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Fare inspection in proof-of-payment transit networks: A review

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ABSTRACT

In proof-of-payment transit systems worldwide, fare inspection is the most widely adopted strategy against fare evasion from transit authorities and public transport companies. Although these actors attempt to make the inspectors' work as easy, effective, and equitable as possible, several issues need to be analysed according to a unifying approach, i.e., "*How, where and when to inspect*", "*Who and why evades the fare*", "*How many and how to distribute inspectors*" as well as improve the *inspectors' effectiveness*. Since no study exists in the literature investigating all these issues together, this paper aims to fill this gap with a review of several key papers that covered the full spectrum of relevant literature which, whole or partially, focused on fare inspection. Results show fare inspection is a beneficial strategy against fare evasion, but there are still many challenges and research limits that should be overcome in the years ahead. A possible research agenda is provided. It calls for specific options (i.e., data collection and fare evasion risk in hotspot definition, digital support and bottom-up approaches, size of inspection staff and scheduling of inspectors under realistic conditions and follower responses, effectiveness of actions focused on the visibility of fare inspection, managing interactions between fare inspectors and passengers) and integrated approaches (i.e., linking the planning, organisation, and activities of fare inspection with who and why evade). Nevertheless, even if this review may not be conclusive, these results support a unifying literature development on fare inspection.

1. Introduction

Fare evasion is a relevant concern for Transit Authorities (TAs) and Public Transport Companies (PTCs) worldwide, owing to the relevant economic and social implications it produces (Bonfanti and Wagenknecht, 2010; Wolfgram et al., 2022). Addressing fare evasion is complicated due to policy, enforcement, deterrence, operational, cost and equipment facets (e.g., Multisystems Inc. et al., 2002; Wolfgram et al., 2022). So far, a rigorous solution to this problem is not available, otherwise it would be in use by most TAs/PTCs worldwide. Notwithstanding, in *Proof-of-Payment* ticketing systems, one of the most relevant solutions is the ticket (or fare) inspection of passengers and the imposition of a fine if they are caught without a valid ticket. However, relevant revision of fare inspection policy and practice is needed to encourage the use of scientific approaches in TAs/PTCs.

Ticket (fare) inspection can be perceived as a natural bridge between TAs/PTCs (which aim to provide a valuable service for money) and evaders (who aim to avoid the fare payment). Inspection seems crucial, being applied by most TAs/PTCs worldwide (e.g., Dauby and Kovacs, 2007; Egu and Bonnel, 2020; Li and Min, 1985; Wolfgram et al., 2022). It is key in *Proof-of-Payment* ticketing systems without barriers because it represents the only means to verify that fares have been paid. Moreover, fare inspection has different positive impacts/benefits. During the day, its primary role is revenue protection; at night, as an ancillary role, it might increase the sense of security among passengers by providing a reassurance function against, e.g., harassment of passengers, violence, and could discourage social disorder (*e.g.,* Killias et al., 2009; Hansen et al., 2012). As an additional ancillary role, fare inspection could be associated with increased surveillance on transit that could deter vandalism against PTCs' apparatus and infrastructures (Barabino et al., 2020). Nevertheless, while the primary role is usually practiced by inspectors, other personnel could exercise the ancillary roles, as it happens in some TAs/PTCs worldwide. Finally, its effectiveness may improve revenues of public transport services and, hence, the viability of higher

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quality due to improved financial returns.[4]

There are complex, subtle, interlinked and sometimes conflicting issues associating equity and inequality concerns with fare inspection strategies. We define equity in this context to refer to the social application of inspections which should not be socially biased towards certain groups or individuals and hence 'unequal'. Rather an equitable inspection strategy would cover all groups equally.[5] The most obvious direct equity concern for fare inspection planning is the role of target profiling strategies in identifying passengers who are more likely to fare evade. Table 2 (below) synthesises research evidence on who fare evades; evidence of this type can be used to target selected passenger groups (termed 'profiling'). Since these groups include the unemployed, those on low/no income, students and older passengers, profiling can be interpreted as an attack on disadvantaged groups in society and hence highly unequal. For this reason, many researchers stress the need for equitable inspection strategies, since a regressive and inequitable strategy is very unlikely to be supported by the community (Barabino et al., 2020; Barabino and Salis, 2020; Barabino et al., 2022). In contrast targeting those avoiding fare payment is seen as equitable and fair by those who pay fares (Dauby and Kovacs, 2007) suggesting a need for balance between conflicting perspectives.

Significant social injustice as a cause of widespread fare evasion has been found in social protests in Chile (Busco et al., 2021) where some of the highest fare evasion rates are evident. Research has yet to explore the difficult implication of this for ticket inspection strategies in Chile; however, research on ticket inspector methods in France recognised the role of 'ideological opponents' for fare evasion (Suquet, 2010). In this case 'ideological opponents' were any individuals, usually a small minority, who challenge the legitimacy of fare inspections. Social injustice can by one of the many possible motivations for 'ideological opponents' though there can be many varied flavours of this. Currie and Delbosc (2017) found that some passengers believed that public transport outsourced to commercial businesses was only run for profit rather than for social benefit. These views acted to influence more permissive attitudes to fare evasion which predicted deliberate fare evasion.

Determining a suitable inspection planning, providing an accurate inspection, and increasing the efficiency of inspectors against fare evasion through several options connected to their daily activities are not trivial issues. All these issues derive from aims and policies of TAs/PTCs, operational characteristics, and constraints.

Many empirical studies have investigated the relationship between fare inspection and fare evasion in the attempt to show the positive effects by increasing the inspectors' recruitment (Van Andel, 1989) and/or inspectors' interaction (Hauber, 1993; Hauber et al., 1996; Killias et al., 2009; Keuchel and Swertz, 2020; Troncoso and de Grange, 2017). It is expected that fare evasion should vary with fare inspection, but the relationship is not clear. On the one hand, Dauby and Kovacs (2007) and Currie and Delbosc (2021) discovered negative correlations between fare evasion and fare inspection (the larger the inspection, the lesser fare evasion). For instance, in Melbourne, Currie and Delbosc (2021) found that doubling ticket-checking rates would reduce fare evasion on tram about a third. On the other hand, no clear correlations have been established elsewhere (Clarke et al., 2010; Multisystems Inc. et al., 2002; Wolfgram et al., 2022). In addition, results represent a quantitative summary index that lacks detail on how aspects of the inspection approach may affect its efficiency (e.g., evasion patterns, number of inspectors, inspectors with/without a uniform). This unclear trend might be observed because disagreements often exist among TAs/PTCs regarding the definition of fare evaders and inspected passengers (e.g., Lee, 2011; Barabino et al., 2020; Wolfgram et al., 2022). Therefore, this lack of standardisation makes comparing fare evasion rates and assessing the impact of changes in fare enforcement strategies challenging (if not impossible) and could lead to biased results.

Usually, TAs/PTCs attempt to address fare evasion by trying to make the inspectors' tasks as easy and effective as possible, but several issues need to be investigated. A pivotal element in boosting cost-effectiveness lies in strategically determining *"how, where, and when"* to perform inspections informed by diverse strategic factors (e.g., passenger volume, risk of fare evasion), with methods varying from targeted to random. Simultaneously, concentrated or higher ticket inspections can sometimes provoke negative reactions from some passengers for different reasons (Friis et al., 2020). Therefore, a range of research stresses the relevance of defining effective ticket inspection strategies based on a comprehensive understanding of evasion patterns and ascertaining "*who*" evades fares and "*why*", aiming for mindful and non-discriminatory inspection solutions (e.g., Mujcic and Frijters, 2021).

The effectiveness of inspection often requires several inspectors that could exceed the budget constraints of TAs/PTCs. Therefore understanding "*how many"* inspectors are needed and "*how to distribute"* them is crucial for TAs/PTCs. Moreover, because the public transport service runs for money, enhancing the inspectors' effectiveness is relevant, as they impact economic performance of TAs/PTCs. Notwithstanding, no study investigating all these issues exists to date in the literature.

In the literature, there have been two worthy reviews and a discussion article connected indirectly and directly to some facets of inspection against fare evasion. Delbosc and Currie (2019) focused on psychological issues highlighted three perspectives: (1) the conventional transit system, focused almost entirely on physical and processes control (e.g., inspection rates and fines); (2) the customer profiling, which isolated several segments of passengers that could be affected by inspection activity; (3) customer motivations, which focused on causal factors and motivations behind fare evasion that relate to inspection activities.

Barabino et al. (2020) characterised research on fare evasion into the areas of fare evader-oriented, criminological, economic, technological, and operational. They briefly revealed the interdisciplinary dimension of inspection, mainly reviewing criminology as a deterrence measure, economics as costs-benefit ratio strategy, and operations research as operational planning tasks on the distribution of inspectors along routes.

Boyd (2020) revised the foundations of fare evasion research. He argues that existing mathematical models assume that ticket inspections have a unidirectional effect on fare evasion. Therefore, they might overlook the chance of a bidirectional dependence of fare evasion and ticket inspection i.e., increased evasion could reduce inspection rates as well as increasing inspection could reduce fare evasion. However, as he recognised, "…*there is hardly any empirical evidence the idea that there is a bi-directional relationship between evasion and inspection…*" (pp. 318). In addition, he argues there may be multiple balance points between inspection and evasion that could be reached adopting a constant inspection resource. Finally, he provided some suggestions about inspection management, such as the deceptive manipulation of the perceived inspection activities.

The majority of methodological and empirical contributions cover detailed application-operational approaches on inspection that (often) developed solutions of explicit facets on specific contexts such as identifying the hotspots (e.g., Killias et al., 2009), verifying the effectiveness of inspector concentration (e.g., Guarda et al., 2016a), defining the optimal number of inspectors (e.g., Barabino and Salis, 2019) and their scheduling (e.g., Brotcorne et al., 2021; Escalona et al., 2023), or proposing some inspection visibility and perceived inspection actions (e.g., Keuchel and Swertz, 2020; Currie and Delbosc, 2021). However, the fragmentation of methods, solutions, and results makes it difficult to synthesize current knowledge on fare inspection and fare evasion.

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[4] In this study, the effectiveness of inspections is intended only as a tool of revenue protection, unless it is not specified.

[5] For instance, an inspection strategy is equitable if all passengers on a sample of rides surveyed (it is impossible to inspect all rides during a day because there are no inspectors on each ride) have their tickets checked, independently from the final act of the inspection (which can be "do nothing", i.e., ticket ok; "a warning" or "a citation", i.e., a fine).

Indeed, most fare evasion literature only partially considers the topic of fare inspection. Moreover, most previous research focused on a unidirectional perspective of one or a few inspection issues and could not overlap and integrate several aspects that may affect inspection, i.e., key similarities and differences. For instance, research often analyses ticket inspection through the observation of generic passengers, partially disregarding that most passengers seem unaffected by the level of inspection (Hauber, 1980; Suquet, 2010; Salis et al., 2017; Delbosc and Currie, 2019).

Therefore, this study attempts to explore the above issues by a review of the existing literature on ticket inspection. It covers both academic and grey or practitioner literature to identify inspection planning approaches (how, where, and when; who and why), organisation issues (how many inspectors; how distributed) and the inspectors' activities useful to increase their efficiency and effectiveness against fare evasion. This study aims to identify explicit research gaps in the literature and contribute to both theory and practice, crafting avenues for future research. Specifically, the added value of this study is:

- Studying relevant issues to ticket inspection, clarifying its effectiveness against fare evasion, and highlighting possible interdependencies.
- Providing a supporting document for TAs/PTCs in the design and evaluation of inspection strategies against fare evasion in public transport systems, as deterrence tools. For instance, vanguard PTCs aim to organise the activities of inspectors in the same structured way as the duties of drivers. Thus, providing some knowledge about these facts may be useful.
- Providing a research agenda of future developments.

The literature was retrieved from Barabino et al. (2020) isolating relevant findings on inspection strategy and adding few (if any) recent documents (largely journal articles) according to The PRISMA Group, 2009. References were retrieved using Scopus according to the search terms "Fare inspection", "Fare inspector", "Inspection-Transport-Evasion", and "Inspector-Transport-Evasion" on the title, keywords, abstract and type of sources.

The rest of the paper is organised as follows; Section 2 reviews inspection planning approaches. Section 3 analyses inspection organisation methods. Section 4 details inspector activities and explores the factors that affect their effectiveness. Section 5 outlines a summary, identifies research limitations, provides a research agenda, and concludes this review.

2. Inspection planning: how, where, and when, who and why

Traditionally research and practice has focused on defining how, where and when inspectors should be deployed to catch evaders and dissuade further evasion. Conversely, recent studies deepen understanding on who evades fares and why, to enhance inspection strategies.

2.1. How, where, and when

Strategies in conducting ticket inspections should be cost-effectiveness-based since available resources are limited and can vary considerably (Dauby and Kovacs, 2007). There are several approaches to conduct inspections, e.g., covering the whole system at all day times according to a plan or through random activities (Table 1). However, most studies focused on hotspots approaches, i.e., inspector activities planned on specific routes and/or points on certain periods.

Hotspots are dependent on passenger volumes and characteristics in several ways. The aim is to maximise ticket inspection efficiency by checking the largest number of passengers in a "short" period. Some studies report that hotspots are generally identified during peak periods, because it assumed that the highest absolute value of evaders travel then (Hansen et al.; 2012; Multisystems Inc. et al., 2002; Wolfgram et al., 2022). However, recent research contrasts these hypotheses (e.g., Cantillo et al., 2022; Barabino et al., 2023) According to Dauby and Kovacs (2007) and Currie and Delbosc (2021), inspection rates measured as a share of trips checked are correlated to fare evasion rates. Therefore, they suggest targeting inspectors to peak and high-demand locations (and times) to efficiently maximise passengers' volume exposure to inspections.

Other studies developed models or applied innovative technologies to identify hotspots directly or indirectly. Guarda et al. (2016a) applied a negative binomial regression model to estimate and predict changes in fare evasion at bus stops. Then, the authors developed a Cost-Benefit Analysis to enable inspectors to optimise cost-effectiveness in hotspots, i.e., at overcrowded stops, in the afternoon and evening. Differently, Sánchez-Martínez (2017) analysed disaggregate fare transaction

Table 1
How, where, when perform inspection.

How	Where	When	Source	Type	Context	Main focus
Constant concentration	Hotspot (stops)	Peak hours (probably highest number of evaders)	Hansen et al., 2012	Empirical	Calgary (Canada)	Inspection practice
			Multisystems Inc. et al., 2002; Wolfgram et al., 2022	Empirical	EU & USA agencies	Inspection practice
		Higher evasion hazard	Pourmonet et al., 2015	Empirical	Montreal (Canada)	Integrate Infrared automatic passenger counting and validated tickets
		Morning peak hour	Sánchez-Martínez, 2017	Empirical	Boston (USA)	Disaggregate fare transaction data on systems without automatic passenger counting
	Overcrowded stops	Afternoon and evening	Guarda et al., 2016a, 2016b	Empirical	Santiago (Chile)	Cost-effectiveness analysis
	Places of major criminal activities	Periods of criminal activities	Del Castillo and Lindner, 1994	Empirical	New York (USA)	Inspection practice
			Li and Min, 1985	Empirical	Shanghai (China)	Inspection practice
			Wolfgram et al., 2022	Empirical	EU & USA agencies	Inspection practice
Temporary concentration	Hotspot (routes or stops)	-	Boyd, 2020	Theoretical	-	-
Random inspection	-	-	Dai et al., 2017b	Empirical	Lyon (France)	Simulation of effects of inspection
			Assaf and Van den Broeck, 2022	Empirical	Brussels (Belgium)	Virtual communities of fare evaders

data and formulated a stochastic model to estimate fare non-interaction and fare evasion in systems without automatic passenger counting. While primarily focusing on an analysis of the implications of an operations decision and the variation across time can be caused by operational factors (e.g., not all the doors being opened), the research might also provide a useful framework for indirectly identifying "hotspots", i.e., peak periods and stations with a high level of fare evasion. Notably, the results revealed that during the morning peak hour, 57 % of non-interaction (i.e., missed ticket validation) occurred, demonstrating a significant variance in non-interaction and fare evasion across different stops and times.

In contrast, Pourmonet et al. (2015) identified hotspots at the busiest stops subject to a higher evasion hazard threshold according to an indicator. Specifically, this indicator returned the ratio between the number of validated tickets measured by smart cards and passengers boarded measured by automatic passenger counting, for each location at hand. The lower the indicator the higher fare evasion.

Other papers focused on periods and places of criminal activities,[6] associating the beneficial role of inspection activities with enhanced perceived security of passengers (Del Castillo and Lindner, 1994; Killias et al., 2009; Hansen et al., 2012; Li and Min, 1985; Wolfgram et al., 2022). Therefore, intensifying inspection efforts in these 'hotspots' has generally enhanced passenger security, e.g., during evening hours, while increasing the number of passengers (a safer environment can attract more people) and mitigating social disorder, violence, and vandalism (e.g., Killias et al., 2009; Van Andel, 1989; Weidner, 1996).

This analysis underscores inherent conflicts arising from divergent hotspot identification methods within the transit context. Notably, a conspicuous lack of convergence exists between inspection strategies tailored for peak times, and those targeting areas associated with criminal activities. This divergence is primarily attributed to the prevalent emphasis on revenue protection within many TAs/PTCs. Econometric studies have proposed varied hotspot identification methods, primarily driven by 'economic' considerations. These investigations posit that the effective identification of 'economic' hotspots can substantively improve fare compliance. Conversely, criminological studies assign inspection an auxiliary role, positioning it as a tool for security protection. This is pivotal due to the potential of an appropriately calibrated level of inspection to mitigate 'criminal' issues and enhance overall security (e.g., Killias et al., 2009). Moreover, the identification of 'criminal' hotspots holds promise in shielding the equipment and infrastructures of TAs/PTCs from vandalism (Barabino et al., 2020). This nuanced perspective underscores the manifold roles of inspection, encompassing both revenue protection and security considerations within the intricate public transport sector.

An intriguing challenge if is the inspection level should be kept constant for a long period or sporadically revised. This is according to a decrease in the effectiveness of the inspection depending on the repetitiveness of the planning of inspections. Furthermore, such concentrated and constant inspections often require several inspectors that exceed the budget constraints of PTCs.

Boyd (2020) suggested a concentrated enforcement strategy consisting of a temporary concentration (or crackdowns) of inspectors on one route (or hotspot); a form of 'concentrated blitz' strategy. Theoretically, this would address the loss of effectiveness of inspections that are spread over large areas, improve budget constraints, and speed up the process of observing the effectiveness of inspection settings. However, one laboratory experiment contrasted the effectiveness of inspector concentration strategies (Dai et al., 2017a). Results showed how crackdowns are less effective than random inspections: they reduce fare evasion rates by around 50 % in the first four days and result in a burst of fraud during subsequent periods with no inspection. Only when alternated with random inspections do these crackdowns stand a chance at achieving greater overall compliance. However, data from real (controlled), rather than laboratory experimentations are missing from the literature to our knowledge. The random inspections can be (i) programmed with the aim to make the movements of inspectors unpredictable or (ii) discretionary of inspectors that rotate freely on the network. For instance, Assaf and Van den Broeck (2022) showed how information shared between passengers on inspections in real-time within virtual communities of fare evaders produced a map of the potential places/routes of inspection activities. However, the two random options involve some problems. First, greater efforts are required on PTCs that should plan patrol activities to reduce fare evasion. Second, the discretionary ways are difficult to measure.

The comparison of concentrated and random approaches for conducting ticket inspections highlighted the benefits of hotspot approaches in scenarios where resources are limited (e.g., when the number of inspectors to be deployed for inspection is very low), achieving promising results in a short period. Simultaneously, random inspections seem most effective in achieving overall compliance and sustaining long-term efficacy since they are more spread out on the network. However, if not planned and data-driven, both strategies might be biased and influenced by subjective judgments of reliability or personal preferences of inspectors. For instance, Mujcic and Frijters (2021) investigated the causal effect of race on discretionary favours in the bus market through a natural experiment involving white and black testers boarding buses without money to buy a ticket. They uncovered substantial evidence of racial bias because bus drivers were twice as willing to let white testers ride free as black testers. Thus, their results seem to show an inequitable inspection. Thus, the discretion of inspectors in selecting stops or routes to inspect can lead to minor effectiveness in mitigating fare evasion with concerns about inequalities.

2.2. *Who and why*

Inspection strategies presuppose monitoring activities to identify evasion patterns in transport systems. Indeed, besides identifying hotspots (places and/or periods) subject to a higher evasion threshold, monitoring evasion patterns helps understand the types of passengers who are riding (e.g., never-evaders *vs* risk-takers) and their sensitivity (or not) to inspection activities (on board and/or at the station/stop). Consequently, in recent years three groups of studies have been focused on understanding passenger demographics, behaviours, and motivations with increasingly refined methodologies. Usually, these (empirical) studies collect data using passenger surveys to formulate descriptive and inferential models (cluster analysis, logistic and probit regressions, hybrid discrete choice models) to cluster passengers/evaders.

A summary of all these studies is reported in Table 2.

The first group of studies deepen knowledge of specific socio-demographics, travel behaviour and situational factors through a 'one-size-fits all model' and evaluates if inspection empirically affects the likelihood to evade fares. Specifically, on the one hand, if the levels of inspection provided by TAs/PTCs are currently sufficient and optimally set, one-size-fits-all-models showed that increased inspections (and/or the perception of inspection) could reduce fare evasion (e.g., Barabino et al., 2015; Cools et al., 2018; Porath and Galilea, 2020). On the other hand, if the previous assumptions do not hold, the effectiveness in detecting evaders is low (Bucciol et al., 2013; Guzman et al., 2021). Nevertheless, since the final act of the inspection is the fine, other situational factors are relevant to explain fare evasion. Indeed, the knowledge of the value of fines and previous ticket violations (recidivity) could increase the likelihood of passengers evading fares. Barabino et al. (2015) argued this last fact from the relevant discount applied if

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[6] According to Clarke (1993) and Bijleveld (2007) definition, criminal activities can be clustered as: (i) "crimes committed against passengers" as robberies, thefts and assaults and verbal abuse against passengers, (ii) "crimes committed against the system or its employees" as graffiti, vandalism, verbal abuse, threats, intimidation, disorderly behaviours, spitting, and physical assaults on staff.

Table 2
Attributes of who evade fares.

Attributes	Who	Source	Type	Context	Main focus
Specific socio-demographics, travel behaviour and situational determinants	Generic passenger	Bucciol et al., 2013	Empirical	Reggio Emilia (Italy)	One-size-fits all model
		Barabino et al., 2015	Empirical	Cagliari (Italy)	One-size-fits all model
		Cools et al, 2018	Empirical	Flanders (Belgium)	One-size-fits all model
		Dai et al., 2017b	Empirical	Lyon (France)	One-size-fits all model
		Cantillo et al., 2022	Empirical	Santiago (Chile)	One-size-fits all model
		Guzman et al., 2021	Empirical	Bogotà (Colombia)	One-size-fits all model
	Students, workers and unemployed	Barabino & Salis, 2020	Empirical	Cagliari (Italy)	A priori segmentation
	Male, Female, young, middle and older passengers	Barabino et al., 2022	Empirical	Cagliari (Italy)	A priori segmentation
	Choice-workers, (seldom evade); Captive students (often evade); Captive unemployed, (Always evade)	Barabino & Salis, 2023	Empirical	Cagliari (Italy)	A posteriori segments
Motivations and behaviour	Career, accidental, deliberate and opportunistic	Delbosc & Currie, 2016a; b	Empirical	Melbourne (Australia)	A posteriori segments
		Currie & Delbosc, 2017	Empirical	Melbourne (Australia)	A posteriori segments
	Recidivist	Currie and Delbosc, 2017	Empirical	Melbourne (Australia)	A posteriori segments
	Who cannot afford fares, gamblers, ideological opponents, passengers dissatisfied, cheats, and who cannot understand the fare structure	Suquet, 2010	Empirical	Val d'Oisi (France)	A posteriori segments
	Radical, strategic, ambivalent, accidental, proud, empathetic, circumstantial	Gonzales et al., 2019	Empirical	Santiago (Chile)	A posteriori segments
	Items and factor related to social norms, public transport service's image, social acceptance of evasion, trip planning, ineffective anti-evasion methods, fear of law enforcement for evaders and non-evaders	Busco et al., 2021	Empirical	Santiago (Chile)	A posteriori segments
	Who cannot afford fares (poverty)	Guarda et al., 2016a, 2016b	Empirical	Santiago (Chile)	A posteriori segments
		Perrotta, 2017	Qualitative	New York (USA)	A posteriori segments
		BRP, 2023	Empirical	New York (USA)	A posteriori segments

fines are paid soon, other studies from recidivist behaviours of passengers. In contrast, Dai et al. (2017b) showed that passengers already fined in the field behave more honestly in the lab, emphasising the positive effect of fines.

The second group of studies has recently investigated passenger segments that may respond differently to inspection activities. These segments were *a priori* clustered according to 'Gender', 'Age', and 'Employment' variables. Next, these variables defined different demographic segments: males, females, young, middle-aged, older passengers, students, workers, and unemployed passengers. Afterwards, key sociodemographic factors, travel behaviour, and situational variables were isolated for each segment to understand if they vary for each segment. Specifically, Barabino and Salis (2020) investigated students, workers and unemployed passengers that represent the largest quota on many transit systems worldwide. They show that students are more likely to evade fare if they travel for less than 15 minutes, by separate logistic regression models. Barabino et al. (2022) studied males, females, young, middle-aged and older passengers. They used separate logistic regressions to show how the intention to evade fares increases for males who travel a lot during the day and for young passengers who make short trips. Therefore, the *a priori* segmentation suggests inspection strategies to increase the worry of being caught since the literature on deterrence emphasises that potential fare evaders prioritise the certainty of being caught over the severity of punishment (i.e., fine) (e.g., Clarke et al., 2010). For these segments, inspection strategies could focus on assigning inspectors to routes and times with a high volume of 'critical' passengers (e.g., younger), ensuring inspectors remain on board long enough to discourage fare evasion and investing in conductors (if any) while respecting equity: they inspect all on board passengers not only younger, independently from the final act of the inspection.

The last group of studies focused on segments of fare evaders *a posteriori* built. These studies clustered fare evaders after the data analysis and analysed their motivations and behaviours. Descriptive statistics, cluster analyses and/or models were adopted to identify segments within the data and several groups of passengers were derived. Depending on the study context and indentation, past studies identified five large groups of segments that could be affected by the inspection activity at several levels. They may be clustered largely as follows according to the increasing trend of fare evasion: i) honest; ii) accidental; iii) opportunistic; iv) chronic and v) miscellaneous.

Honest passengers quasi-never evade the fare. Indeed, they have high morality and likely experience an internal reward from behaving in a manner consistent with their values, thus respecting the rules (*e.g.*, Bijleveld, 2007; Boyd et al., 1989). They are also so-called never-evaders (Delbosc and Currie, 2016a). Usually, these passengers could correspond to the quota of pass-holders in a transit market (*e.g.*, Barabino and Salis, 2019). While inspections might not seem relevant for these passengers, they should be carried out to ensure fairness and prevent future evasion. Honest passengers may be tempted to evade the fare if they see others doing so without consequences (copy-cut syndrome). Therefore, inspecting all passengers signals that TAs/PTCs monitor fare evasion in an equitable way and this activity carries consequences. However, systems such as "*seamless ticket inspection*" may be more practical than other methods, including staff and turnstiles, only staff, and only turnstiles (Alhassan et al., 2022).

Accidental evaders include passengers who usually pay the fare but on occasion they may evade. These passengers have a strong view against fare evasion and are not real transgressors, because they accidentally forget to buy the ticket or sometimes evade due to structural aspects of the system such as when the validation machine is out of order, running out of farecard funds, etc (Barabino and Salis, 2023; Currie and Delbosc, 2017; Delbosc and Currie, 2016b, 2016a; Gonzalez et al., 2019). They are also referred to as 'naïve' passengers in Hauber (1980) and proud, empathetic, and circumstantial evaders in Gonzalez et al. (2019). Although the inspection for these passengers could not be key, it would be useful to promptly act when some onboard devices are out of order, thus, to avoid reasons for passengers to not validate the ticket. For instance, an inspection strategy involving collaboration with drivers can swiftly address issues with ticketing systems and ensure a prompt response from inspectors. Drivers could receive training to spot signs of potential fare evasion, like passengers exhibiting suspicious behaviour next to out of order validators.

Opportunistic evaders or calculated risk-related–evaders choose to evade according to their own perceived probability of being checked and caught. This segment is the most sensitive to inspection rates. Indeed, these passengers evaluate whether it is more profitable to buy a ticket or evade and pay the fine when being caught by a ticket inspector (Barabino and Salis, 2019, 2023, Delbosc and Currie, 2016b, 2016a). This segment also includes 'strategic' evaders detected by Gonzalez et al. (2019). Although they admit that evasion is not right, 'strategic' evaders take care to have a ticket with them to be taped if an inspector gets on-board. For this segment, the role of inspection is key, and several strategies could be implemented. For instance, they could include route rotation (e.g., random inspections on different bus routes and times for broad coverage), mobile inspection teams (i.e., inspectors moving among buses along the route without disrupting service), surprise inspections (i.e., unannounced checks by plainclothes inspectors), collaboration with onboard staff (i.e., involving drivers and staff in identifying possible fare evaders), and utilisation of surveillance cameras (i.e. monitoring critical areas to identify potential evaders).

A range of research indicates the existence of a distinct segment of 'chronic fare evaders', a group of passengers who habitually evades the fare and seem unresponsive to more stringent enforcement measures. These passengers typically do not actively attempt to evade detection; instead, they might nonchalantly provide false identification, ignore subsequent fines, etc. These passengers are also referred to as 'cunning' in Hauber (1980), as 'career evaders' or 'recidivist evaders' in Delbosc and Currie (2016b) and Currie and Delbosc (2021), respectively, and as 'radical' in Gonzalez et al. (2019). Moreover, existing research indicates a possible correlation between fare evasion perpetrated from a quota of these evaders and criminal behaviours—as in Nederlandse Spoorwegen in the Netherlands, where a significant number of repeat fare evaders had a history of criminal behaviour (Bijleveld, 2007). Nevertheless, this characteristic does not define the entire group or causation. The correlation highlights potential complexities within this group, which might also include underlying issues such as substance abuse, mental health challenges, or homelessness. Often, they already have an extensive 'rap sheet', as shown in Hauber (1980), Levine (1987), Stockdale and Gresham (1998), Weidner (1996), Smith and Clarke (2000), Bijleveld (2007), Brisman (2016), and Barabino et al. (2020). Additionally, we distinguish 'artful evaders' as another category: these individuals are not only habitual fare-dodgers but also possess an in-depth understanding of the transit system's operational weaknesses. This knowledge enables them to evade fares with a calculated approach, avoiding penalties with minimal risk. This classification, described by Bijleveld (2007), suggests a need for tailored strategies beyond standard fare enforcement practices.

Notwithstanding, these studies highlighted how little could be done for chronic and 'artful' passengers because traditional and tougher inspection policies do not seem to discourage them. However, the inspection of this kind of passengers could benefit from the deployment of specialised teams with specific skills and additional tools. For instance, a strategy could combine enforcement with social services to address the broader issues associated with chronic fare evasion. Cooperation with authorities to identify known chronic fare evaders could be another useful strategy. Behavioural programming by inspectors can also contribute significantly to the prevention of fare evasion. Moreover, strategies that hinder access to the transportation system may be effective against this segment (e.g., Delbosc and Currie, 2016b; Salis et al., 2017). Although this segment is present, it is not numerous (Barabino and Salis, 2023; Currie and Delbosc, 2021; Salis et al., 2017). Nonetheless, Currie and Delbosc (2021) have shown that career recidivist evaders are responsible for most revenue loss in Melbourne (a quota of career evaders of 8 % originates a share of total revenue loss of 68 %).

Finally, other groups of evaders were identified. 'Ambivalent' evaders contradict themselves: they believe that it is wrong to evade fare, but do not always take care to carry their ticket when traveling. As reported by Gonzalez et al. (2019), this group feels that turnstiles and fines do not reduce evasion but did say that this could change if fines were bigger. Therefore, the inspection strategies detailed for opportunistic evaders could be beneficial because inspectors issue fines. 'Political' fare evaders include those fare evaders that may use an ideological justification for their behaviour. For instance, "Evasion is a valid way of protesting" in Busco et al. (2021); "public transport fares are a second tax" in Assaf and Van den Broeck (2022). Indeed, they consider public transportation as a public service that everybody should use freely (Hauber, 1980; Assaf and Van den Broeck, 2022). For this segment, inspection could be beneficial by adopting strategies like those for chronic passengers. Other studies identified the 'poverty' motivations of 'low-income passengers' who struggle to afford transportation for their essential daily needs (Perrotta, 2017). Consequently, they resort to methods such as experimenting with fare evasion, which determines high rates of evasion in low-income areas of cities, both middle-income and high-income countries (Guarda et al., 2016a, b; Perrotta, 2017; BRP, 2023). Therefore, the results suggest the relevance of actions that face economic challenges to reduce fare evasion. Guarda et al. (2016b) and BRP (2023) suggested public policies of subsidies to decrease fare pricing rather than increase enforcement strategies in low-income areas: even if a marginal decrease in fare evasion rates may occur, it can result in the risk of limiting accessibility for individuals unable to afford tickets. Similar inspection strategies adopted for chronic passengers could be useful for this segment, particularly those that combine traditional inspection approaches with social and community services.

Busco et al. (2021) examined the motivation of both evaders and non-evaders identifying six topics and related factors that concern social norms, expectations and perceptions of public transport services, acceptable norms, trip planning, information related to the efficiency of measures pursued by public authorities to stop evasion, and relevance of fear of law enforcement. The findings shed light the inefficacy of turnstiles and fines in the Transantiago system, revealing that they fall short of instilling fear in passengers. Instead, the pivotal factor shaping behaviour is the discernible presence of inspectors for both non-fare-evaders and fare evaders.

All previous segments were discovered according to the passengers' viewpoint. Conversely, only one qualitative ethnographic study in France classified fare evaders along with the inspector's perspective, which could differ from that of passengers (Suquet, 2010). While some categories could fall under the previous classification (e.g., ideological opponents, gamblers not likely to meet inspectors as opportunists, cheats who pretend to pay the fine but never pay as chronic, individuals who have no choice), others introduced new perspectives: i) users dissatisfied with the quality of service (e.g., safe, clean, regularly); ii) individuals who have difficulties understanding the fare structure. Although the reliability of the inspector's perspective may be questionable regarding the definition of segments, the inspection activity seems particularly beneficial for gamblers, unsatisfied users and individuals who find the current fare structure complicated and could apply similar methods of opportunistic and accidental segments.

3. Inspection organisation: how many and how distributed

Once ticket inspection methods and fare evasion patterns are established, it is key to determine how many inspectors to engage and how to distribute them. Maximising the ticket inspection requires an appropriate number of inspectors that must be efficiently distributed in the public transport network. Therefore, mainly econometric-based research has been concentrated on models to size the inspection

Table 3
Approaches to set the optimal number of inspectors.

Approach	How many*(depending on)*	Source	Type	Context	Main focus
Data driven	Risk perception of passengers	Kooreman, 1993	Empirical	Europe and Canada	Inspection probability model
	Passenger per day	Multisystems Inc. et al., 2002; Wolfgram et al., 2022	Empirical	Europe and USA	Inspector based index
Game theory	Fare-to-fine ratio	Avenhaus, 2004	Theoretical	-	Uncooperative inspection games
		Jankowski, 1991	Theoretical	-	Cooperative inspection games
Econometric models	Objective and subjective probability	Barabino et al., 2013	Empirical	Cagliari (Italy)	Deterministic model setting from passengers' profiles
		Barabino et al., 2014	Empirical	Cagliari, (Italy)	Dynamic model considering the variable inspection
		Barabino and Salis, 2019	Empirical	Cagliari, (Italy)	Dynamic model considering the variable inspection (new formulation)
		Boyd et al., 1989	Theoretical	-	Deterministic model setting from passengers' profiles
		Boyd, 2020	Theoretical	-	Discussion on some issues of inspection and fine

workforce (*How many inspectors*) and operation research methods on planning their activities (*How to distribute inspectors*).

3.1. How many

Determining the optimal number of inspectors (i.e., inspection level, or setting) requires an equilibrium among several facets: size and operating characteristics of the transit system, passenger volumes by day, hours and/or season, inspection strategies implemented, inspection activities procedures, cost of inspectors, and budget constraints of PTCs. Studies seek for an equilibrium level among the number of inspectors, revenue of TAs/PTCs and fare evasion levels. Therefore, studies are concentrated on methodological issues and found the optimal inspection level according to three distinct approaches by (largely) empirical research. A summary of these studies is reported in Table 3.

The first approach is data driven. Authors empirically linked the probability of fare dodgers being caught and the amount of the corresponding fine. The equilibrium (i.e., fare evasion decreased as inspection increased) depended on the risk perception of passengers who maximised expected utility (Kooreman, 1993). In addition, other studies considered the ratio of the number of inspectors per day to the number of passengers per day by aggregating inspection data collected using a sample of 40 transit agencies worldwide. In this case, results amounted to about 0.3 inspectors per 1000 passengers per day (Multisystems Inc. et al., 2002) on light rail systems, 2–3 inspectors in heavy rail systems (Wolfgram et al., 2022).

The second approach concerned game theory-based modelling. It sets the optimal inspection level, simulating inspection activities according to fare-to-fine ratio, in the case of perfect information, i.e., everybody knows everything (Jankowski, 1991). Perfect information is about the enforcement policy of PTCs. Consequently, in the case of unperfected information, PTCs could incur higher inspection costs without the benefit of a decrease in fare evasion. The problem could be addressed through tools of non-cooperative games. Avenhaus (2004) concluded that it was useful for setting inspection frequency to check passengers, by applying the theoretical game model and setting a fine and fare. Fines taken permit the equilibrium between the strategy of passenger and investment in inspection. However, specific situational conditions (e.g., frequent fare evaders may recognise inspectors) did not enable it.

The third approach adopt econometric methods to determine the optimal number of inspectors by maximising the profit of PTCs. These methods merged the probability that a passenger has his/her ticket checked (objective, actual probability) and the probability that a passenger feels it will be checked (subjective, perceived probability), respectively. Three different profiles of passengers were usually considered (honest, opportunistic, and chronic) to account for these probabilities. Boyd et al. (1989) founded the theory of objective and subjective probability distribution. However, they neglected passengers caught evading who did not pay their fine, which brings revenues down and increases associated costs.[7] Thus, as this issue is relevant in real transit networks, it was introduced and empirically tested by Barabino et al. (2013). Nevertheless, both these studies: (i) equated the number of caught passengers to the number of collected fines (i.e., each caught evader passenger is fined) and (ii) maintained the hypothesis of fixed perception of inspection (although it may vary during different time windows according to the level of inspection set). Therefore, a variable model was developed and applied recognising that ticket inspectors could not capture and fine all evaders. Moreover, because the number of checked passengers is a function of the number of inspectors, the perception of being inspected varies and this fact impacts whether s/he decides to pay the fare (Barabino et al., 2014). Hence, that model demonstrates how inspection levels vary among several equilibrium points based on the percentage of passengers who decide to evade fares in a fixed period according to a different level of inspection. This percentage is computed by the values of subjective probability of being inspected during an established period, and it varies among time windows (Barabino et al., 2014). Therefore, unlike Boyd (2020), who argued that a given inspection level does not inevitably define a unique fare evasion level, the previous results empirically demonstrated a relationship between variable inspection and, indirectly, fare evasion. Finally, Barabino and Salis (2019) further refined the previous model by providing (i) an alternative formulation for estimating the percentage of passengers who decided to evade and (ii) a new formulation of the probability of a passenger being fined for getting caught in fare evading. The trend of (i) was estimated using a log-linear function because the marginal effect of the number of inspectors on the previous percentage was decreasing at an accelerated rate. Considering the case of no inspection and full inspection (i.e., having the conductor), the authors demonstrated that if the level of inspection overcomes a limit, the reduction in fare evasion may not be appreciable. Nevertheless, in full compliance inspection, fare evasion should be close to zero. The trend of (ii) was modelled considering that the probability of effectively fining an evader depends on inspection level and inspection effectiveness, which, in turn, depends on inspection level. The effectiveness of inspectors

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[7] Many who are given a fine notice do not pay as noticed, e.g., in Bijleveld (2007), Pricewaterhouse Coopers (2007), Clarke et al. (2010), and Barabino and Salis (2019). Collection procedures (e.g., to take nonpayers of fines to court) are expensive for TA/PTCs and probably generally more costly than the damage done (Bijleveld, 2007). However, fines do not mean much unless court and policy action are taken. Therefore, in some countries (e.g., Italy), TA/PTCs waive the fine collection or apply a discount to collect money as soon as possible. Otherwise, non-evaders who understand the permissiveness of the system could become dodgers, possibly encouraged by friends' evaders.

implicitly assumed that each inspector cannot fine every evader, therefore, there is a chance that other evaders escape. This fact removes the assumption of constant capacity of inspectors raised by Boyd (2020).

3.2. *How distributed*

Unlike the number of inspection settings, a second group of studies focused on inspectors' activities planning according to optimisation methods. Such a plan affects daily activities along the network, covering specific zones or single routes to prevent, usually, opportunistic passengers from discovering the movement patterns of inspectors that are, consequently, "random-objective". The planning organises the duties of inspectors, while spatial and temporal distribution highlights the way inspectors must be deployed on the network (Borndörfer et al., 2012; Correa et al., 2014). Inspection scheduling and distribution were formally modelled as a Leader (i.e., the PTC) – Follower (i.e., the fare evader) Stackelberg's game. The leader sets randomised strategies (e.g., it moves on several paths to inspect passengers), and the follower plays the best response to each strategy. For instance, Brotcorne et al. (2021) investigated the marginal patrolling strategy and the mixed patrolling strategy for scheduling random patrolling paths based on the daily timetable. Recently, Escalona et al. (2023) developed unpredictable patrolling schedules based on a joint strategy-schedule approach with in-station fare inspection policy. Depending on cases, the objective function maximises total revenues cashed by PTC (Delle Fave et al., 2014; Bahamondes et al., 2017), or the difference between total revenues and minimum penalty due to switching patrol strategies (Yin et al., 2012). Also, it minimises the shortest paths for evaders along networks and highlights uncovered task subjects, e.g., duty length (Bahamondes et al., 2017).

All models include constraints to reflect realistic temporal and spatial conditions of inspection activities, e.g., upper bound on total patrol units or the time of patrolling and of breaks (Jiang et al., 2012). Snijders and Saldanha (2017) included as a spatial constraint coverage of each segment of the network by inspectors. By assigning jobs to a fixed set of duties, results showed how an increase of capacity of patrols (+50 %) involved a security increase (about +71 %) and the profits of PTC (+81 %) due to a decrease in fare evasion. Interestingly, Delle Fave et al. (2014) complicated the Stackelberg game by including uncertainty in inspection, as some patrols were interrupted from ticket control activities (e.g., the time to issue a fine). Moreover, they used three adversary models to develop three different crew schedules for crime, terrorism, and fare evasion threats.

However, inspection distribution is deeply affected by the cost of inspectors, data gathering and budget constraints of PTCs. Therefore, many studies use statistics to determine the probability to catch fare dodgers, rather than disseminate inspectors along all transit routes.

A summary of these studies is reported in Table 4.

4. Inspector activity effectiveness

This section introduces the concept of effectiveness of inspection, which is characterised from 'direct' and 'indirect' activities of inspectors. 'Direct' activities are related to the productivity of inspectors, 'indirect' activities are linked to strategies of greater perception of inspection, i.e., visibility.

Generally, the inspector's productivity is defined as the average number of passengers an inspector checks each day and it is calculated as: *"inspection rate x the daily ridership / the number of inspectors"* (Multisystems Inc. et al., 2002; Wolfgram et al., 2022). However, the productivity of inspectors is a complex concept affected by several facets (Table 5).

The first facet concerns the constant capacity of inspectors in checking tickets. Guarda et al. (2016a) introduced it as a variable, which can modify the productivity due to a work condition resulting in a decrease in inspection activities. For instance, this can occur due to fatigue, non-fulfilment at certain stops, or depending on how many inspectors are present. The time needed to discover, and process evaders can also affect productivity. Thus, other authors suggested some solutions that can increase their effectiveness. For instance, Li and Min (1985) and Dauby and Kovacs (2007) hypothesised that productivity could be improved by integrating the salary of inspectors with a variable bonus for each fine given to offenders.

Combined with inspectors' capacity in checking tickets, a second facet that could affected the effectiveness of inspectors concern the 'role' of inspector. Police power can be conferred to inspectors or a specific team with non-sworn officers can be created (e.g., Multisystems Inc. et al., 2002; Larwin and Koprowski, 2012; Wolfgram et al., 2022). The adoption of these types or mix of types could be an additional deterrent for accidental and opportunistic passengers and facilitate the verification of the identity of passengers that is one of the main problems also in collecting fines (Multisystems Inc. et al., 2002; Wolfgram et al., 2022). However, each specialization task included in the inspector's "role" incurs higher costs which influences cost-benefit issues in their deployment.

All previous issues may be considered as traditional measures of effectiveness.

Currently, several studies proposed adopting inspection "visibility" actions as indirect actions able to discourage fare evasion by working on the inspection perceived by passengers. Although many actions can be adopted, in what follows, they are summarised according to two main options.

The first option aims to "educate" passengers through the deterrent of a uniform. Inspectors wearing uniforms (or using visible vehicles of inspectors) had a positive impact of prevention on passengers who behave opportunistically. Nevertheless, effectiveness could be reduced for those passengers who are insensitive to authority (Dauby and

Table 4
Approaches to distribute inspectors.

Approach	How distributed	Source	Type	Context	Main focus
Set Covering problem	From risk of fare evasion and aggression	Snijders and Saldanha, 2017		Randstad Noord (Netherland)	Software prototype
Stackelberg's games	From temporal constraints	Delle Fave et al., 2014	Empirical	Los Angeles (USA)	Optimise total revenue
		Jiang et al., 2012	Empirical	Los Angeles (USA)	Optimise total revenue
		Yin et al., 2012	Empirical	Los Angeles (USA)	Optimise total revenue
	From randomised patrolling vs two passengers' reactions	Bahamondes et al., 2017	Theoretical	-	Optimise randomised inspection and adaptive and non-adaptive strategies
		Correa et al., 2014	Empirical	Germany, Netherlands	Optimise randomised inspection and adaptive and non-adaptive strategies
	From spatial distribution of the network's inspection capacity	Borndörfer et al., 2012	Empirical	Germany	Inspection practice
	From exact formulation of inspection probabilities	Brotcorne et al., 2021	Empirical	Los Angeles (USA)	Quality measure of feasible solutions
		Escalona et al., 2023	Empirical	Los Angeles (USA)	Quality measure of feasible solutions

Table 5
Inspector effectiveness.

Who/Which	How	Source	Type	Context	Main focus
(Un)stable capacity of inspection	Work condition	Guarda et al. (2016a)	Empirical	Santiago (Chile)	Benefit-Cost analysis
	Stipendiary bonuses	Li and Min, 1985	Empirical	Shanghai	Agency/PTC policy
		Dauby and Kovacs, 2007	Empirical	Worldwide	Agency/PTC policy
Types of inspectors	Police power	Larwin and Koprowski, 2012	Empirical	USA	Agency/PTC policy
		Multisystems Inc. et al., 2002; Wolfgram et al., 2022	Empirical	Europe, USA	Agency/PTC policy
Visibility	Adoption of uniform	Dauby and Kovacs, 2007	Empirical	Worldwide	Agency/PTC policy
		Hansen et al., 2012	Empirical	Calgary (Canada)	Agency/PTC policy
		Multisystems Inc. et al., 2002	Empirical	Europe, USA	Agency/PTC policy
	Actors with inspectors' uniform	Boyd, 2020	Theoretical	-	Perceived inspection activities
	Plain clothes inspectors	Currie and Delbosc, 2017	Empirical	Melbourne (Australia)	Perceived inspection activities
		Currie and Delbosc, 2021	Empirical	Melbourne (Australia)	Perceived inspection activities
		Keuchel and Swertz, 2020	Empirical	Münster (Germany)	Perceived inspection activities
		Reddy et al., 2011	Empirical	New York (USA)	Agency/PTC policy
	Announces of inspection activities	Hansen et al., 2012	Empirical	Calgary (Canada)	Agency/PTC policy
		Dai et al., 2017a	Empirical	Lyon (France)	Agency/PTC policy
	Misleadingly announces of inspection activities	Barabino et al., 2013	Empirical	Cagliari (Italy)	Agency/PTC policy
		Boyd, 2020	Theoretical	-	Agency/PTC policy
	Social punishment	Porath and Galilea, 2020	Empirical	Santiago (Chile)	Socio-political variables
	Posters/pictures of 'inspector' watching you	Ayal et al., 2021	Empirical	Occitanie (France)	Perceived inspection activities
		Currie and Delbosc, 2021	Empirical	Melbourne (Australia)	Perceived inspection activities
	Information	Celse and Grolleau, 2023	Empirical	Bordeaux, Aix, Angers, Lyon, Paris (France)	Perceived inspection activities

Kovacs, 2007; Hansen et al., 2012; Multisystems Inc. et al., 2002) or at worst, generate aggressive responses in the case of ideological opponents who identify in the uniform the "guilty" of state's decisions (Assaf and Van den Broeck, 2022). Differently, Reddy et al. (2011) asserted that support from plain-clothes inspectors could also be effective. Boyd (2020) proposed to adopt actions of deceptive manipulation of the perceived probability of inspection. Actors in uniforms of inspectors could persuade passengers that the inspection force was greater than it was. Both authors unconsciously considered as an option the perceived inspection activity, a key variable to address fare evasion and that could be more valuable than the actual inspection: it is about changing perceptions not actual that can be very cost-effective as it does not cost staff time. Indeed, Currie and Delbosc (2017) demonstrate that perceived control influences fare evasion intention; it may be affected by personality factors, according to concepts from the criminology literature on what is termed "consumer misbehaviour", or "shoplifting" (Tonglet, 2006). The structural equation model of Currie and Delbosc (2017) stressed the benefit of plain-clothes inspections, as passengers never know who an inspector is. Therefore, fare evaders could perceive inspection levels are greater than actual. Other approaches to inspectors' uniforms could include provision of posters, and life-size pictures of inspectors (Currie and Delbosc, 2021). These act to increase perceptions of inspection rates emphasising the risks and consequences of being apprehended. Moreover, it could be an original solution to discourage career fare evaders. This strategy was a success in Melbourne using the 'Freeloader' anti-fare evader campaign (Currie and Delbosc, 2021). Finally, Keuchel and Swertz (2020) have featured the first empirical evidence of inspection visibility actions (inspectors with uniforms) vs perceived inspection activity (plain-clothes inspectors). Using the Poisson regression, results showed a significant statistical difference between different types of inspector clothing. Change of clothing from officer to civilian proved positive, especially for the share of passengers without tickets. Moreover, the authors showed how the size of inspector teams only matters when they are wearing plain-clothes.

The second option concerns the announcement of inspection controls. Hansen et al. (2012) asserted that announcing the inspection two stops before it took place resulted in 70 passengers buying a ticket right away. However, Dai et al. (2017a) showed how preliminary announcements of inspections reduced their overall effectiveness (above −21.4 % and −11.6 %), especially in the following periods without checks. Barabino et al. (2013) and Boyd (2020) proposed misleadingly announcing inspections since evaders would get out of the vehicle without knowing if inspection took place or not. Porath and Galilea (2020) proposed an innovative measure of visibility that acts by reducing the moral restriction of anonymity. Inspectors could apply direct social punishment that induces shame; for instance, in the Transmilenio transit system of Bogotá (Colombia), inspectors forced fare evaders to write, *"I will no longer sneak into the system"*.

Recently, Celse and Grolleau (2023) conducted experiments to explore how specific types of information (fine or inspection rate) and the framing of that information (minimum, maximum, average, and range) can deter individuals from engaging in fare evasion. They demonstrated that people have limited sensitivity to both the content and framing of information when making decisions about fare evasion. They suggest that the primary factor influencing fare evasion is an individuals' beliefs regarding its prevalence, such as the social norm surrounding it.

5. Discussion and conclusions

Fare inspection has many facets that have led to insights into the complex relationships of its role against fare evasion by ideas, theories, methods, and empirical applications to improve its effectiveness and profitability. Planning approaches aim to determine "*how, where and when*" to intercept fare evaders, "*who*" is a fare evader sensitive to inspection activities and "*why*". The organisational methods explore "*how many*" inspectors are needed to achieve a balance in transit network features and "*how to distribute*" inspectors along transit routes as a response to the choices of fare evaders. Finally, the operational proposals on the daily activities of inspectors aims to determine the factors able to improve their "*effectiveness*".

In this section, we synthesise findings of Sections 2, 3 and 4 and draw up a possible research agenda without any order of priority. It could be considered in two different ways: (i) the "stand-alone undertakings" of specific options; and (ii) the integrated approach among them.

5.1. Specific options of a future agenda

5.1.1. Data collection and fare evasion risk in hotspot definition

Approaches to planning fare inspection consider the concentration of inspectors primarily in hotspots since they have a "better chance" to catch evaders. Research highlights how the definition consists of measuring and quantifying fare evasion level. This measurement is known as the Fare Evasion Ratio (FER) and is affected by two dilemmas[8]: (i) the different definitions of fare evaders by TAs/TPCs, i.e., include or not warnings, citations, passengers escaping; (ii) the number of passengers inspected, i.e., sample in terms of size, routes and daily hours considered. The former depends on TA/TPC policies, while the latter might be enhanced by adopting innovative technologies and devices in inspections. Intelligent Transportation Systems (ITS), Information Communication and Technology (ITC) and big data could improve measurement accuracy and real-time knowledge (Pourmonet et al., 2015; BRP, 2023). However, biases associated with the use of these data (e.g., smart cards and automatic passengers counting could have inconsistencies) are known. Therefore, research must focus on how and to what extent they can be integrated into traditional inspection. Similarly, fare evaders have developed spontaneous socially innovative virtual community initiatives (e.g., website, Facebook groups and Twitter) to help others evade the fare, according to a sense of solidarity and community (Alhassan et al., 2022; Sträuli and Kębłowski, 2023). Therefore, developing a technological response in public transport systems is logical. In addition, palmtop devices represent an innovation in inspection activities that collect data, e.g., the number of passengers inspected, warnings and citations. Therefore, they could capture and record a large sample daily.

On the downside, the main critical issues in hotspots and technological devices might concern the lack of ticket inspection due to overcrowded stations/stops that characterise non-optimal inspection activities and data collection. Higher passenger volumes could decrease the likelihood of catching an evader and bias (low statistical significance). An alternative future development could move towards applying the metric of fare evasion risk recently introduced in this field (Barabino et al., 2023). It integrates the frequency, severity, and exposure measures of fare evasion as well as prediction models. This metric could cover the whole system and, thus, includes places with low fare evasion as opposed to specific routes and/or points on some hotspots. Moreover, the risks-based method could support the fixed nature of hotspots that could change in space and time. Thus, novel studies are expected toward the application of real-time deterrence against fare evasion risk in public transport.

5.1.2. Digital support and bottom-up approaches

Another option in inspection planning concerns understanding fare evaders' behaviours and motivations with increasingly and further refined categorisations. Although indirectly related to the inspection strategy, this option can help define approaches and strategies for targeting ticket inspections but maintaining equitable approaches. Computer vision suggests digital clustering of user behaviour using cameras as a further option. Indeed, recent development adopts pattern recognition in images, as Huang et al. (2022) showed. In a first lab experiment in Shanghai (China), using video image processing, authors proposed an approach to detect individual fare evasion behaviours using a random forest algorithm on metros. Nevertheless, computer vision must implement appropriate measures according to the risk involved in the data processing (e.g., according to the European General Data Protection Regulations). Alternatively, the motivations and behaviours of fare evaders could be studied through a bottom-up approach (Carra et al., 2018), shifting the perspective beyond traditional surveillance and control. For instance, Assaf and Van den Broeck (2022) suggested that fare evaders might be stakeholders and actors in public transport. By approaching inspection through the lens of fare evaders, these "actors" could inform public transport policies and inspection practices, e.g., paving the way for "precision inspecting" approaches (BRP, 2023). Some experimental cases have involved participatory sessions (e.g., surveys, focus groups) to collect feedback and recommendations from passengers that are free from technical-managerial bias (Wolfgram et al., 2022; BRP, 2023). Moreover, this inclusive approach could be experimented with and piloted by inspectors, front-line employees, and first moderators, who should encourage participation and build a relationship of trust with passengers. Therefore, future studies could investigate the effects of these experimental approaches in addressing fare compliance, seeking equity, and triggering socioeconomic and political reforms in public transport policy. Notably, the analysis will need data-driven experiments to learn which strategies are effective. Moreover, they will have to be approached by considering the specificities and particularities of the phenomenon that are context-based.

5.1.3. Size of inspection staff and scheduling of inspectors under realistic conditions and follower responses

The inspection organisation has applied computational issues of sizing and allocation using easily identifiable factors (i.e., features of network, TAs and TPCs) and probability measurement of passengers' behaviour. The sizing of the optimal number of inspectors considers primarily key factors of budget limits and a few segments of passengers (i.e., honest passengers, career, and opportunistic evaders). Nevertheless, previous issues could be refined by further disaggregating the objective and subjective probabilities to refine and enhance the estimation of the number of inspectors. Specifically, analytical models could incorporate several constraints considering the network length, the daily operating hours of the service, the frequency, the number of stops/stations, vehicles, and ticketing system types. For instance, operations in transit (e.g., lower dwell time, front-door queues, crowding, slow service) often require all-door boarding in non-POP ticketing systems, to make boarding more efficient (Jara-Díaz and Tirachini, 2013). This contrasts with extra costs due e.g., possible fare evasion, recognised by several studies connected to all-door boarding option (e.g., Larwin and Koprowski, 2012; Lee, 2011). Therefore, non-POP systems might require more inspectors (Stewart and El-Geneidy, 2014; Lee and Papas, 2015; El-Geneidy et al., 2017). This further corner of evasion calls for more accurate inspection plans that should be studied and implemented, thus including the option of all-door boarding in non-POP systems.

New analytical models could consider further context factors. For instance, the perception of passengers being inspected/fined depends on the route, time of day, or demographic. Therefore, it would be interesting to incorporate these factors providing specific models for clusters of passengers, which could be of particular interest for large PTCs. Finally, a more refined passenger segmentation (e.g., unintentional, ideological opponents) is recommended for further research.

The complexity of inspection scheduling necessitated simplification of factors and probabilities. In the future, research needs to configure scheduling in additional realistic scenarios that consider a large scale of more complex networks, i.e., integrated networks consisting of several transportation modes, many possible paths for a given origin/

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[8] A third dilemma concerns TAs/TPCs embarrassing by fare evasion. Consequently, detailed fare evasion data are not usually made available (or measured) since TAs/TPCs are not eager to give publicity to these facts that may affect their image, associating fare evasion to negative feedback of public transit service.

destination pair, vehicles, and daily operating hours to be close to transit systems of large cities. Preliminary studies have been undertaken by Escalona et al. (2023). Moreover, the modelling of opportunistic “followers” response considers an absolute correspondence between the perfect information of inspectors’ distribution (provided by TAs/PTCs) and the knowledge of followers about it. However, the response of followers is non-optimal both in terms of spatial and timing reactions (Avenhaus, 2004). Consequently, the followers can take different strategies (e.g., choose the shortest or longest path) that need to be modelled.

5.1.4. Effectiveness of actions focused on the visibility of fare inspection

Inspection activities include a broad set of options that could affect the effectiveness of inspectors in their daily activities. Although productivity is the traditional measure, this field of research is focusing mainly on experimental proposals of a different “nature” (indirect effectiveness). Generally, they aim to increase the feeling of “being inspected”, i.e., the perceived probability of inspection. This topic concerns mainly the “inspection visibility” that suggests adopting uniforms, actors instead inspectors, misleading inspection announcements or social punishment, and perceived inspection activities. This approach serves two primary purposes: firstly, it plays a reassuring role for passengers, and secondly, it aims to encourage compliance among riders who engage in a risk–reward analysis when deciding whether to pay. However, visibility actions disregard empirical evidence and comparability of their effects, a part Keuchel and Swertz (2020). They should be evaluated by scientific experiments specifically built for it and not based on a retroactive examination of already implemented measures.

5.1.5. Managing interactions between fare inspectors and passengers

There are some aspects of inspectors’ activities that we know little about. First, research needs to clarify how an adequate educational path for inspectors could affect their effectiveness in managing passengers’ misbehaviour, violent reactions (e.g., verbal insults and attacks), and punishment phase choices (issuing citations or warnings). For instance, Friis et al. (2020) analysed how (both verbal and physical) actions of bus ticket inspectors may shape passenger aggression in ticket fining. The experiment applied in Copenhagen utilising a body-worn camera by inspectors emphasises how interactional dynamics play a crucial role in aggressive and non-aggressive events. Their findings show how aggression may be prevented through specific actions of inspectors if formally instructed and trained by TAs and PTCs. For instance, physical dominance incites aggression, how inspectors communicate to the passenger determines possible aggressive escalation (e.g., ridiculing the fare evader) as well as authority actions. Alternatively, accommodating the actions of inspectors makes the risk of passenger aggression smaller (Friis et al., 2020).

How inspectors could react to fare evasion can be supported by palmtop devices. They can provide data to manage passengers’ misbehaviour. For instance, they can inform the inspector of how many minutes the ticket has expired and, therefore, not fine the passenger but warn them; if an evader is a “recidivist” or a first evader who warrants more lenient attention. Moreover, palmtop devices can potentially improve the productivity of inspectors by contrasting some features of the “unstable capacity” of inspectors in checking tickets (Guarda et al., 2016a). Specifically, they could reduce timing in ticket controls and automate the citation process.

An additional consideration concerns the danger of inspection activities. Many inspectors get assaulted, as reported in press reviews and technical reports (Nakanishi and Fleming, 2011). Therefore, even if empirical evidence is still missing, this issue affects the effectiveness of inspectors. For instance, inspectors can avoid the ticket inspection of passengers under the influence of alcohol and drugs or notoriously dangerous subjects.

Finally, future research should evaluate the effectiveness of innovative education and enforcement strategies in managing interactions between fare inspectors and passengers (e.g., BRP, 2023). For instance, moving from a “citations first” approach (exclusively as a policing problem) to a “warnings first” approach (customer service approach) is relevant to ascertain whether these approaches are effectively managing fare evasion or only address crime challenges (safety, security, and vandalism).

5.2. Integrated approaches

Besides the specific options, the review of existing literature demonstrates how they could be integrated (see Table 6). The complexity of inspection strategy needs enforcement solutions from an integrated approach.

In inspection planning, determining the “*who and why*” of a fare evader could inform on “*how*, *where and when*” to intercept them due to identifiable characteristics and passengers’ motivations. For instance, it could allow the merge of motivational factors in localising hotspots according to a proper trade-off between cost-effectiveness and equity. However, this approach could lead to biased and ethically questionable results due to a generalisation of some groups, but it is a useful and economic solution in the absence of ICT tools and specific modelling, specifically in the context of little and midsized cities. Similarly, the knowledge of passengers’ behaviours affects the improvement in inspection level estimates and in inspection distribution of the “followers” modelling. Hitherto, the research has considered followers as “rational”, i.e., subjects who evade the fare according to a rational *calculus*: They compare the values of the tickets and the related fine if caught (i.e., opportunistic evaders). However, this contrasts with the extensive progress achieved in the research field in defining passenger behaviours and motivations. Research needs to integrate these two fields to determine a better modelling of behaviours, which can lead to different responses of followers to the placement of leaders, as defined within the specific options of future agenda. Again, the psychological understanding of a “type” of fare evader can be introduced as a training support to inspection activities in managing passengers’ misbehaviour.

The integrated approach should consider the inspection organisation according to additional and refined segments of passengers. It could affect the different segments of evaders as well as the minor or major level of inspectors’ productivity and, consequently, can affect their number. On the one hand, refining passengers’ segments could help in provide more accurate estimations of objective and subjective probability of inspection to enhance the computation of the number of inspectors. On the other hand, the optimal number of inspectors also could change depending on their productivity, for instance, varying the ratio of staff costs-effectiveness by adopting a specialised type of inspectors or adding stipendiary bonuses. Alternatively, it could vary adopting

Table 6
Research avenues for an integrated approach of fare inspection.

Fare inspection	**Fare evaders** *(who and why evade)*
Planning *(how, where and when inspecting)*	• Demographic characteristics and passengers’ motivations to describe hotspots
Organisation *(how many inspectorshow distributing inspectors)*	• Refine objective and subjective probability by enlarging passengers’ segmentation
	• Non-optimal follower’s behaviour modelling
	• Variability of inspector number due to an increase in productivity (ratio of staff costs-effectiveness)
Activities	• Managing passengers’ misbehaviour by training on passengers’ profiling

concentrated inspections, which must consider a ratio of non-interaction-effectiveness and, therefore, depends on the definition of the hotspots (passenger volumes *vs* fare evasion level). However, the development of knowledge is quite sectorial and is not integrated into an overall framework. What the interdependences suggest is the existence of several points of equilibrium between the variables involved, according to a 'minimisation' of fare evasion and 'maximisation' of the effectiveness of the resources used. Academics and TAs/PTCs need to consider improving in strategy relationship among inspection options, e.g., adopting or experimenting an effective method capable of exploiting and combining the possible measures.

Finally, there exist intricate, nuanced, interconnected, and occasionally contradictory matters linking fairness and inequality considerations to fare inspection approaches. Despite the significance of this issue, specific evidence remains still unavailable. Therefore, further research is needed.

CRediT authorship contribution statement

Benedetto Barabino: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Martina Carra**: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Graham Currie**: Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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