IMPACT OF SPEED AND ACCELERATION ON INSTANTANEOUS FUEL CONSUMPTION RATES USING MATLAB

By

Eng. Peter Ramzy Zaki Bakhit

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of The
Requirements for the Degree of
MASTER OF SCIENCE
In
CIVIL ENGINEERING - PUBLIC WORKS

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Under the Supervision of

Prof. Dr. Laila Salah El Din Radwan

Prof. of Highway, Traffic and Airport Engineering
Faculty of Engineering
Cairo University

Dr. Dalia Galal Said

Assistant Prof. of Highway, Traffic and Airport Engineering
Faculty of Engineering
Cairo University

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Approved by the
Examining Committee

Prof. Dr. Laila Salah El Din Radwan, **Faculty of Engineering** **Cairo University**	**Prof. of Highway, Airport and Traffic Engineering**
Prof. Dr. Ahmed Atef M. Gadallah, **Faculty of Engineering** **Cairo University**	**Prof. of Highway, Airport and Traffic Engineering**
Prof. Dr. Ali Zine El Abidine Salem Haichael, **Faculty of Engineering** **Ain Shams University**	**Prof. of Transport Planning and Traffic Engineering**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2015

Engineer's Name: Peter Ramzy Zaki Bakhit
Date of Birth: 23-5-1990
Nationality: Egyptian
E-mail: Peter.ramzy@staff.cu.edu.eg
Phone: 01225882639
Address: Masr El Qadima – Cairo.

Registration Date: 1 / 10 / 2012
Awarding Date: / /
Degree: Master of Science.
Department: Civil Engineering - Public Works

Supervisors: Prof. Dr. Laila Salah El Din Radwan
Dr. Dalia Galal Said

Examiners: Prof. Ali Zine El Abidine Salem Haichael Professor at Ain Shams University
Prof. Dr. Ahmed Atef M. Gadallah
Prof. Dr. Laila Salah Eldin Radwan

Title of Thesis:

Impact of Speed and Acceleration on Instantaneous Fuel Consumption Rates Using Matlab.

Key Words:

Fuel Consumption; Speed; Acceleration; VT-CPFMs; Driving Behaviour.

Summary:

The main goal of this research is to introduce and validate microscopic fuel consumption models named Virginia Tech Comprehensive Power based Fuel Consumption Models (VT_CPFMs). These models estimate the rate of fuel consumption for light duty vehicles on different roads. The VT-CPFMs are established to be easily calibrated using publically available data without necessity to collect in-field instantaneous data. The study additionally determines the relationship between different speeds and rates of fuel consumption. Furthermore, a model was generated to calculate the fuel consumption as a function of speed to get the most economic speed range. Driving with such speeds achieves a high rate of fuel savings and thus reduces the operating cost. Moreover, the study indicated the influence of different acceleration types (mild, normal and aggressive) on fuel consumption using MATLAB® model. Finally, it was found that the results of fuel consumption obtained from the VT_CPFMs can be applied on Egyptian roads. It was also proved that optimal speeds range from 60 to 80 km/h. The study demonstrated that as the level of aggressiveness for acceleration maneuvers increases, the fuel-consumption per maneuver decreases because the vehicle spends less time accelerating.

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DEDICATION

I dedicate this thesis to my parents. I hope that this achievement will complete the dream that you had for me all those many years ago when you chose to give me the best education you could.

Peter Ramzy

TABLE OF CONTENTS

List of Tables

List of Figures

ABSTRACT

Changes in vehicle fuel-consumption and emission rates are associated with changes in vehicle speeds and acceleration. Higher levels of speed are believed to be one of the most prevalent factors contributing to fuel consumption. As a result, the relationship between fuel consumption and driving speed behaviour has been the subject of investigation by many researchers. The main goal of this research is to introduce and validate microscopic fuel consumption models named Virginia Tech Comprehensive Power based Fuel Consumption Models (VT-CPFMs). These models estimate the rate of fuel consumption for light duty vehicles on different roads. The VT-CPFMs are established to be easily calibrated using publically available data without necessity to collect in-field instantaneous data. The study additionally determines the relationship between different speeds and rates of fuel consumption. Furthermore, a model was generated to calculate the fuel consumption as a function of speed to get the most economic speed range. Driving with such speeds achieves a high rate of fuel savings and thus reduces the operating cost. Moreover, the study indicated the influence of different acceleration types (mild, normal and aggressive) on fuel consumption using MATLAB® model.

Finally, it was found that the results of fuel consumption obtained from the VT_CPFMs can be applied on Egyptian roads. It was also proved that optimal speeds range from 60 to 80 km/h. The study demonstrated that as the level of aggressiveness for acceleration maneuvers increases, the fuel-consumption per maneuver decreases because the vehicle spends less time accelerating.

Chapter 1: INTRODUCTION

1.1 Problem Definition

Vehicular fuel consumption and emissions are two significant factors of sustainable transportation systems. Transportation in Egypt accounts for the largest consumption of energy and generation of air pollution (JICA, 1993). According to the Central Agency for Public Mobilization and Statistics, Egypt (Fuel Statistics Report, 2014), there were 7.51 million registered vehicles in Egypt in 2014. Gasoline, which is the main product from crude oil refining, is one of the major fuels consumed by vehicles in Egypt. The average nationwide consumption level reaches 10 liters per day in 2013. This total consumption is about half of the total gasoline consumption for any purpose in Egypt (Statistics report, 2014, November, 13). As such, the transportation sector is also the largest emitter of CO_2 among all energy-use sectors such as industrial, residential, and commercial sectors. Among three common fossil fuels – petroleum, natural gas, and coal – 90% of the 2009 Egypt primary transportation energy consumption depends on petroleum or crude oil (Ministry of Petroleum 2008). This trend continues despite the oil price increase which peaked at over $140 a barrel in June 2008 (Organization of Petroleum Exporting Countries (OPEC) organization).

In motor vehicles, CO_2 is the by-product of the combustion process and is emitted to the atmosphere as a tailpipe emission. It is one of the greenhouse gases contributing to global warming. Between 1990 and 2007, the carbon dioxide emissions of the transportation sector became the most. A 26.8% increase through the 10-year period (1990 -2000) and a 1.4% raise from 2006 to 2007 alone (U.S. Department of Energy, 2008). Consequently, improving the energy efficiency of the transportation sector including improving vehicle shape, weight, engine size, speed limit, driving behaviour and wheel quality plays an important role in decreasing fuel consumption and exhaust gas emissions. Pavement surface type and surface properties for example skid resistance, roughness, and longitudinal slope also have an effect on vehicular fuel consumption.

1.2 Study Objectives

This study aims to examine vehicular fuel consumption differences under two different travel related factors, speed and acceleration. These factors were tested when operating a vehicle under urban driving speeds, rural driving speeds, constant speeds and under different levels of acceleration. The proposed methodology follows a new experimental design to identify the fuel consumption. This method was used to determine the rates at which the test vehicle consumes fuel reserved in the tank. The primary objective of this thesis is to introduce and validate mathematical models used in prediction of vehicle fuel consumption under various traffic conditions. Existing state of- the-art models estimate fuel consumption rates based on standard driving cycles. A standard driving cycle is a series of data points representing the speed of a vehicle versus time. Driving cycles are produced by different countries and organizations to assess the performance of vehicles in various ways, as for example fuel consumption and polluting emissions. Federal Test Procedure (FTP-75) in United States and Extra Urban Driving Cycle (EUDC) in Europe are two famous driving cycles used in modeling process. Many of these models provide simplified mathematical expressions to calculate fuel based on average link speeds without much consideration to the transient effects on speed and acceleration. Furthermore, most models use an aggregate modeling technique where a 'characteristic' vehicle is used to represent different vehicle populations. Macroscopic models use average aggregate network parameters to estimate emission and fuel consumption inventories for large regional areas according to the relationships between speed, flow, and density of a stream. While this technique has been approved by transportation planners and Federal Organizations to calculate road impacts on the environment, it could be argued that modeling individual vehicle fuel consumption with the modeling of vehicle kinematics on a highway network could lead to more reliable estimations of fuel consumption.

This thesis addressed this problem, presenting and validating two mathematical models CPFM-1 and CPFM-2 to predict fuel consumption. The CPFMs were demonstrated to be easily calibrated using publically accessible data without the need to collect in-field instantaneous data. The study also attempted to find if the results obtained from the proposed models could be taken as a guide to determine the rate of fuel consumption on Egyptian