



A PERCEPTUAL FORWARD COLLISION WARNING MODEL USING NATURALISTIC DRIVING DATA



Mostafa H Tawfeek, M.Sc., E.I.T.

Karim El-Basyouny, Ph.D., P.Eng.

Department of Civil & Environmental Engineering
University of Alberta

CONTENTS

INTRODUCTION

- Background
- Objectives

METHODOLOGY

- Data Description
- Identification of Candidate Rear-end Events
- Perceptual FCW Model Development

RESULTS AND CONCLUSIONS



BACKGROUND

- Early/late warnings reduce users' acceptance and develop a mistrust due to the conflict between drivers' expectations and the warning system ^{1,2,3}
- The development of an efficient warning system should be based on the knowledge of unassisted driving behavior ⁴



OBJECTIVES

- Develop a perceptual FCW algorithm based on naturalistic driver behavior
- Compare the proposed warning distance to the warning distances of various kinematic and perceptual FCW models



BACKGROUND

○ Perceptual FCW algorithms

- Consider the human perceptual ability of following a lead vehicle too close address rear-end collisions
- Usually measured by Time-to-Collision (TTC) ^{5, 9, 11}

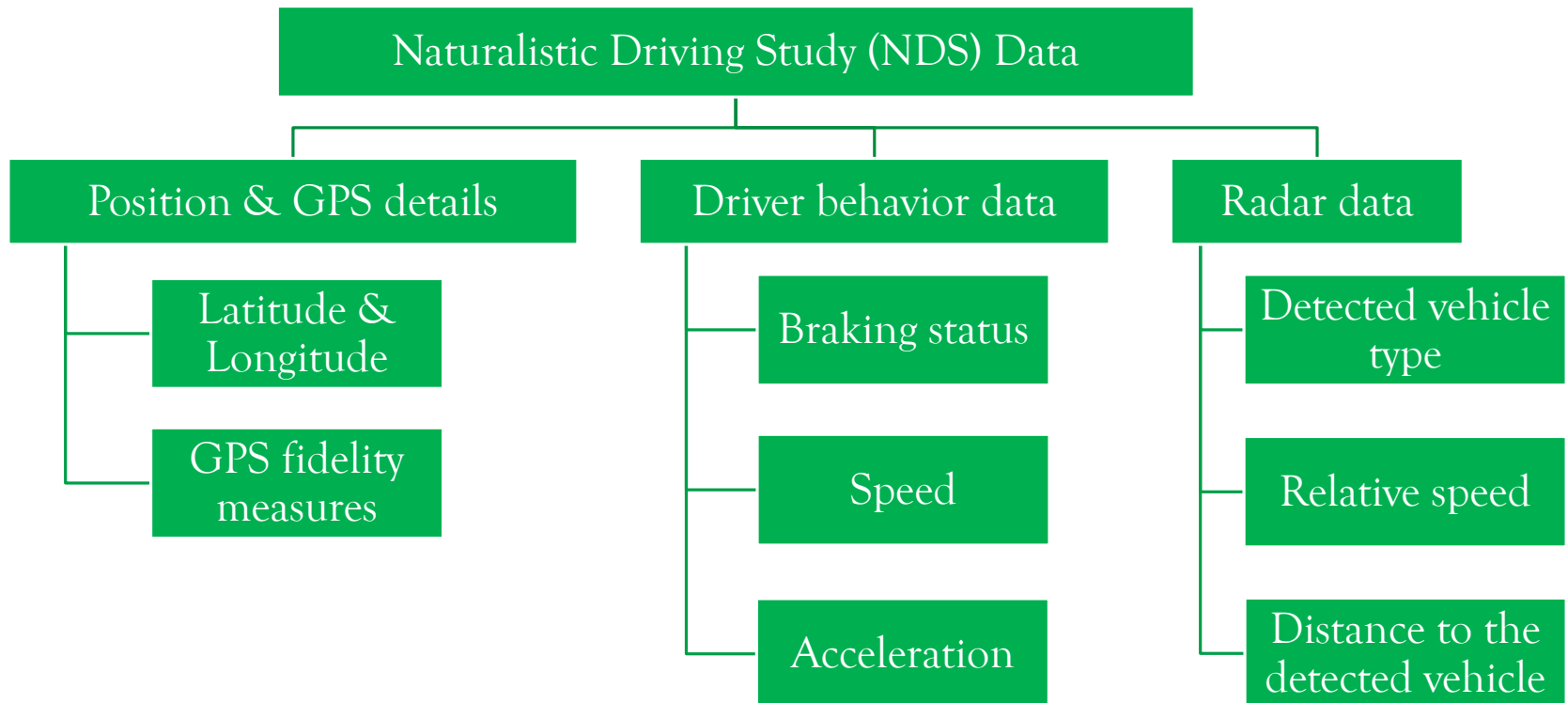
○ Kinematic FCW algorithms

- Consider vehicle kinematics (i.e., motion equations) with various assumptions on accelerations
- Depend on following and leading vehicles speeds ¹²⁻¹⁴



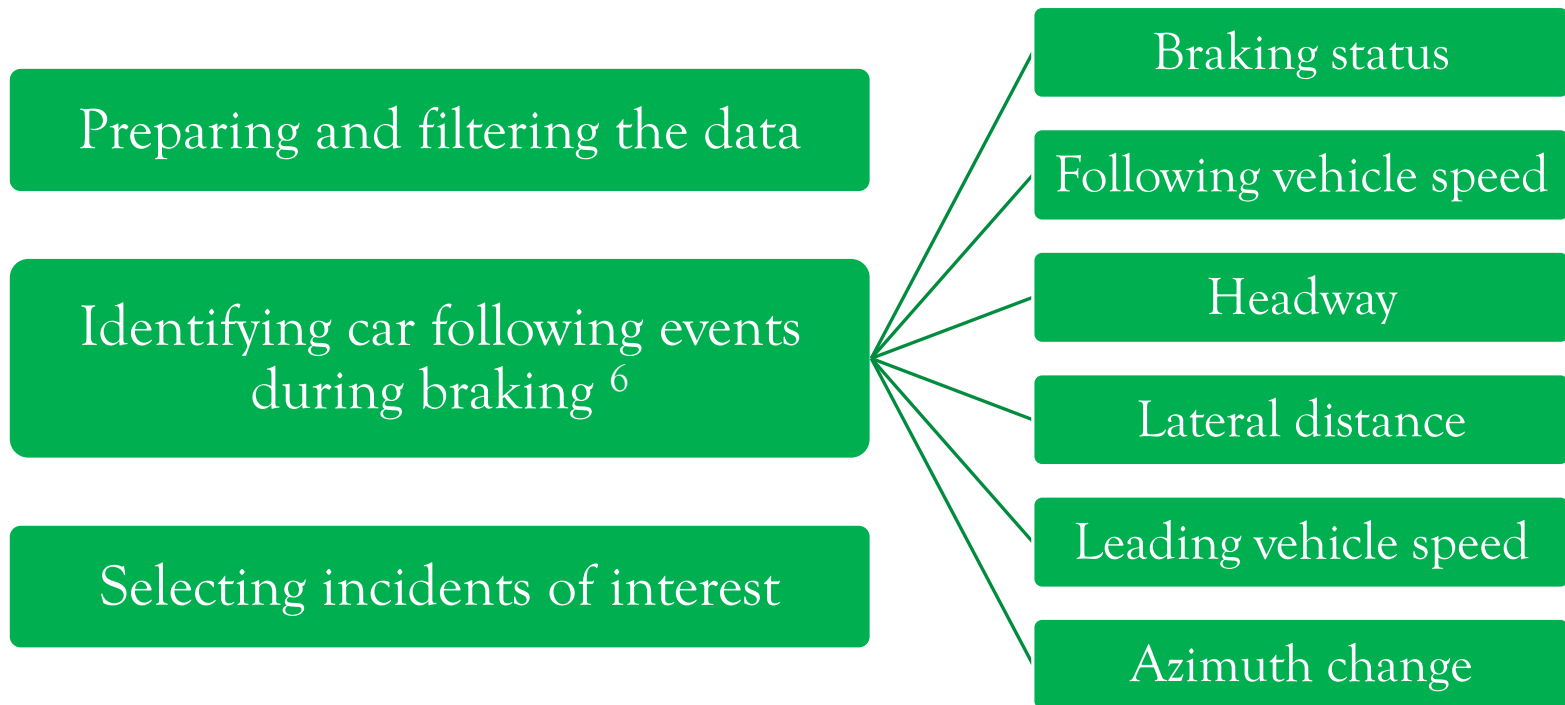
DRIVER FOLLOWING BEHAVIOR DURING BRAKING

DATA DESCRIPTION



DRIVER FOLLOWING BEHAVIOR DURING BRAKING

CAR FOLLOWING IDENTIFICATION



DRIVER FOLLOWING BEHAVIOR DURING BRAKING INCIDENTS OF INTEREST SELECTION

- Extract TTC, vehicle speed, lead vehicle speed, relative speed, and vehicle acceleration at the minimum following distance while braking
- Select events within TTC range of 3 to 5 seconds which was assumed as the warning range⁷⁻⁹



DRIVER FOLLOWING BEHAVIOR DURING BRAKING

PERCEPTUAL FCW MODEL DEVELOPMENT

$$d_{warn} = f(v_f, v_l, a_f, v_{rel})$$

where

d_{warn} : minimum warning distance

v_f : following vehicle speed

v_l : leading vehicle speed

a_f : following vehicle acceleration

v_{rel} : relative speed between following and leading vehicles



DRIVER FOLLOWING BEHAVIOR DURING BRAKING

PERCEPTUAL FCW MODEL DEVELOPMENT

	Estimate	p-value
Intercept	0.237	0.003
Host vehicle acceleration (m ² /s)	0.122	<0.001
Host vehicle speed (m/s)	0.150	<0.001
Relative speed (m/s)	3.479	<0.001

Model Goodness-of-fit: $R^2 = 0.916$



RESULTS

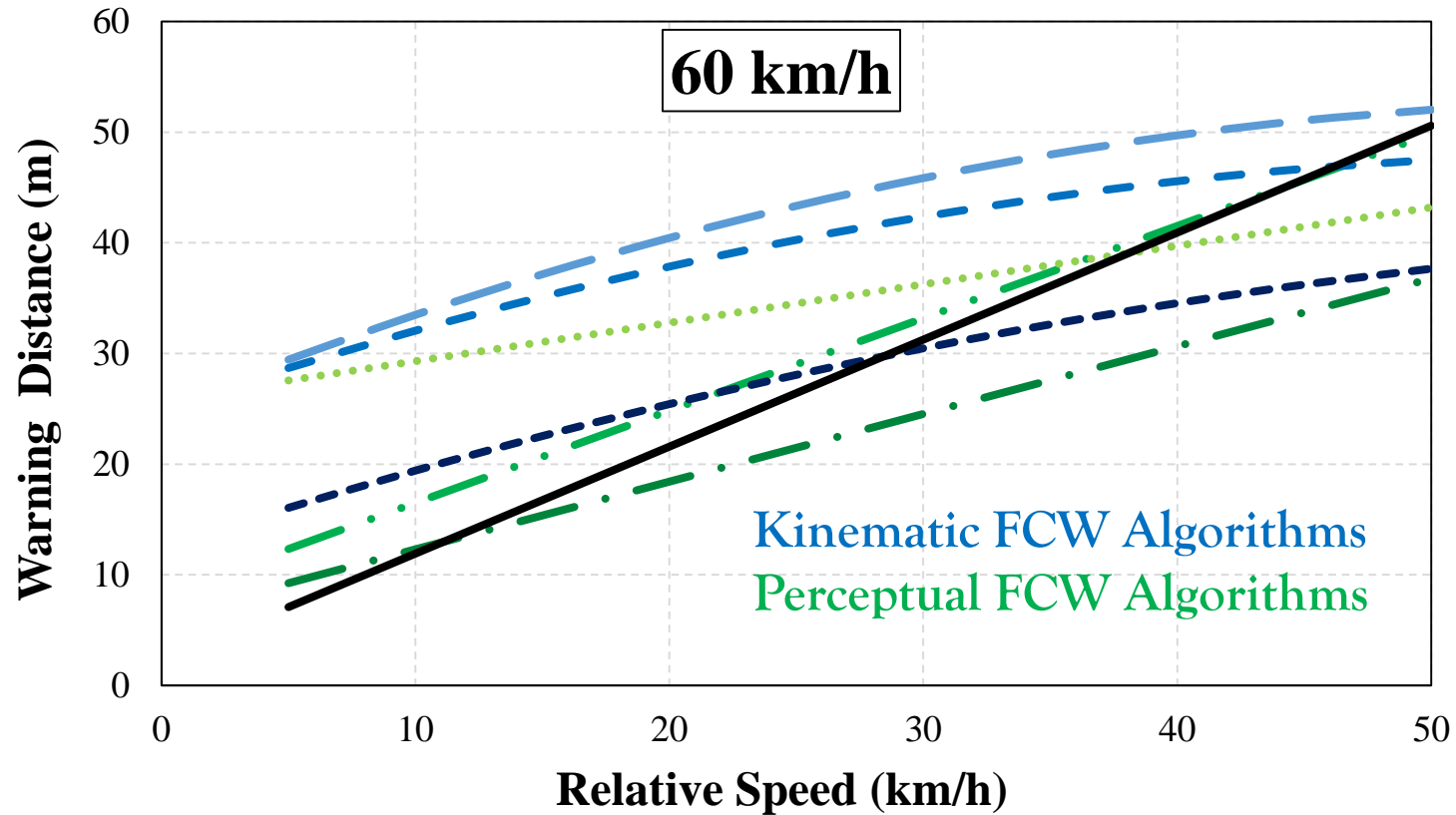
MODEL ASSESSMENT

- Six of the most commonly cited FCW algorithms⁹⁻¹⁴ were compared to the proposed model
- The warning distances were plotted against the relative speed at four levels of following (i.e. host) vehicle speeds (60, 80, 100, and 120 km/h)



RESULTS

MODEL ASSESSMENT

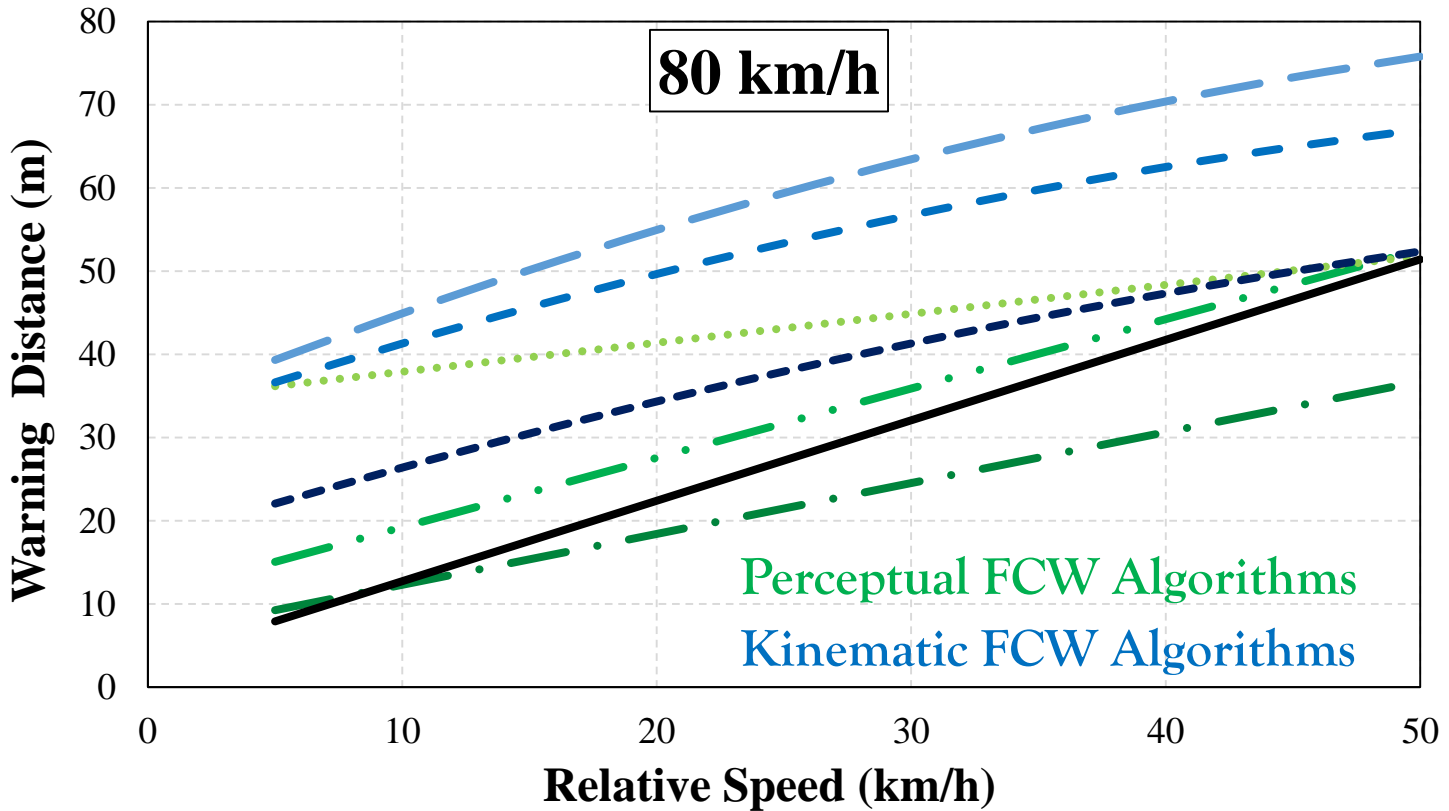


— Alg.1 — Alg.2 Alg.3 - - - Alg.4 - - - Alg.5 — Alg.6 — Proposed



RESULTS

MODEL ASSESSMENT

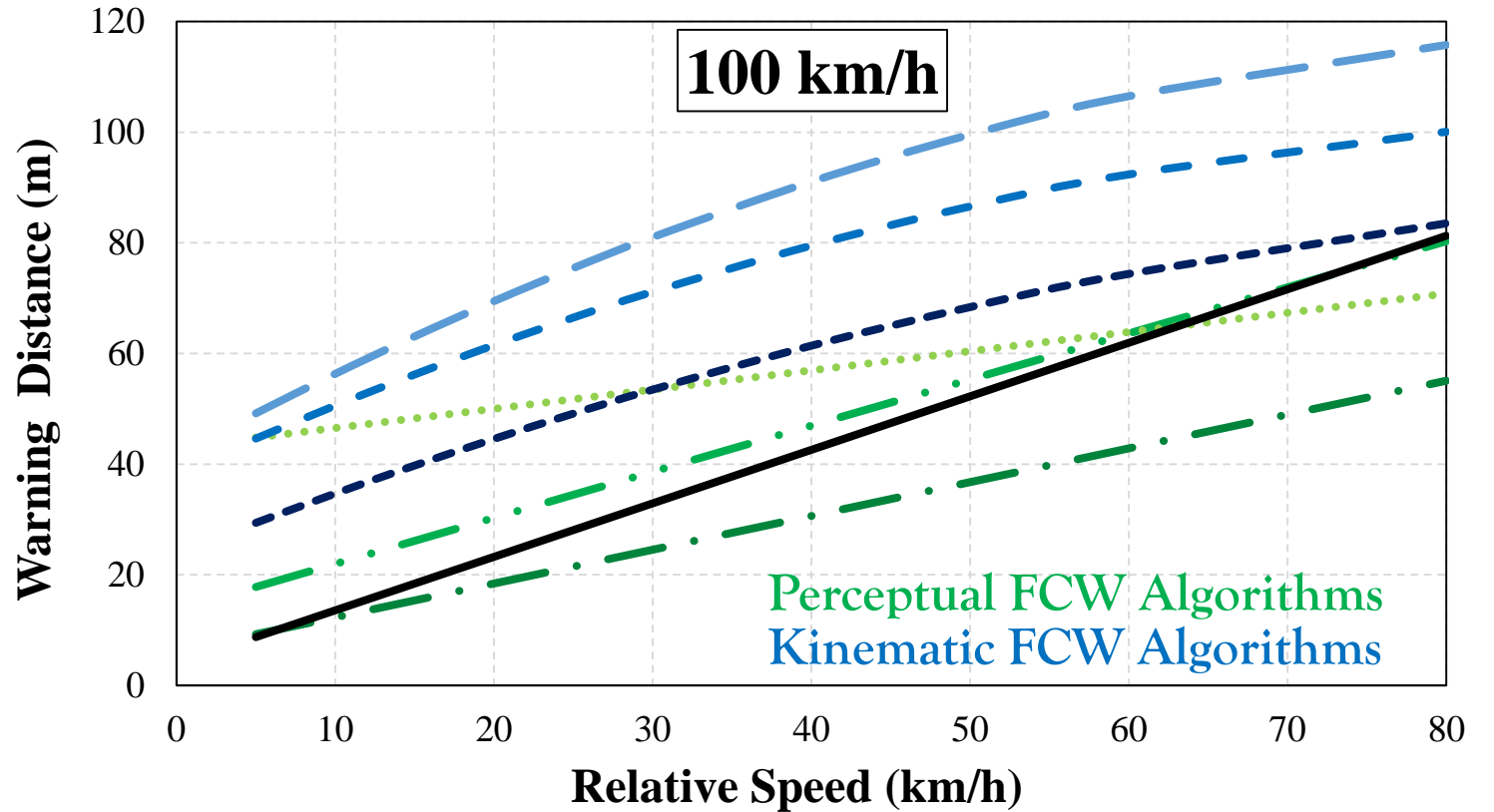


— Alg. 1 — Alg. 2 Alg. 3 - - - Alg. 4 - - - Alg. 5 — Alg. 6 — Proposed



RESULTS

MODEL ASSESSMENT

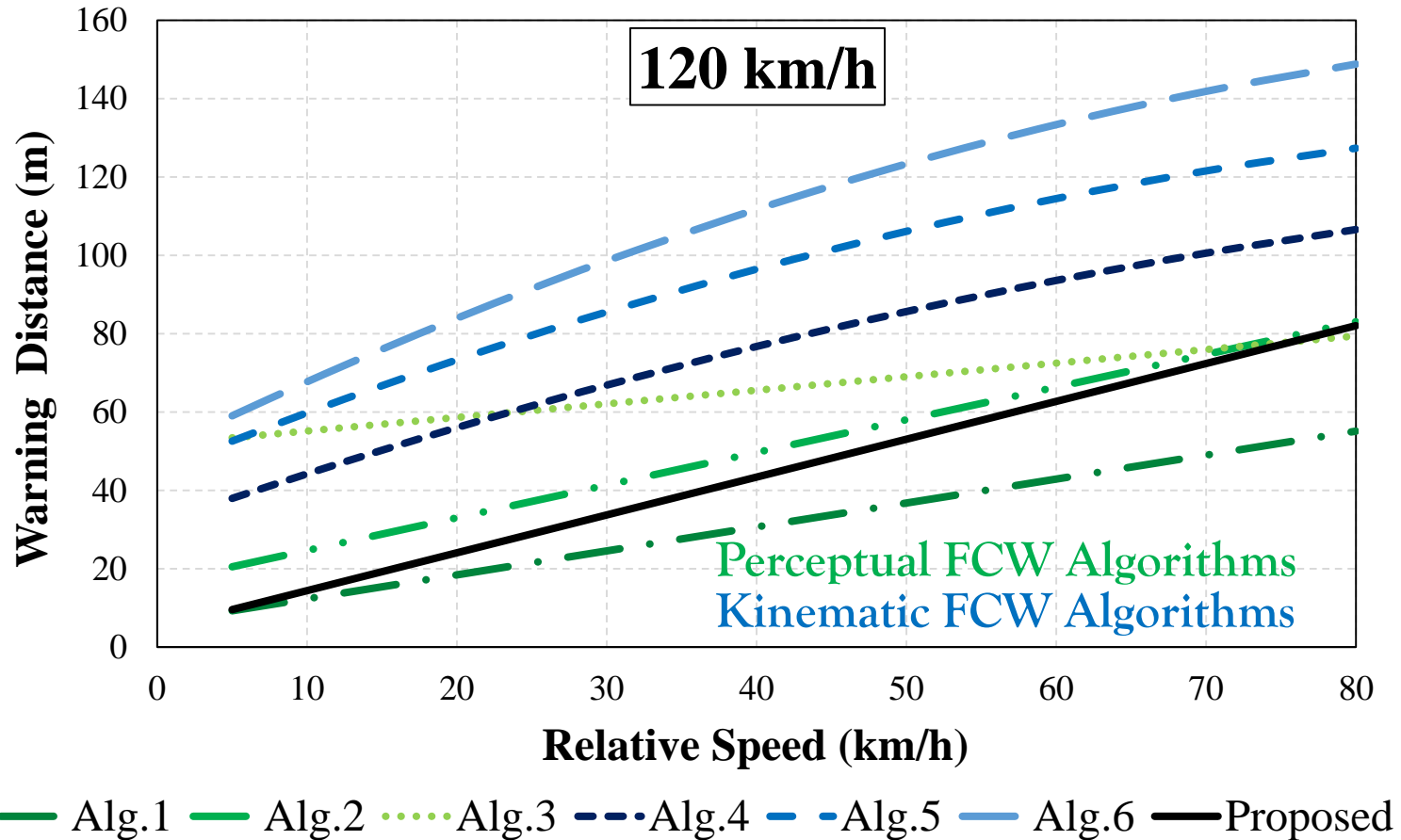


— Alg.1 — Alg.2 Alg.3 - - - Alg.4 - - - Alg.5 — Alg.6 — Proposed



RESULTS

MODEL ASSESSMENT



CONCLUSIONS

- The results of the proposed algorithm were consistent with the other perceptual algorithms
- The warning distances varied widely between algorithms with **perceptual** algorithms having **shorter** distances compared to **kinematic** algorithms



CONCLUSIONS

- The distance produced by the proposed algorithm is **less than** the distance produced by the perceptual algorithms which were developed based on driving simulator data (early warning)



FUTURE RESEARCH

- The variation of warning distances due to the differences in drivers' demographics (i.e., age and gender) should be investigated
- The impact of the proposed FCW on the network level should be assessed



REFERENCES

1. Staubach M, Schebitz N, Köster F, Kuck D. Evaluation of an eco-driving support system. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2014
2. Van Driel CJG, Hoedemaeker M, van Arem B. Impacts of a Congestion Assistant on driving behaviour and acceptance using a driving simulator. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2007
3. Abe G, Richardson J. The influence of alarm timing on braking response and driver trust in low speed driving. *Safety Science*. 2005
4. Berndt H, Wender S, Dietmayer K. Driver braking behavior during intersection approaches and implications for warning strategies for driver assistant systems. *Proc IEEE Intelligent Vehicles Symposium*. 2007
5. Wang, X., Zhu, M., Chen, M., Tremont, P., 2016. Drivers' rear-end collision avoidance behaviors under different levels of situational urgency. *Transportation Research Part C Emerging Technologies* 71, 419-433. doi:10.1016/j.trc.2016.08.014
6. Kusano KD, Montgomery J, Gabler HC. Methodology for identifying car following events from naturalistic data. *IEEE Intelligent Vehicles Symposium, Proceedings*. 2014;281-5
7. X. Yan, Y. Zhang, and L. Ma, "The influence of in-vehicle speech warning timing on drivers' collision avoidance performance at signalized intersections," *Transp. Res. Part C Emerg. Technol.*, vol. 51, pp. 231-242, 2015.
8. N. Aksan *et al.*, "Forward Collision Warning: Clues to Optimal Timing of Advisory Warnings," *SAE Int. J. Transp. Saf.*, vol. 4, no. 1, pp. 2016-01-1439, 2016.
9. S. J. Hirst and R. Graham, "The Format and Presentation of Collision Warnings," *Ergon. Saf. Intell. Driv. interfaces*, pp. 203-219, 1997.
10. Y. Fujita, K. Akuzawa, and M. Sato, "Radar brake system," *JSAE Rev.*, vol. 16(2), pp. 95-101, 1995.
11. F. Bella and R. Russo, "A Collision Warning System for rear-end collision : a driving simulator study," *Procedia - Soc. Behav. Sci.*, vol. 20, pp. 676-686, 2011.
12. A. Doi, T. Butsuen, T. Niibe, T. Takagi, Y. Yamamoto, and H. Seni, "Development of a rear-end collision avoidance system with automatic brake control," *JSAE Rev.*, vol. 15, no. 4, pp. 335-340, 1994.
13. P. Seiler, B. Song, and J. Hedrick, "Development of a collision avoidance system," *Automot. Eng.*, vol. Vol. 106, pp. 24-28, 1998.
14. A. L. Burgett, A. Carter, R. J. Miller, and W. G. Najm, "A collision warnig alorithm for rear-end collision," *Natl. Highw. Traffic Saf. Adm. Washington, DC*, pp. 566-587, 1998.

Images:

<https://automobiles.honda.com/images/2016/pilot/features-safety/forward-collision-warning.jpg>



QUESTIONS?

CONTACT INFO

Mostafa H Tawfeek, M.Sc., E.I.T

Department of Civil and Environmental Engineering

University of Alberta

Mostafa.h.tawfeek@ualberta.ca