underground are not displayed on the platforms or on TfL's website).

## 4. Results.

The main results are presented in Table 1. The first column shows result from the linear dwell time model, while the second and third columns are results for the delay time model described in section 3.7. The second column shows the impact of the green lanes on regular dwell times, while the third column shows the effect on delay times. We start by comparing the dwell times before and after the Green Lane intervention on the Southbound Victoria line at King's Cross station. The result suggests no significant drop in dwell time on the treated platform from pre to post treatment (*Simple difference*). We then use dwell time on the same platform and in the same period in 2016 as control to measure the possible treatment effects in 2017; this is intuitive as it accounts for any seasonal patterns on dwell time by comparing platform dwell times for both years (*Difference-in-differences (1)).* We observe no significant reduction in dwell time changes between 2017 and 2016 at the treated platform. However, if we compare the dwell times between 2017 and 2016 at the other untreated platforms at King's Cross station, we observe a significant increase in dwell time of just over 2 seconds (not reported). This suggests that while dwell times may not have changed on the southbound Victoria line platform at King's Cross station between the 2016 and 2017 study period, it however increased at all other London Underground platforms at King's Cross station over the same period. Under the assumptions discussed in sections 3.5 and 3.6, this *suppression* of dwell time increase at the treated platform can be attributed to the Green Lane treatment policy.

Table 1: Treatment effect estimates of Green Lanes

| | Dwell Analysis | Delay Analysis | |
|---|---|---|---|
| Model | Effect on dwell time | Effect on dwell time | Effect on delay time |
| *Simple difference* | -0.2 | 3.1 | -9.3** |
| | (0.4) | (2.9) | (2.6) |
| *Difference-in-differences (1)* | 0.3 | 5.7* | -12.6** |
| | (0.4) | (2.6) | (2.5) |
| *Difference-in-differences (2)* | -1.4** | 0.2 | -4.7** |
| | (0.2) | (1.4) | (1.4) |
| *Difference-in-differences (3)* | -1.2** | 2.3 | -8.0** |
| | (0.3) | (1.4) | (1.1) |
| *Triple difference (1, 2)* | -2.2** | 0.4 | -9.4** |
| | (0.3) | (2.0) | (2.0) |
| *Triple difference (1, 3)* | -5.4** | -0.8 | -10.5** |
| | (0.4) | (2.1) | (1.7) |
| *Triple difference (2, 3)* | -3.5** | -1.4 | -8.6** |
| | (0.3) | (1.8) | (1.5) |
| *Quadruple difference (1, 2, 3)* | -8.7** | -6.2* | -11.8** |
| | (0.5) | (2.6) | (2.2) |

Notes: The coefficients are percentage changes in dwell/delay times. Standard errors are in parentheses.
* $p < 0.05$, ** $p < 0.01$. (1) uses the treatment platform in 2016 as control observations, (2) uses adjacent stations on the Victoria line as control observations, (3) uses other service line platforms at King's Cross station as control observations. All regressions control for *Demand, Interchange, DemandPerLine, ServiceLevel, ServiceLevelDemand,* month dummies, day of the week dummies, dummies for each 15-minute interval of the day, as well as linear time trends for 2017 and, where applicable, 2016. See also methodology section.

*Difference-in-differences 2* shows the treatment effect when we use Victoria line platforms on either side of King's Cross station, (Euston and Highbury & Islington) and in the same direction of travel as control platforms. We observe a 1.4% decrease[4] in dwell time at the treated platform compared to the dwell time change at the control platforms. Since the policy intervention happened at King's Cross and not at the other stations the decrease can be attributed to the Green Lane policy. If we compare dwell times at the treated platform to

[4] The mean dwell times at the treated platform before treatment is 37.4 seconds.

those at the other untreated London Underground lines in the same station, in 2017 and the same direction, we find a reduction of dwell time by 1.2% (*Difference-in-differences 3*).

The next three rows display the estimated treatment effect for the triple difference estimator. *Triple difference (1, 2)* uses adjacent stations on the Victoria line and the treated platform in 2016 as the second control observations. *Triple difference (1, 3)* uses other service lines at King's Cross station and the treated platform in 2016 as control observations. *Triple difference (2, 3)* uses adjacent stations on the Victoria line and other service at King's Cross station as control observations. The estimated reductions in dwell times range from 2.2% to 5.4%. Finally, the quadruple difference estimator – the most general model – suggests that dwell times were reduced by close to 9% – a reduction of more than 3 seconds.

The second and third columns explain whether these changes in dwell times came about through a general reduction of dwell times or through cutting the delay times of trains which were behind schedule. Since the service level and timetable in 2017 was not changed we would expect the reduction to come mainly through reduced delay times. This is what we observe. For all specification we observe highly significant reductions of delay time, ranging from 4.7% to 12.6%, while we find a significant reduction in the latent dwell time only in the quadruple difference model. The green lanes might well have had an effect on latent dwell times if trains at the margin of being delayed were able to depart without being delayed thanks to the green lanes.

We next turn to the analysis of dwell times differentiated by time of day. London Underground typically splits the day into AM peak (07.00 to 10.00), PM peak (1600 to 1800), Inter-peak (10.00 to 1600) and off peak (any time outside these times). Trains dwell longest in the AM and PM peaks due to demand as these are when commuters go to work, do school runs, etc.  The purpose is to examine if the Green Lane policy had a differing effect in any part of the day. Figure 7 is a plot of the estimated effects and confidence intervals against time of the day. We observe a significant reduction in dwell time in both the morning and evening peaks. As platform demand ramps up in both peak periods, it appears that passengers tend to conform to the platform norm by obeying the Green Lane policy; this in turn drives down dwell time by a fraction. During periods of less demand the Green Lane's effect is not so significant because the main driver of dwell time and a major cause of impedance to boarding and alighting is demand.

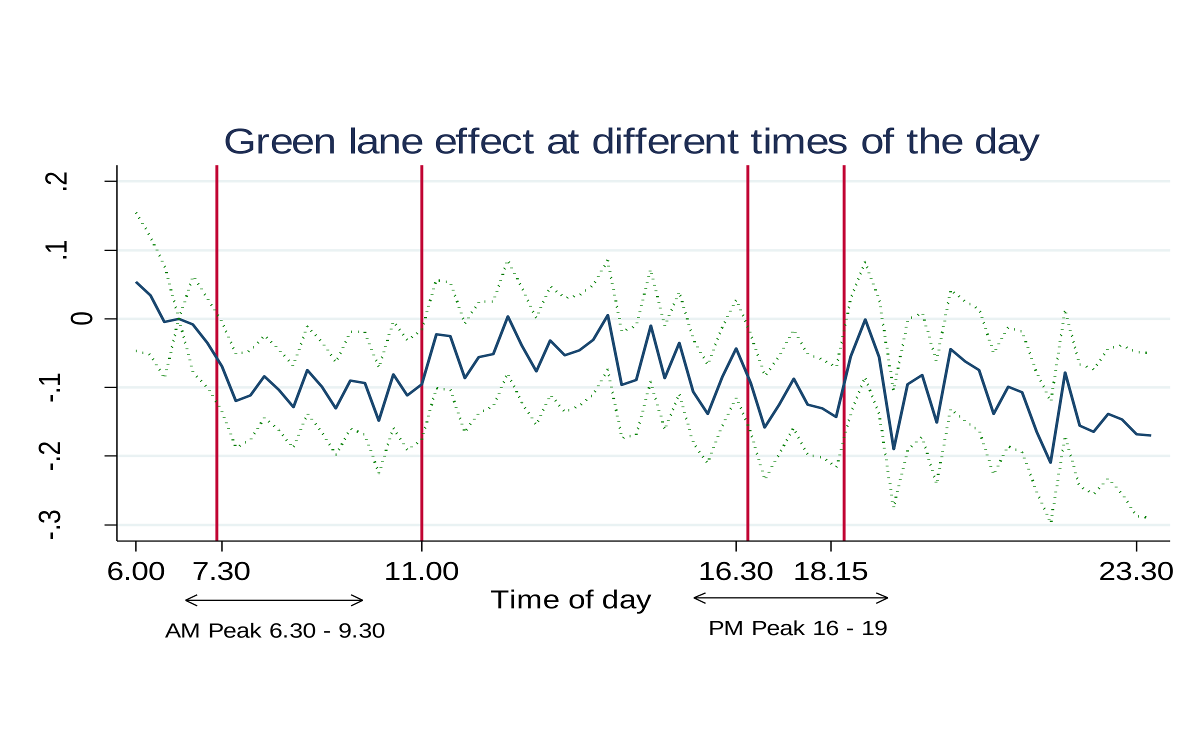


*Figure 7: Estimated effects and confidence interval plot.*

In a nutshell the graph suggests that the Green Lane had higher peak effects (both AM and PM) than on the inter-peak and off-peak periods. This concurs with the normative theory that passengers tend to conform more when they know their actions impact on others, which is more pronounced at peak times because of high demand for waiting area. At other times, when there the supply of waiting area out strips demand, passengers do not bother so much about how or where they wait as there is abundant space for alighting and boarding to take place, sometimes simultaneously. In passing, it should be pointed out that the off-peak period immediately preceding the evening peak appear to have a reduced dwell time affect vis-à-vis the inter-peak period, this due to difference in demand in both time periods.

We next analyse whether the green lanes had any effect on the opposite direction of travel. The effect of the Green Lanes on the opposite travel direction can be regarded as a placebo experiment because of the similarities of the two platforms. The outbound platform of the Victoria line at King's Cross station shares most characteristics with the inbound platform: it serves the same line, and therefore has the same service level. It is located at the same station (the two platforms are immediately connected, only separated by a passenger corridor; in particular, the platforms are not on opposite ends of the rails), and therefore has the same daily station demand and the same number of interchanges. The exact number of passengers served by a platform is not observed/measures, but it is probable that the platforms serve roughly the same number of people within a day – e.g. commuters whose return journey is the same as their onward journey. The outbound platform differs from the inbound platform in two respects: First, the distribution of passengers over the day is probably different, e.g. most traffic on the inbound platform might be concentrated in the morning, while most of the traffic on the outbound platform might be concentrated in the evening. Unfortunately, we observe only daily station demand, but do not know the exact time of day, nor how it is distributed across the service lines. Second, the outbound platform was not treated with the green lanes.

Table 2: Treatment effect estimates of Green Lanes - outbound direction

| Model | Dwell Analysis<br>Effect on dwell time | Delay Analysis<br>Effect on dwell time | Effect on delay time |
|---|---|---|---|
| *Simple difference* | 0.9 | 4.2 | -1.8 |
| | (0.5) | (3.4) | (2.3) |
| *Difference-in-differences (1)* | -1.4** | 2.7 | -9.8** |
| | (0.5) | (2.9) | (2.4) |
| *Difference-in-differences (2)* | -0.8** | -0.4 | 1.9 |
| | (0.2) | (1.6) | (1.2) |
| *Difference-in-differences (3)* | 0.3 | 2.3 | 0.6 |
| | (0.3) | (1.6) | (1.0) |
| *Triple difference (1, 2)* | -1.1** | -1.5 | 1.9 |
| | (0.4) | (2.1) | (1.9) |
| *Triple difference (1, 3)* | -1.5** | 0.5 | 1.9 |
| | (0.4) | (2.3) | (1.7) |
| *Triple difference (2, 3)* | -2.1** | -4.1* | 1.8 |
| | (0.3) | (2.0) | (1.3) |
| *Quadruple difference (1, 2, 3)* | -2.9** | -5.6* | 3.1 |
| | (0.5) | (2.8) | (2.1) |

Notes: The coefficients are percentage changes in dwell/delay times. Standard errors are in parentheses.
* $p < 0.05$, ** $p < 0.01$. (1) uses the treatment platform in 2016 as control observations, (2) uses adjacent stations on the Victoria line as control observations, (3) uses other service line platforms at King's Cross station as control observations. All regressions control for *Demand, Interchange, DemandPerLine, ServiceLevel, ServiceLevelDemand,* month dummies, day of the week dummies, dummies for each 15-minute interval of the day, as well as linear time trends for 2017 and, where applicable, 2016. See also methodology section.

Table 2 reports the results from this placebo experiment. While most specifications indicate a reduction in dwell times, the magnitudes are significantly below the effects we found for the inbound direction. When we analyse dwell and delay times jointly, we observe virtually no effect on delay times, except for the difference-in-differences model with 2016 as control observations – possibly reflecting a downward trend in demand which is not captured by our demand variables. It is curious that in the more general models (triple and quadruple differences) we observe dwell time reductions but no significant effects on delay times. One possibility is that the behavioural nudge not to block the opening doors might have had some externality on the outbound platform (since it will often serve the same passengers as on the inbound platform), but that this externality breaks down when trains are crowded and passengers are eager to get on the train leading to further delays in train departure. It is perhaps visually cogent to show the Green Lane effect graphically. Figure 7 shows a plot of the natural log quadruple difference regression coefficients and their confidence intervals plotted against time for every 15mins of the day.

## 5. Conclusion

Transport remains a key player in any major economy. The study of transport economics has become an important subfield of economics which, *inter alia*, deals with the cost-effective management of the demand and supply of transport services. If demand continues to grow, then economies and train operating companies must investigate and indeed invest in smarter ways of managing demand so that transport services can be supplied efficiently. One of such ways is the management of passenger behaviour through establishing norms that would encourage a paradigm shift and sustained behavioural change. This paper shows that norms can be very cost efficient when applied properly as was achieved at London King's Cross station. The Green Lanes changed passenger behaviour as people conformed to the existing platform norm. Passengers knew where the doors would be when the train comes to a complete stop at the platform edge. This reduced the interactions at the train side as passengers queued at the space provided by the Green Lane, which allows for clear doorway for the alighting passengers. The reduction in dwell time was achieved because of the combination of passengers standing at the right place and allowing passengers off the arriving train. This is particularly relevant to established transport networks operating close to or at full capacity and for which infrastructural adjustments can be prohibitively expensive. For a fraction of the cost of procuring new rolling stock or adjusting station structure to meet growing demand, the Green Lane policy achieved a reduction, or at least a prevention in the increase of dwell times at the treated platform vis-à-vis the control platforms. The mathematical modelling used in this paper controls for many variables such that the probability of the reduction in dwell time can be attributable to anything else, but the Green Lane is minimal.

That said, this study does nothing to diminish the importance of investments in transport structure and infrastructure, after all, norms can only work on existing structures. Many train operating companies invest in capacity-increasing methods that include technical and engineering solutions which consist of upgraded and new rolling stock and signalling systems that leads to more operation automation. But to achieve the anticipated increase in capacity the human-factor side of the equation must be considered appropriately. This paper advocates for a policy mix of both hard and soft measures to achieve optimum utility for all stakeholders. It is important that transport companies are dynamic and evolving in their approach to transport supply and management, which should be evidence based.

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