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Excess passenger weight impacts on US transportation systems fuel use (1970–2010)

Michelle Tom [a,*], Paul Fischbeck [b], Chris Hendrickson [a]

[a] Civil and Environmental Engineering, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA 15213-3890, USA
[b] Department of Social and Decision Sciences, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA 15213-3890, USA

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A B S T R A C T

Over the past 40 years, the percentage of the US population that is overweight and obese has increased significantly, with nearly 70% of American adults now overweight or obese (National Center for Health Statistics (NCHS), 2013). The excess weight that Americans are carrying is taking a toll on the social and physical infrastructure of the country, and may also be counteracting the efforts of industries and policymakers to move towards a more energy efficient and sustainable future. This article analyzes the transportation industry to determine the amount of additional fuel use, greenhouse gas emissions, and fuel costs that are attributed to excess passenger weight in light-duty vehicles, transit vehicles, and passenger aircraft in the US from 1970 to 2010. Using driving and passenger information in the US and historical anthropometric data, it is estimated that since 1970 over 205 billion additional liters of fuel were consumed to support the extra weight of the American population. This is equivalent to 1.1% of total fuel use for transportation systems in the United States. Also, excess passenger weight results in an extra 503 million metric tonnes of equivalent carbon dioxide emissions and $103 billion of additional fuel cost over the last four decades. If overweight and obesity rates continue to increase at its current pace, cumulative excess fuel use could increase by 460 billion liters over the next 50 years, resulting in an extra 1.1 billion metric tonnes of equivalent carbon dioxide and $200 billion of additional fuel costs by the year 2060.

1. Introduction

Over the past 40 years, the percentage of the US population that is overweight and obese has increased significantly, with nearly 70% of American adults now overweight or obese (National Center for Health Statistics (NCHS), 2013). This year, the American Medical Association officially recognized obesity as a disease (American Medical Association (AMA), 2013) that afflicts approximately one out of every three adults in the US (National Center for Health Statistics (NCHS), 2013). The excess weight that Americans are carrying has a number of documented effects, including increased rates of health problems (Dixon, 2010), greater lifetime healthcare costs (Thompson et al., 1999, 2001), increased absenteeism at work (Frone, 2007), and added burden on transportation systems (Jacobson and McLay, 2006). These effects are associated with increased social, economic, and environmental costs and may also be counteracting the efforts of industries and policymakers to move towards a more energy efficient and sustainable future. For example, most automobile manufacturers are developing strategies to reduce vehicular weight in order to achieve higher fuel efficiency ratings. However, the extra weight of overweight and obese passengers may be curtailing these efforts. In general, as weight in vehicles increases, fuel consumption also increases, which results in more greenhouse gas (GHG) emissions and greater spending on fuel.

This article builds upon existing literature to evaluate the impacts of increasing passenger weight on fuel use, GHG emissions, and fuel costs for three modes of transportation: light-duty vehicles, public transit, and commercial passenger aircraft. Furthermore, this study examines the trends of these impacts over 40 years, from 1970 to 2010, and performs an uncertainty analysis of the data and results.

Several studies evaluate the impacts of increasing passenger weight on various modes of transportation. Dannenberg et al. (2004) evaluate the impact of the average American weight gain from 1990 to 2000 on jet fuel consumption and associated fuel costs for

* Corresponding author. Tel.: +1 901 652 5228.
E-mail addresses: mtom@andrew.cmu.edu (M. Tom), pf12@andrew.cmu.edu (P. Fischbeck), cth@cmu.edu (C. Hendrickson).

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passenger airliners in the year 2000. Jacobson and McLay (2006) develop a mathematical model to quantify the additional fuel consumed by noncommercial light-duty vehicles in the US that is attributable to excess passenger weight. They calculate that in 2003, between 272 and 938 million gallons (1.0 to 3.6 billion liters) of fuel were consumed because of increasing passenger weight in light-duty vehicles.

Contrary to the Jacobson and Mclay (2006) model, which assumes constant values for vehicle-kilometers traveled, annual fuel consumption, and other critical parameters between 1960 and 2002, this analysis develops a more inclusive model that accounts for changes in all input variables over time. Furthermore, the Dannenberg et al. (2004) and Jacobson and Mclay (2006) studies develop excess weight estimations based on average body weights of American adults, which accounts for the underweight and healthy weight portion of the population, thereby, offsetting the extra weight of the overweight and obese populations and reducing the estimated impacts attributable to excess weight. This article, however, excludes the underweight and healthy weight portion of the population in order to determine the amount of fuel use, GHG emissions, and fuel cost savings that would be achieved if individuals were not overweight or obese. This approach yields excess weight impacts that are roughly two times higher than if the average body weights were used for this analysis. And lastly, unlike most other studies, which examine one mode of transportation for one year, and in some instances, only evaluates one type of impact, this article investigates the GHG emissions and economic impacts of increased fuel use for light-duty vehicles, transit systems, and passenger aircraft over four decades. An uncertainty assessment of input variables and impacts is also established.

Finally, many studies explore the wide-ranging health and environmental impacts of transportation. In particular, growing evidence indicates that overweight and obesity are linked to a lack of infrastructure for active mobility (Frank et al., 2006). Active transport modes such as walking, cycling, and accessing public transit have many health benefits, which include reduced risk of obesity, cardiovascular disease, cancer, and type 2 diabetes, as well as increased life expectancy (Genter et al., 2008). Active transport also benefits individuals and society through reduced air pollution, noise pollution, and congestion associated with decreased automobile travel. Air pollution in the form of GHG emissions contribute to global climate change, which plays a significant role in human health. Warmer temperatures can lead to more extreme heat waves, which cause heat-related illnesses, such as heat exhaustion or heat stroke. Global climate change also contributes to extreme weather events, such as floods, droughts, and windstorms, which pose direct threats to human life and can also contribute to the spread of diseases (Costello et al., 2009). Automobiles also increase fine particulate matter, which is known to exacerbate asthma and bronchitis (Grabow et al., 2012). Additionally, vehicle noise pollution has been linked to health issues such as stress related illnesses, high blood pressure, hearing loss, and sleep disruption U.S. Environmental Protection Agency (EPA), 2012a). The health and environmental impacts of vehicle air pollution, noise pollution, and climate change are later compared to the results found in this study.

This article is organized into four main sections. The first section summarizes the data collected for the analysis. The second section describes the models used to determine impacts of increasing passenger weight on different transportation systems. The third section provides results of the models and uncertainty associated with the data and results. And the last section performs a critical analysis and discussion of the results.

2. Data

Data for this study is collected or estimated for light-duty vehicles, public transit, and passenger aircraft from 1970 to 2010, and includes vehicle, passenger, anthropometric, greenhouse gas (GHG) emissions, and economic data. These variables are then incorporated into the excess weight, fuel consumption, GHG emissions, and economic models for this analysis. When information for a particular year is not available, estimates are developed using linear interpolation from the surrounding years. Refer to the Supplementary information for detailed analysis of all data used in this study.

Light-duty vehicles include passenger cars and light-duty trucks, which include pick-up trucks, SUVs, and vans. Public transit consists of commuter rail, light rail, and heavy rail (also known, in the US, as metro, subway, or rapid rail) systems, as well as public buses. Taxis are not included in transit. For passenger aircraft, information is collected and used for common carrier, domestic services. Table 1 lists vehicle data used and sources.

Passenger data is based on demographic and passenger statistics from various government sources and is listed with sources in Table 2.

Anthropometric data is retrieved from the National Center for Health Statistics and includes the percentages of male and female adults who are overweight or obese and mean weight and height data for different age groups in the US. The Body Mass Index (BMI) method, which is detailed in Section 3.1.1, is used to determine the healthy or "normal" weight of individuals within specific age groups. This information is then used to estimate the average excess weight of passengers, which is detailed in Section 3.1.2.

Greenhouse gas emissions data is retrieved from the Environmental Protection Agency (EPA) (1999, 2006, 2012b, 2013b), and includes only tailpipe emissions (Table 3). Greenhouse gases included in this study are carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Hydrofluorocarbons (HFC) are omitted from this analysis because they are not emitted via combustion of fuels, but rather from vehicle air-conditioning leaks and end-of-life disposal (U.S. Environmental Protection Agency (EPA), 2008a–d), which are beyond the scope of this project.

Lastly, economic data include fuel or energy costs for each mode of transportation (Table 4).

3. Models

This section describes four models that are used to determine the impact of excess passenger weight on fuel use for light-duty vehicles, transit systems, and passenger aircraft in the US from 1970 to 2010. The first model builds upon the Jacobson and McLay (2006) model, which determines total occupant weight, to estimate excess occupant weight in vehicles. This process is discussed in more detail in Section 3.1.3. The second model computes additional fuel use attributed to excess occupant weight for each mode of transportation. And the last two models estimate GHG emissions and energy costs associated with this additional fuel use. For this article, the terms "excess occupant weight" and "excess passenger weight" are used interchangeably.