Vehicle inspections – from safety device to climate change tool

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Abstract

In November 2010, data from the UK MOT (vehicle inspection) test were released into the public domain for the first time, with further releases since then. This has led to an ongoing stream of work in the UK by both the UK Department for Transport, and as part of a Research Councils UK Energy Programme project, in order to explore the potential offered by such data to investigate issues relating to vehicle ownership and use, energy consumption and emissions generation. This paper reviews the available literature about the practices of vehicle inspection around the world, in order to understand whether analytical techniques being developed in the UK have the potential to be useful elsewhere; the similarities and differences in the types of data collected through vehicle inspection regimes elsewhere; the types of analyses that have previously been conducted using vehicle inspection information; and the potential uses for the data in the future.

1. Introduction

Data collected through periodic technical inspections of vehicles[1] have a number of potentially exciting features for those researching transport policy, energy use and climate change. This information is being collected anyway; it is often relatively comprehensive in relation to the vehicle stock; it is often held at national level; and it is increasingly available in computerised form. There has been extensive use of data from vehicle inspections in the past to look at issues relating to vehicle safety, and, separately, transport-generated air pollution, particularly in relation to the efficacy of periodic inspections to improve safety or reduce emissions. This paper is part of a research project looking at the potential to use British vehicle inspection (MOT test) data to explore a number of further issues - in particular, to understand trends in traffic and patterns of car ownership; to inform climate change policy; and to understand the role of vehicle use in general household energy use, and the implications for future power demands.[2]

In November 2010, data from the British MOT (roadworthiness) tests were first released. The first data release consisted of the results of 150 million MOT tests, from the beginning of 2005 (when a computerised system of reporting was introduced) to the spring of 2010, for vehicles in Great Britain required to take an MOT test. Since then, further releases have provided updated test results. Some fields, such as vehicle registration number and vehicle identification number have been withheld in order to preserve vehicle anonymity. However, the dataset does include the results of the MOT test itself (including detailed reasons for failure), the vehicle odometer (mileage) reading; the vehicle manufacturer, type and engine capacity; and the time when the vehicle was first registered. The dataset also includes the top-level postcode for the Vehicle Testing Station (VTS) that carried out each test.

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[1] Terms such as 'periodic technical inspection', 'vehicle inspection', 'MOT',' vehicle testing' and 'vehicle inspection and maintenance programmes' (I/M programmes) are used in different countries to broadly mean the same thing.

[2] Further details of the project are given in an acknowledgements section at the end.

The dataset has limitations - for example, private vehicles are not required to have an MOT test until they are 3 years old; the current publicly released dataset does not distinguish between vehicles kept by organisations and vehicles kept by private individuals; the information about vehicle location is limited; and there is no information about the characteristics of the vehicle keepers. However, it still represents a vast wealth of data about car ownership and use which can potentially be used to explore a range of important policy issues, if appropriate and cost-effective analytical techniques can be developed (see, for example, Cairns et al. 2014; Wilson et al. 2012, Wilson et al. 2013, Moyce & Lloyd 2013, DfT 2013, Chatterton et al. 2014). For example, such activities could dramatically reduce the need for conventional survey techniques for estimating the effects of transport policies and schemes on traffic levels; they could be used to improve understanding about the relative importance of car travel as a component of household energy use (in conjunction with evidence from the fine-scale datasets available about household gas and electricity use); and they could provide new insights about the spatial and temporal contribution of vehicle pollution to greenhouse gas emissions.

This paper aims to provide some insights into the potential usefulness of such techniques for other places, by reviewing the nature of vehicle inspection data collected elsewhere. Specifically, the objectives of this paper are:

- To provide a brief history and overview of vehicle inspection programmes worldwide.
- To provide some insight into the similarities and differences in the types of data collected through vehicle inspection programmes in other countries.
- To identify past and current uses of vehicle inspection data.
- To discuss potential future uses of such data, together with the issues that need to be resolved.

This paper forms the first stage of work to investigate these issues, with future activities planned to investigate international experience in more depth.

2. Background

Vehicle roadworthiness inspections fall into two types: periodic technical inspections (PTI) and road-side inspections, (European Commission, 2012). The former category is performed in a designated test centre, where the motorist/owner brings their vehicle to be tested at a pre-determined interval. The latter category is performed at the road-side, and is less likely to take place at regular intervals, since testing is usually targeted for maximum effectiveness. Both private and commercial vehicles are subject to inspections, with commercial vehicles usually subject to particular scrutiny. For example, under EU law, unannounced roadside inspections of commercial vehicles can be carried out at any time, in any EU country, irrespective of the country where the vehicle is registered. This paper is focused on the former category of inspection – i.e. of periodic inspections – since its focus is on the potential of such tests to generate comprehensive and predictable data sets. Further, the focus of this paper is on cars and light goods vehicles (excluding heavier goods vehicles), given the scope of the research project that it informs, which is itself focused on issues relating to private car ownership, use and emissions.

Initially, when vehicle inspections were introduced, their main purpose was to undertake mechanical safety checks. However, over time, emissions control has become an increasingly important component of the inspection process, not least due to concerns about air pollution.

This paper is based on literature review, including academic literature, project papers, unpublished reports, and documents on websites. Table 1 shows a summary of the most important sources of literature/information which have been reviewed for particular countries.

Table 1: Sources of information for different countries reviewed in this paper

Country / Association	Source of Information
UK	Cuerden et al. (2011), Cairns et al. (2011/13), Wilson et al. (2012), Wilson et al. (2013), Chatterton et al. (2014), DfT (2013) ; Moyce & Lloyd (2013)
Norway	Odeck (2000), Christensen and Elvik (2007), Fosser (1992)
Netherlands	de Jong (1996), Wee et al. (2000), SWOV (2012)
France	Yamamoto et al. (2004)
Spain	Trillas et al. (2011)
Sweden	Ylvinger (1998)
USA	Bin (2003), Washburn et al. (2001), Easley (2011), Harrington et al. (2000), Hubbard (1997), Hubbard (1999), Stedman et al. (1997), Bishop & Stedman (2008), Calvert et al. (1993), Merrell et al. (1999), Beaton et al. (1995) http://en.wikipedia.org/wiki/Vehicle_inspection_in_the_United_States
Canada	Moghadam et al. (2010)
Mexico	Riveros et al. (2002)
Lebanon	Kazopoulo et al. (2007)
UAE	Selim et al. (2011)
Japan	http://japan.angloinfo.com/transport/vehicle-ownership/vehicle-roadworthiness/
Australia & New Zealand	Keall et al. (2012), Blows et al. (2003), Paine (2000)
South Africa	(http://www.services.gov.za/services/content/Home/ServicesForPeople/Driving/Testingvehicle/roadworthinesscertificate/en_ZA, http://www.cita-vehicleinspection.org/LinkClick.aspx?fileticket=4u8K1E7Neto%3D&tabid=494,
Namibia	http://www.cita-vehicleinspection.org/LinkClick.aspx?fileticket=Y7qtxaliY8M%3D&tabid=494
Nigeria	http://www.academia.edu/3584014/Vehicle_Testing_in_Nigeria,
38 Asian countries	UNEP (2011)
India	Sundar & Deb (undated); Bhanot & Sekar(undated); UNEP (2011)
Thailand	Taneerananon et al. (2005) ; UNEP (2011)

It should be noted that the existing literature is limited, patchy and often only available through national websites. Most of the academic papers are based on developed countries. Moreover, most are focused on particular issues such as the air quality impacts of vehicle inspection programs. We have not, so far, come across any papers which have looked at the data collected through vehicle inspections as a way of understanding traffic levels, car ownership issues or topics relevant to energy policy.

3. The history of vehicle inspections

Periodic technical inspections of vehicles were introduced more than fifty years ago in various industrialised/ motorised countries such as the UK. Initially, their main purpose was to ensure vehicle maintenance, and mechanical items (such as brakes or steering) were checked. Over the years, the list of items tested has been continually expanded, in particular, to include emissions control. There have also been changes to the rules governing when, and how often, such inspections are carried out.

In the UK, a national vehicle inspection test, usually known as the 'MOT (Ministry of Transport) test', was first introduced in 1960 under the direction of the Minister of Transport[3]. The test was originally relatively basic, involving a check of brakes, lights and steering, which was to be carried out after the vehicle was ten years old and every year thereafter. In 1967, the testable age for an MOT was reduced to three years. The list of items tested has been continually expanded over the years. For instance, tyre checks were added in 1968, whilst emissions testing for petrol-engine vehicles, together with checks on the anti-lock braking system, rear wheel bearings, rear wheel steering and rear seat belts were added in 1991. A computerised administration system for issuing non-secure test certificates as well as for reporting annual MOT (roadworthiness) test results was introduced in 2005.

At present, many countries have implemented vehicle inspection programs, though timing and content varies significantly. For example, there are reports of comprehensive testing programmes being introduced in the Netherlands in 1978 (SWOV, 2012); in France in 1986 (Yamamoto et al., 2004); in Norway after 1995 (Christensen and Elvik, 2007); and in Lebanon in 2001 (Kazopoulo et al., 2007).

As a general trend, the components of inspection and maintenance programmes are becoming more harmonised. In particular, the development of the European Union (EU) has influenced member countries to introduce either tighter or more extensive programmes, which are relatively similar, not least given that vehicles from one member country may drive on the roads of another. For example, Christensen and Elvik (2007) report that Norway's extensive I/M programme was introduced after it was granted access to the EU inner market via the EEA Treaty. There has been a series of EU Directives on the topic dating back to 1976, which outline common aspects (minimum standards) that should be followed for vehicle inspections in a given country within the EU.

Globally, the development of regulations and standards for vehicle testing is led by the United Nations Economic Commission for Europe (particularly 'The World Forum for the Harmonisation of Vehicle Regulations – WP 29'), which has been responsible for various agreements on type approval of vehicles (such as the 1958 and 1998 agreements). The UN position on vehicle inspections is to encourage harmonisation between countries, and with the EU approach, and, in 1997, it put in place the'1997 Agreement' on "*the adoption of uniform conditions for periodical technical inspections of wheeled vehicles and the reciprocal recognition of such inspections*"[4], although this is not yet formally adopted by many countries. Meanwhile, the organisation CITA, discussed in the next section, acts as an international advisory body.

Despite the general trend towards harmonisation of schemes, important differences remain in terms of local conditions, test content, vehicles covered etc.. For example, the EU minimum standards do

[3] http://en.wikipedia.org/wiki/MOT_test

[4] http://staging.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp291997.html

not require periodic inspections of motorcycles, so, in countries such as France, motorcycles are exempt. (There are proposals that this should change). Some of the differences between national programmes are discussed further below.

There is also an important debate relating to the overall cost-effectiveness of periodic vehicle inspection as a means of achieving either safety or environmental aims. This is reflected in some of the academic literature discussed in section 8, and is also shown in the patchy situation of vehicle inspection programmes between different parts of the USA. According to Wikipedia[5], only 17 states have a periodic (annual or biennial) safety inspection programmes, whilst 32 states have full or partial emissions inspection programmes (which were partly generated by the 1990 Clean Air Act, which required states to have vehicle emissions inspection programmes in metropolitan areas whose air quality did not meet federal standards). Some states have discontinued their programmes – for example, it is reported that New Jersey discontinued its passenger vehicle safety inspection programme in 2010, whilst Kentucky and Minnesota, have discontinued their emissions testing programmes.

Historically, there has been a divide between developed and developing countries, although, over the past 15 years, many developing countries in Asia and Africa have also started or initiated vehicle inspection programmes. In 2011, UNEP prepared a list of selected countries in Asia and the Pacific, describing their I/M programmes. This showed that at least 9 countries (including China) were testing for both roadworthiness and emissions[6]; at least 8 countries (including India) were primarily testing for emissions only[7]; and at least 19 countries (often relatively small island states[8]) had no such programmes. Concerns about air pollution have often been a major reason for introducing such programmes. However, this is not universally the case in developing countries – for example, in Namibia, the focus remains on road safety rather than emissions.

4. CITA (International Motor Vehicle Inspection Committee)[9]

CITA – the International Motor Vehicle Inspection Committee - is the world-wide non-profit association of vehicle inspection organisations. It is based in Brussels and present members (approximately 120 organisations) are drawn from almost 60 countries. CITA represents all types of organisations including stakeholders such as government, private sector, dedicated inspection centres, garage-based test centres and test equipment manufacturers.

CITA started its activities in 1958 by organising National Road Safety days and, since then, has played an important role in vehicle inspections. Since 1969, it has organised regular international meetings. In 1989, CITA was registered under Belgian law as an international non-profit organisation. CITA is

[5] http://en.wikipedia.org/wiki/Vehicle_inspection_in_the_United_States

[6] Bangladesh, Bhutan, China (including Hong Kong and Taiwan), Malaysia, Philippines, Samoa (Western), Singapore, Thailand and Vietnam.

[7] Bhutan, Cambodia, India, Indonesia, Myanmar, Nepal, Pakistan and Sri Lanka.

[8] Cook Islands, Republic of Korea, Fiji, Lao People's Democratic Republic, Maldives, Marshall Islands, Micronesia (federal State of), Mongolia, Myanmar, Nauru, Niue, Papua New Guinea, Samoa (Western), Solomon Islands, Timor Leste, Tokelau, Tonga, Tuvalu and Vanuatu.

[9] http://www.cita-vehicleinspection.org/

recognised by the Commission of the EU and the UN Economic Commission for Europe (UNECE) for its expertise in relation to vehicle inspections.

CITA focuses on improving transport sustainability with particular emphasis on road safety and environmental protection. Its five topic areas are:

- safety systems;
- environmental protection systems;
- standardised inspection outcomes;
- continuous compliance; and
- information systems.

CITA regularly organises conference and conducts commissioned research to promote and disseminate knowledge on vehicle inspections. Since 2000, CITA has organised an official international conference on a two-yearly basis.

CITA also conducts regular surveys of its members, exploring issues such as the nature of organisations involved in vehicle inspection, details of test regimes (including, for example, test frequencies, fees etc.), inspection numbers and vehicle failure rates, and other relevant issues.

5. The content of vehicle roadworthiness testing

As highlighted previously, the content of vehicle inspections is becoming more uniform. As the most recent development in the EU, Member States have been required to bring into force *Directive 2010/48/EU* by 31 December 2011 (with the exception of the provisions of paragraph 3 of Annex II roadworthiness certificate, which applied from 31 December 2013) and the *Directive 2010/47/EU* by 1 January 2012[10]. The former directive applies to periodic roadworthiness inspections, whilst the latter applies to roadside inspections of commercial vehicles.

Minimum standards are mandated by these directives for conducting inspections. They are intended to encourage road safety, environmental protection and fair competition in terms of how vehicles are maintained and tested. *Commission Directive 2010/48/EU* suggests that the roadworthiness certificate issued in the case of mandatory periodic vehicle tests in EU member states shall cover at least the following elements or items:

- VIN (vehicle identification number) number;
- Registration plate number and country symbol of state of registration;
- Place and date of the test;
- Odometer reading at time of test if available;
- Vehicle class if available;
- Identified defects and their categorisation (into MiD (Minor Defects), MaD (Major Defects), and DD (Dangerous Defects));
- Overall assessment of the vehicle;
- Date of next periodic test (if this information is not provided by other means); and

[10] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:173:0047:0072:EN:PDF

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:173:0033:0046:EN:PDF

- Name of inspection organisation, and the signature or identification of the inspector responsible for the test.

Emissions are listed as one of the areas on which vehicles should be assessed, and could be listed as a reason for failure. However, emissions readings are not directly recorded. In terms of geography, it is notable that vehicle testing location is recorded, rather than the location of the vehicle keeper.

Clarity on what information is recorded in countries outside the EU is harder to ascertain, although Moghadam and Livernois (2010) mention increasing similarities between the inspection and maintenance (I/M) programs in use in urban areas in the US and Canada. Nonetheless, it is clear that important differences remain. For example, in Mexico, Riveros et al. (2002) report that the mandatory I/M programme operating in 1996 and 1998 involved recording information on the owner's identification, odometer reading, and tailpipe concentrations for CO, HC, NOx, CO_2 and oxygen at idle and at 2300 revolutions per minute.

In some countries, there is also concern about the discrepancy between theory and practice. For example, Taneerananon et al. (2005) report on the vehicle inspection programme introduced in Thailand in 1994. In their subsequent assessment, they report on issues such as vehicle owners "*buying forged inspection certifica*tes" and inadequate testing standards, such that "*only a few items of insignificant checks are performed, such as engine ID, and body paint, while the key safety features are overlooked, such as brakes, tyre treads, headlights*". Kolke (2005) also discusses problems with fraud and corruption in existing I/M programmes; whilst Hubbard (1999) analyses data from California to suggest that inspection regimes may be biased. Clearly, the accuracy with which testing takes place, and results are reported, will have a significant effect on the reliability of any dataset which is associated with it, and should not be forgotten as an important data property.

6. Data creation and storage

For non-federal countries, I/M programmes are usually organised nationally. In contrast, in federal countries (such as the USA, Australia and Germany), I/M programmes are often run at state level. For example, the Department of Environmental Quality (DEQ) administers the I/M program in Oregon (USA) and the vehicle emission check program in Seattle (USA) is administered by Washington State Department of Ecology (WSDOE).

Often, inspections/tests are performed by private agencies that have been licensed to do inspections, which are then required to submit their data to the appropriate national or federal agency. For example, Christensen and Elvik (2007) report that, in Norway most inspections are performed by private agencies that have been licensed to do inspections; completed inspection forms must then be sent to the Public Roads Administration for storage in the motor vehicle registry. Similarly, the Department of Land Transport (DLT) in Thailand has established regulations for vehicle inspection and adopted a private-sector inspection policy in 1994 (Taneerananon et al., 2005). In contrast, in Namibia, eNaTIS (Namibian Traffic Information Systems) is responsible for vehicle tests; and there are no private test centres[11]. Issues relating to the regulation and licensing of organisations to carry out vehicle inspections has been the subject of analysis by various

[11] http://www.cita-vehicleinspection.org/LinkClick.aspx?fileticket=Y7qtxaIiY8M%3D&tabid=494

commentators, notably for Norway (Odeck, 2000), Spain (Trillas et al., 2011) and Sweden (Ylvinger, 1998), with analysis largely being in favour of more deregulated systems.

In terms of data storage, it is likely that many countries are using computerised storage systems. However, from the available literature, it has proved very difficult to establish how long records have been held in standardised form, and/or whether any countries provide access to their data in the way that the UK does.

7. The timing and frequency of vehicle testing

There is considerable variation in the age at which vehicles must be first tested and the frequency of testing.

The EU mandates a minimum frequency of 4:2:2:2[12], whereby vehicles are first tested when they are four years old, and then every two years after that.

A number of countries choose a different initial threshold. For example, the UK first tests vehicles when they are 3 years old, as do, for example, Singapore and Japan. In contrast, in Thailand, the 1994 inspection policy introduced required cars to be first tested when they were over 7 years old, (Taneerananon et al., 2005), as is also the case in Brunei Darussalam (UNEP, 2011). In India, roadworthiness testing is required after 15 years for private vehicles (Sundar & Deb, undated.)

Some countries, such as the UK and South Africa, require annual checks, rather than biennial checks. Various places, such as Ontario, Canada, and New South Wales, Australia, require a further check when vehicles change ownership (Moghadam et al. 2010, UNEP 2011). Some places, such as Nebraska[13], require checks when vehicles are introduced into their area. Some places, such as the Philippines, also require inspection prior to registration as well as for renewal of registration (UNEP, 2011).

It is generally accepted that vehicle defects increase with vehicle age (see, for example, Bin 2003, Cuerden et al. 2011, Maghadam & Livernois 2010, SWOV 2012). Hence, there is a debate about whether testing frequency should increase with vehicle age. At EU level, there has been discussion as to whether a 4:2:1:1:1 testing regime should be introduced. In the Netherlands, since 2008, testing frequency increases from biennial to annual once vehicles are more than 8 years old, (SWOV 2012). In Singapore, the same is true for cars that reach 10 years old (UNEP, 2011).

New Zealand has an unusually frequent regime, known as the warrant of fitness (WoF) scheme, whereby vehicles are required to be inspected every year when they are under six years old and every 6 months when they are over six years old (Keall et al., 2012). In India, all vehicles are required to undergo a periodic emission check twice a year, (4 times in a year in Delhi), via the Pollution Under Control (PUC) programme which has been operating since 1991 (UNEP, 2011; Bhanot and Sekar, undated). Both the New Zealand and Indian programmes have been subject to criticism (Sundar and Deb, undated, Keall et al. 2012).

[12] This notation is used to indicate that a vehicle should first be tested when it is 4 years old, and at two year intervals after that.

[13] http://www.dmv.state.ne.us/dvr/mvtitles/inspect.html

8. Uses of vehicle inspection data

There have been two primary purposes for undertaking roadworthiness tests – improving road safety, and reducing vehicle emissions – and much of the data collected through the roadworthiness tests has been used to analyse these issues. Meanwhile, the data has the potential to be used for a wider range of purposes. These topics are discussed in turn.

a) Road safety

Work on road safety has typically attempted to understand the importance of vehicle defects to accident rates, and, consequently, the impacts of MOT testing on levels of vehicle defects, and the potential improvement to accident rates that result from introducing roadworthiness inspections. For example, the impact assessment behind the EU directives on roadworthiness concluded "*on average 6% of accidents are caused by technical defects of vehicles and 'more than 2,000 fatalities per year in the EU may be linked to technical defects of vehicles. Based on available studies, between 900 and 1,100 of these could be avoided if adequate improvements to the roadworthiness testing system were put in place'*" (EP, 2012).

Blows et al. (2003) have shown road safety benefits from regular inspections in Auckland, New Zealand, whilst DEKRA 2005 (as quoted in SWOV 2011) has done so for Texas, although Merrill et al. (1999) argue against reductions in fatality rates from vehicle inspections in the US. Fosser (1992) and Christensen & Elrik (2007) have explored the issue for Norway, though with inconclusive results. Keall et al. (2012) have also explored the issue for New Zealand and Victoria, showing safety benefits but raising issues about the cost-effectiveness of periodic vehicle inspections as a tool for achieving them (not least given New Zealand's frequent testing regime). SWOV (2012) estimates the effect of the MOT test are to reduce fatalities by 2.5-3% per year in the Netherlands. Paine (2000) argues that the importance of roadworthiness testing may be underplayed in analysis, since "*vehicle defects contribute to crashes to a much greater extent than suggested by police statistics. Police investigations tend to assign "blame" but overlook the contribution of defects to crash severity*" and that "*in depth studies suggest that vehicle factors, particularly defects, are "causal, possibly causal or contributory" in at least 12% of all crashes. Rates for older cars and heavy vehicles tend to be much higher*."

At the time of the recent EU Directive, there were proposals in the UK to change from a 3:1:1:1 testing regime to a 4:2:2:2 regime. A detailed study by Cuerden et al. (2011) analysed MOT data to show:

- In 2009, approximately 40% of vehicles tested failed their initial (normal) MOT test;
- As vehicle age increases, the rate of MOT failure increases - for cars, this reaches nearly 60% when they are 13 years old; and
- The greater the cumulative distance travelled, the higher the rate of MOT failure, for example all cars which had driven over 90,000 miles experienced above a 50% failure rate.

Cuerden et al. (2011) highlighted that: "*There is no established link between MOT measured roadworthiness and vehicle defects contributing to accidents, other than the common sense approach, where the greater the number of defects, especially the most safety critical ones in the fleet at a given time, the greater the likelihood of accidents being caused, at least in part, by roadworthiness issues*". Using two different modelling approaches, they then estimated that the effect of changing the UK testing regime could be to increase both accidents and casualties (perhaps by 300-400 serious casualties per year).

b) Vehicle emissions

The use of vehicle inspections to regulate emissions has been discussed in various forums (see, for example, Faiz et al. (1996), reporting for the World Bank). In particular, following on from the 1990 Clean Air Act in the US, which stipulated that areas which did not meet national air quality standards due to motor vehicle emissions needed to develop plans to reduce those emissions, many US states introduced I/M programmes. These were subject to significant criticism (see, for example, Bin, 2003; Harrington et al., 2000; Washburn et al., 2001; Hubbard 1997; Beaton et al. 1995), on the basis that they were an inefficient use of resources (since all vehicles were subject to inspection); they were not particularly effective at reflecting emissions in real world driving conditions (given that they did not allow for acceleration and deceleration cycles etc); they were not the most efficient way to identify high polluting vehicles; and they failed to provide drivers with incentives to minimise their vehicle emissions. Similar points have been made for other locations – for example, Riveros et al. (2002) argue that emissions work should primarily focus on the intensively used taxi fleet in Mexico City (rather than all vehicles).

Consequently, various analyses have been carried out to explore the potential for more targeted programmes. For example, Washburn et al. (2001) used 1994 data from three testing stations in the Seattle area to identify characteristics associated with vehicles more likely to be higher polluters. Their results suggested that vehicle age, vehicle manufacturer, number of engine cylinders, odometer reading, and whether or not oxygenated fuels were in use were all important in determining I/M emissions test results.

With a similar purpose, Bin (2003) used logit regressions on I/M testing data from Portland, Oregon to identify the characteristics of vehicles that were significantly associated with emission test failures. Results again suggested that vehicle age, make and class, engine size and odometer reading all play a significant role in determining I/M test results. Bin (2003) concludes that "*for example, targeting vehicles of more than 10 years old, engine size smaller than 2000 cc, and odometer reading over 100,000 would substantially increase the likelihood of finding high polluting vehicles*".

Various other analyses have also been conducted, specifically to explore the effects of I/M programmes on vehicle emissions – see, for example, Easley (2011), Zachariadia et al. (2001), Bishop and Stedman (2008), Stedman et al. (1997), Calvert et al. (1993), and Moghadam & Livernois (2010).

c) Other purposes

In previous work (Cairns et al., 2014), we have explored the *potential* to use the MOT data for a wider range of purposes, particularly if analysed in conjunction with other spatial data sets such as the UK Census data. This potential is also being explored by the UK Department for Transport (Moyce & Lloyd 2013; DfT, 2013), and is being taken forward in our current research work, led by the University of Aberdeen (www.MOTproject.net). Potential topics include:

- Using odometer readings to investigate trends in traffic (see, for example, Wilson et al. 2012, Wilson et al. 2013, DfT 2013), and to analyse the effects of particular transport policies;

- Using odometer readings and vehicle characteristics information to generate estimates of emissions of carbon dioxide, and to look at the spatial implications for climate change policy, (see, for example, Chatterton et al. 2014);
- Using odometer readings and vehicle characteristics information to generate estimates of transport energy use, that can be analysed in conjunction with data about other household energy use such as electricity and gas; and
- Using vehicle characteristics information to explore the spatial diffusion of new technologies, such as hybrid and electric vehicles (see, for example, Pridmore and Anable, 2012).
- Using vehicle characteristics information to understand the relationship between local demographic, economic and infrastructure factors and patterns of car ownership and use.
- Identification and quantification of the number of vehicles used for low annual mileage, which could be an indicator of potential users of electric (or other low carbon) vehicles.

Vehicle inspection data has the potential to be an extremely valuable dataset to investigate these issues.

9. Issues for future analysis of vehicle inspection data

From analysis that has been undertaken so far, it seems that key issues which need to be addressed if vehicle test data is to be used for a wider variety of purposes include:

- Dealing with seasonal patterns in vehicle use, and, separately, vehicle licensing, and how those interact with the timing of MOT tests;
- Understanding patterns of ownership during the early years of a vehicle's life (given the large proportion of new vehicles that are not privately owned), and how different ownership patterns affect vehicle use;
- Finding acceptable ways of connecting MOT data with data about where vehicles 'live';
- Adding emissions values to the data set; and
- Understanding the interaction between vehicle age and vehicle use.

The final point – about the interaction between vehicle age and vehicle use – seems critical yet is relatively poorly understood. It is widely recognised that the average yearly distance driven by a car does decrease with vehicle age (see, for example, Wee et al., 2000; Hickman, 1999 cited in Zachariadis et al., 2001; Moghadam and Livernois, 2010).

However, it is unclear how far vehicle age is a significant independent variable in its own right. This is an important issue deserving further investigation. If newer vehicles do 'generate' mileage, this has implications for road safety, environmental policy and other transport issues, potentially at least partially undermining the benefits claimed for a newer vehicle fleet – as discussed in Cairns et al. (2014), and also by other commentators. For example, Riveros et al. (2002) comment that the greater level of average emissions from older vehicles in Mexico City shown in some of their work is smaller than expected *"since the tendency to drive newer cars is increasing fuel usage and vehicle emissions"*. Wee et al. (2000), using data from the Dutch car fleet to explore the potential impacts of car scrappage schemes, argue:

> *"the average yearly distance driven by cars older than 10 years is less than half the distance driven by cars only several years old. New cars are often more reliable, comfortable and energy-efficient than old cars. People who intend to drive more in the near future will therefore show anticipative behaviour by purchasing a new(er) car. In addition, a new(er) car will probably generate more kilometres by itself, since the variable costs decrease, the newer car may be more reliable and/or because of the pleasure of driving increases.*
>
> *If the new(er) car is substantially more energy-efficient, it will cause a decline in the cost price per kilometre, which leads to an increase in petrol consumption (Goodwin, 1992). Moreover, incentives will be absent to perform energy-efficient journeys, driving styles and speed, as proved by Rouwendal (1996). In other words, the energy savings due to an improvement in energy efficiency of new cars compared to scrapped old cars will – at least partly – be undone by rebound effects."*

However, other work – for example, by de Jong (1996), Yamamoto et al. (2004) - emphasises that car ownership and use are affected by a wider variety of factors, such as the socio-economic attributes of individuals and households, trip patterns (which will, in turn, be affected by land use patterns) and wider economic conditions. Further understanding of the scale of the 'newer car' effect, as opposed to these other factors, could be particularly important if aiming to use test data for, for example, traffic analysis, since it affects how far changes in the car market need to be factored into any analysis, as separate from other macro-economic trends.

10. Conclusions

This paper aims to provide a brief overview of the literature about regular vehicle inspections, and the regulatory and advisory processes governing their content. Initially, vehicle inspections started in industrialised countries over 50 years ago, aimed at maintaining the mechanical performance of vehicles to ensure road safety. Since that time, many countries have adopted similar programmes. EU Directives have required minimum standards across Europe, and the UN is encouraging the adoption of similar standards elsewhere. Meanwhile, managing vehicle emissions has been an important motivation for introducing inspection and maintenance regimes in parts of North America, and many Asian countries.

Most use of I/M data has focused on either road safety or vehicle emissions issues. It is clear that there is the potential to use the data for a wider range of purposes. However, there are also a number of important issues to be resolved if the data are to be used for robust analysis of policy issues relating to traffic trends, energy use and climate change. Within the UK, analysis on this topic is progressing. Given the increasing standardisation of vehicle inspection regimes, it appears that techniques developed in the UK have the potential to be of benefit on a global basis. If appropriate analytical techniques can be developed, the increasingly widespread availability of relatively standardised data about car ownership and use being collected through vehicle inspection regimes worldwide could potentially provide an invaluable and cost-effective resource for improving understanding of traffic trends, energy use and vehicle-related greenhouse gas and local air pollutant emissions.

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12. References

Beaton, S., Bishop, G., Zhang, Y., Ashbaugh, L., Lawson, D. and Stedman, D. (1995) On-road vehicle emissions: regulations, costs, and benefits. *Science*, 268, pp. 3-41.

Bin, O. (2003) A logit analysis of vehicle emissions using inspection and maintenance testing data. *Transportation Research Part D*, 8, pp. 215–227.

Bhanot, B. and Sekar, A. (undated) Approach towards development of an effective in-use vehicle emission inspection for India. Available at: http://cleanairinitiative.org/portal/system/files/59246_bhanot_paper.pdf

Bishop, G. and Stedman, D. H. (2008) A decade of on-road emissions measurements. *Environ. Sci. Technol.* 42, pp. 1651–1656.

Blows S., Ivers R. Q., Connor J., Ameratunga S. and Norton, R. (2003) Does periodic vehicle inspection reduce car crash injury? Evidence from the Auckland Car Crash Injury Study. *Australian and New Zealand Journal of Public Health*, 27(3), pp. 323-327.

Cairns S, Wilson RE, Chatterton T, Anable J, Notley S and McLeod F (2014) *Using MOT Test Data to Analyse Travel Behaviour Change - Scoping Report.* TRL PPR578, Wokingham.

Chatterton T, Barnes J, Wilson E, Anable J, Cairns S (2014) Variations in car type, size, usage and emissions across Great Britain and relationships with socio-demographic characteristics. *In: UTSG Conference*, Newcastle.

Calvert, J., Heywood, J., Sawer, R. and Seinfeld, J. (1993) Achieving acceptable air quality: some reflections on controlling vehicle emissions. *Science*, 261, pp. 37–45.

Christensen, P. and Elvik, R. (2007) Effects on accidents of periodic motor vehicle inspection in Norway. *Accident Analysis and Prevention*, 39, pp. 47–52.

Cuerden, R. W., Edwards, M. J. and Pittman, M. B. (2011) *Effect of Vehicle Defects in Road Accidents*. Published Project Report PPR565, TRL.

de Jong, G. (1996) A disaggregate model system of vehicle holding duration, type choice and use. *Transportation Research Part B*, 30 (4), pp. 263-276.

Department for Transport (13/6/13) *Experimental Statistics – Analysis of vehicle odometer readings recorded at MOT tests*.

Easley, P. (2011) *Environmental Analysis of Vehicle Inspection and Maintenance Program*. MA Public Administration Program, Texas State University, USA.

European Parliament (Nov 2012) *Initial appraisal of a European Commission Impact Assessment: European Commission proposal on the 'Roadworthiness Package'*. PE 494.455.

European Commission (2012) *Roadworthiness package - summary of impact assessment* Staff working document SWD (2102), 207 final.

Faiz, A., Weaver, C. S. and Walsh, M. P. (1996) *Air Pollution from Motor Vehicles: Standards and Technologies for Controlling Emissions*. The World Bank.

Fosser S. (1992) *An experimental evaluation of the effects of periodic motor vehicle inspection on accident rates. Accident Analyses and Prevention*, 24(6), pp. 599-612.

Goodwin, P. B. (1992). A review of demand elasticities with special reference to short and long run effects of price changes. *Journal of Transport and Economic Policy*, 26 (2), pp. 155-159.

Harrington, W., McConnell, V. and Ando, A. (2000). Are vehicle emission inspection programs living up to expectations? *Transportation Research D*, 5, pp. 153–172.

Hubbard, T. N. (1997) Using inspection and maintenance programs to regulate vehicle emissions. *Contemporary Economic Policy*, 15, pp. 52-62.

Hubbard, T. N. (1999) An Empirical Examination of Moral Hazard in the Vehicle Inspection Market, *RAND Journal of Economics*, 29(2), pp. 406-426.

Kazopoulo, M., Kaysi, I. and Fadel, M. E. (2007). A stated-preference approach towards assessing a vehicle inspection and maintenance program. *Transportation Research Part D*, 12, pp. 358–370.

Keall, M., Stephan, K., Watson, L. and Newstead, S. (2012) *Road Safety Benefits of Vehicle Roadworthiness Inspections in New Zealand and Victoria*. Report No. 314, Monash University Accident Research Centre. Available at: http://www.monash.edu.au/miri/research/reports/muarc314.pdf

Kolke, R. (2005) *Inspection & Maintenance and Roadworthiness*. Module 4b, Sustainable Transport – A Sourcebook for Policymakers in Developing Cities, GIZ.

Merrell, D., Poitras, M. and Sutter, D. (1999) The effectiveness of vehicle safety inspections: An analysis using panel data. *Southern Economic Journal*, 65(3), pp. 571-583.

Moghadam, A. K. and Livernois, K. (2010) The abatement cost function for a representative vehicle inspection and maintenance program. *Transportation Research Part D*, 15, pp. 285-297.

MOT Testing Magazine (2012). *History of MOT Test*. Available at: http://www.motester.co.uk/mot-general-information/mot-information-for-motorists/history-of-the-mot-test

Moyce, R. and Lloyd , D. (2013) *Using MOT records to estimate local level vehicle annual mileages*. Proceedings of GISRUK, Liverpool, 3-5/4/13

Odeck, J. (2000) Assessing the relative efficiency and productivity growth of vehicle inspection services: An application of DEA and Malmquist Indices. *European Journal of Operational Research*, 126(3), pp. 501-514.

Paine, M. (2000) *Vehicle Roadworthiness and Accidents*. Submission to the Victorian Parliament Road Safety Committee, Australia. Available at: http://users.tpg.com.au/users/mpaine/defects.html

Pridmore, A. and Anable, J. (2012) *Influence and Innovation – can patterns be detected in the take up of new vehicle technologies?* Universities Transport Study Group 44th Annual Conference, Aberdeen, January 2012.

Riveros, H. G., Cabrera, E. and Ovalle, P. (2002) Vehicle inspection and maintenance, and air pollution in Mexico City. *Transportation Research Part D*, 7, pp. 73-80.

Rouwendal, J. (1996) An economic analysis of fuel use per kilometre by private cars. *Journal of Transport and Economic Policy*, 30 (1), pp. 3-14.

Selim, M. Y. E., Maraqa, M. A., Hawas, Y. E. and Mohamed, A. M. O. (2011) Assessment of vehicle inspection and emission standards in the United Arab Emirates. *Transportation Research Part D*, 16, pp. 332-334.

Stedman, D. H. Bishop, G. A., Aldrete, P. and Slott, R. S. (1997) On-road evaluation of an automobile emission test program. *Environmental Science and Technology*, 31(3), pp. 927–931.

Sundar, S. and Deb, K. (undated) A regime for inspection and certification for in-use vehicles in India. CODATU Proceedings, Available at: http://www.codatu.org/wp-content/uploads/A-regime-for-inspection-and-certification-for-in-use-vehicles-in-India-Sanjivi-SUNDAR-Kaushik-DEB.pdf

SWOV (2012) *SWOV Fact Sheet – Periodic Vehicle Inspection (MOT)*. Available at: https://www.swov.nl/rapport/Factsheets/UK/FS_MOT.pdf

Taneerananon, P., Chanwannnakul, T., Suanpaga, V., Khompratya, T., Kronprasert, N. and Tanaboriboon, Y. (2005) An evaluation of the effectiveness of private vehicle inspection process in Thailand. *Journal of the Eastern Asia Society for Transportation Studies*, 6, pp. 3482-3496.

Trillas, F., Montolio, D. and Duch, N. (2011) Productive Efficiency and Regulatory Reform: The Case of Vehicle Inspection Services. *Revista de Economía Aplicada Número,* 55 (19), pp. 33-59. Available at: http://www.revecap.com/revista/numeros/55/pdf/trillas_montolio_duch.pdf

UNEP (2011) *Asia and Pacific Vehicle Standards and Fleets*. Available at: http://www.unep.org/transport/pcfv/PDF/Maps_Matrices/AP/matrix/Vehicles/AsiaPacific_VehicleMatrix_Nov2011.pdf

Washburn, S., Seet, J. and Mannering, F. (2001) Statistical modeling of vehicle emissions from inspection/maintenance testing data: an exploratory analysis. *Transportation Research Part D*, 6, pp. 21-36.

Wee, B. V., Moll, H. C., Dirks, J. (2000) Environmental impact of scrapping old cars. *Transportation Research Part D*, 5, pp. 137-143.

Wilson, R.E., Anable, J., Cairns, S., Chatterton, T., Notley, S. and Lees-Miller, J. D. (2013) On the estimation of temporal mileage rates. *Transportation Research Part E,* 60, pp. 126-139.

Wilson, R. E., Cairns, S., Notley, S., Anable, J., Chatterton, T. and McLeod, F. (2012) Techniques for the inference of mileage rates from MOT data. *Transportation Planning and Technology,* 36(1), pp. 130-143.

Yamamoto, T., Madre, J. and Kitamura, R. (2004) An analysis of the effects of French vehicle inspection program and grant for scrappage on household vehicle transaction. *Transportation Research Part B*, 38, pp. 905–926.

Ylvinger, S. (1998) The operation of Swedish motor-vehicle inspections: efficiency and some problems concerning regulation. *Transportation*, 25, pp. 23-36.

Zachariadis, T., Ntziachristos, L. and Samaras, Z. (2001) The effect of age and technological change on motor vehicle emissions. *Transportation Research Part D*, 6, pp. 221-227.

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