EFFECTS OF GRADIENT ON SPEED OF VEHICLES ON AN IRANIAN SINGLE CARRIAGEWAY ROAD

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To my beloved mother and father

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ABSTRACT

The effect of an upgrade and its length is very significant for traffic flow characteristics. Road traffic consists of vehicles of wide ranging physical dimensions, weight and dynamic characteristics such as engine power, acceleration rate, etc. Due to these variations, the effect of grade on vehicles may vary significantly among vehicle categories. Variation in the level of the interaction between vehicles on upgrades may result in different sets of traffic flow characteristics. Hence, it is necessary to study speed of vehicle on upgrades. This study evaluates the influence of gradient in vehicle speed in a single carriage way in Iran. Quantify speed reduction for main types of vehicles on various road grades, and establish relationships between speed and road grades are steps to achieve the aim. Road of the study is two lane road located in north of Iran between Semnan and Firouzkouh. It was found that the effect of grade on the vehicle performance speed may not be significant beyond a length of 600 to 800 meter length of upgrade. Operation on a 2-3-percent upgrade has only a slight effect on passenger car speeds. On steeper upgrades (4-6percent upgrade), speeds decrease progressively with increases in the grade. The effect of grades on truck speeds is much more pronounced than on speeds of passenger cars. Speeds of trucks decrease by 6 percent or more on upgrades as compared to their operation on the level.

ABSTRAK

Kesan upgrade dan panjangnya adalah amat penting untuk ciri-ciri aliran trafik. Jalan raya terdiri daripada kenderaan pelbagai dimensi fizikal, berat dan ciri-ciri dinamik seperti kuasa enjin, kadar pecutan, dll. Oleh kerana perbezaan-perbezaan, kesan gred ke atas kenderaan mungkin berbeza-beza ketara antara kategori-kategori kenderaan. Perbezaan dalam tahap interaksi antara kenderaan di atas upgrade boleh menyebabkan set ciri-ciri aliran trafik yang berbeza. Oleh itu, adalah perlu untuk mengkaji kelajuan kenderaan di upgrade. Kajian ini menilai pengaruh gradien dalam kelajuan kenderaan dengan cara pengangkutan satu di Iran. Mengkuantitikan pengurangan kelajuan untuk jenis kenderaan di atas pelbagai gred jalan utama, dan mewujudkan hubungan antara kelajuan dan gred jalan raya adalah langkah-langkah untuk mencapai matlamat. Jalan kajian adalah dua lorong jalan yang terletak di utara Iran antara Semnan dan Firouzkouh. Ia telah didapati bahawa kesan gred pada kelajuan prestasi kenderaan mungkin tidak ketara di luar sepanjang 600-800 meter panjang upgrade. Kuasa pada upgrade 2-3 peratus hanya mempunyai kesan yang sedikit pada kelajuan kereta penumpang. Pada upgrade curam (4-6percent upgrade), kelajuan menurun secara progresif dengan peningkatan dalam gred. Kesan gred pada kelajuan trak adalah jauh lebih ketara berbanding pada kelajuan kereta penumpang. Kelajuan trak berkurangan sebanyak 6 peratus atau lebih pada upgrade berbanding operasi mereka di peringkat.

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LIST OF ABBREVIATIONS

Min	-	Minute
Hr	-	Hour
PHF	-	Peak Hour Factor
veh	-	Vehicle
PCU	-	Passenger Car Unit
sec	-	Second
m	-	Meter

LIST OF SYMBOLS

a	acceleration (m / s2)
d	distance (m)
EMRAT	effective mass ratio
Fa	aerodynamic drag resistance (N)
Fc	Curvature resistance (N)
Fg	gradient resistance (N)
Fi	inertial forces during acceleration and deceleration(N)
Fi	Inertial resistance (N)
Fr	rolling resistance (N)
M	vehicle mass (kg)
Pd	driving power delivered to the wheels (kW)
t	time(S)
v	the vehicle velocity (m/s)

CHAPTER 1

INTRODUCTION

1.1 Introduction

A roadway is designed in such a way to provide a uniform operation of traffic. Appropriate design speed by relating various geometric features of the road reaches this aim. Design criteria should be determined for many highway characteristics. Terrain is one of the criteria that govern the geometry of a highway and thus the performance of vehicle movements. In this research, author wants to reach on the appropriate relationship of roadway grades to design speed. Vehicle operating characteristics on grades are discussed and established relationships of grades and their lengths to design speed are developed. Steep grades affect truck speeds and overall capacity. Therefore they also cause operational problems at intersections. In order to determine the impact of road gradient on vehicular speed and capacity different gradient in many roads should be consider.

1.2 Problem Statement

The effect of up-grade and its length is very significant on traffic-flow characteristics. On up-grades, heavy vehicles such as trucks, buses, etc., will experience significant reduction in their speeds, whereas passenger cars and other smaller vehicles such as motorized two wheelers may experience relatively lesser speed reduction. This variation in speed reduction among the different vehicle categories affects the uniformity of traffic. Vehicles have more reduction in speed prevent others to have smooth and free movement.

The research work is related to the study of the effect of grade and its length in up-grade and down-grade on the performance of different vehicle categories and estimation of speed values on various grades in up-grades and down-grade under free flow condition.

1.3 Aim and Objective of Study

This study is carried out with the aim to evaluate the effects of gradient on speeds of vehicles o single carriageway. To achieve this aim, the study will be carried out based on the following objectives:

(a) To quantify speed reduction for main types of vehicles on various road grades, and
(b) To establish relationships between speed and road grades.

1.4 Scope of Study

This study focuses on the speed of passenger cars and trucks on grades. The analysis is based on data collected for a single carriageway road in Iran. The grades consider in the study were 2%, 4% and 6%.

REFERENCES

A.A.M. Aljanahi a, A.H. Rhodes a,1, A.V. Metcalfe b, (1998) speed limits and road traffic accidents under free flow conditions.

Abaynayaka, S.W., Morosiuk, G. and Hide, H. (1977). The Effect of Vehicle and Road Characteristics on Commercial Vehicle Speeds in Ethiopia. Transport and Road Research Laboratory Supplementary Report 271, Department of the Environment, Crowthorne.

American Association of State Highway and Transportation Officials. (2001) *A Policy On Geometric Design Of Highways And Streets* 2001.USA..

Archilla, A. R., and Fernandez De Cieza, A. O. (1996). Truck performance on Argentinean highways.' *Transportation Research Record No. 1555*, Transportation Research Board, Washington, D.C., 114–123

Bennett, C.R. (1994). A Speed Prediction Model for Rural Two-lane Highways. School of Engineering Report, Department of Civil Engineering, University of Auckland.

Bennett, C. R.; Greenwood, I. D, (2001). *Modeling Road User and Environmental Effects in HDM-4. Volume 7. The Effect of Road Conditions on Speed.* . The highway development and management series, Vol. 7, World Road Association _PIARC_,Paris/The World Bank, Washington, D.C.

Currin, T. R. (2001). Spot Speed Study. In *Introduction to Traffic Engineering: A Manual for Data Collection and Analysis,* ed. B. Stenquist. Stamford, Conn.: Wadsworth Group.

Glennon, J. C. An Evaluation of Design Criteria for Operating Trucks Safely on Grades, *Highway Research Record 312*, Highway Research Board, 1970: 93-112.

Gillespie, T. D. (1985)Methods for predicting truck speed loss on grades. *Federal Highway Administration, Washington, D.C.* Rep. No. FHWA/RD-86/059,

HTC (1999). Calibration of HDM Speed Prediction Model to Thailand. Report DES/99/2 to Dessau-Sopran, Thailand Motorway Project. HTC Infrastructure Management Ltd. Auckland.

Homburger, W. S., J. W. Hall, R. C. Loutzenheiser, and W. R. Reilly. (1996). Spot Speed Studies. In *Fundamentals of Traffic Engineering.* Berkeley: Institute of Transportation Studies, University of California, Berkeley, pp. 6.1–6.9.

Ingle, A.(2004). *Development of passenger car equivalents for basic freeway segments.* MS thesis, Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

Lan, C.-J., and Menendez, M. (2003). Truck speed profile models for critical length of grade. *J. Transp. Eng.*, 129_4_, 408–419.

Lucic, I. (2001). *Truck modeling along grade sections.* MS thesis, Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

.McLean, J.R. (1989). *Two-Lane Highway Traffic Operations: Theory and Practice.* Gordon and Breach Science Publishers, Melbourne.

Shriniwas S. Arkatkar and V. Thamizh Arasan. Effect of Gradient and Its Length on Performance of Vehicles under Heterogeneous Traffic Conditions. *Journal Of Transportation Engineering. D*-2010. 1120-1136

Transportation Research Board _TRB_. _2000_. *Highway capacity manual*, 4th Ed., National Research Council, Washington, D.C.

Walton, C. M., and C. E. Lee. (1975)*Speed of Vehicles on Grades*, Research Report 20-1F, Austin , Texas: Center for Highway Research, University of Texas at Austin.

Yagar, S., and Aerde, M. V. (1983). Geometric and environmental effects on speeds of two-lane highways. *Transp. Res. Part A*, 17_4_, 315–325.