An Effort-Based Model for Pedestrian Route Choice Behaviour

By

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Certificate

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged.

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To my beloved son, Yamen

People choose the paths that grant them the greatest rewards for the least amount of effort

David shore

ABSTRACT

This research proposes a novel effort-based theoretical framework for the pedestrian route choice problem to discover principles that pedestrians use to select their routes. A pedestrian chooses their route by optimising certain criteria, such as distance, time, and effort. Several possible criteria that could be used to predict the route choices of a pedestrian are re-assessed. In most cases, the common criteria of a pedestrian route choice are route length and travel time. Effort is proposed as an additional criterion, which indicates metabolic energy expenditure.

The basic principle and a methodology are proposed for route choice based on the least effort that a pedestrian may consume during travel between destinations. The followed deterministic approach assumes that the perceived utility of a route is deterministic and that pedestrians will only choose the route that features minimum average cost.

A mathematical formulation for solving the pedestrian route choice problem utilising the concept of physical effort is introduced. We compare our effort-based model against time and distance based models and validate against the Brisbane dataset. We demonstrate that our method has higher performance efficiency than the models that exist in the state-of-the-art and thereby the model justifies optimal pedestrian behaviour when choosing a route in a congested environment.

Our discussion concludes with an overview of how our approach could be used by rail service providers to optimise operations and improve customer experience. It is contended that the entire behaviour of an individual is subject to effort minimization. Hence, the pedestrian route choice problem is formulated as a constrained non-linear optimization problem whose objective function is the effort consumed while moving from current position to destination over the route.

This doctoral research is a part of research project entitled “Integrated Passenger Behaviour, Train Operations Diagnostics, and Vehicle Condition Monitoring System”, which aims to consolidate foundation technology for the sensing and perception functions of a system that can monitor passenger behaviour and operational characteristics of passenger trains as they arrive at crowded stations using low-cost multi-sensor network. The Brisbane Central Rail Train Station is selected for a case study for validation of the developed model.

ACRONYMS AND ABBREVIATION

PLE: Principle of least effort

PRC: Pedestrian route choice

SHP: Sensing Hardware Platform

MTC: Minimum time criteria

MDC: Minimum distance criteria

MEC: Minimum effort criteria

V: The walking speed (m/s)

P: Metabolic power (Watts)

L: Length of the route (m)

X: The external load (N)

W: The individual weight (N)

μ: The terrain factor defined as 1 for free walking

G: The grade (%)

s_0: Initial position

s_f: Final position

t_0: Initial time (s)

t_f: Final time (s)

x_0: Initial point at x-axis

x_f: The final point at x-axis

y_0: Initial point at y-axis

y_f: The final point at the y-axis

$\|v\|$: The magnitude of velocity (m/s)

T: Time (s)

D: Distance (m)

O: Origin

D: Destination

$\dot{E}$: Energy rate (Watt)

$\dot{x}$: X Component of the velocity (m/s)

$\dot{y}$: Y Component of the velocity (m/s)

E: Energy (Joul)

$\vec{p}$: Position vector

(x_0, y_0): Initial coordinate, Origin

(x_f, y_f): Final coordinate, Destination

q(t): Number of passengers in the queue

n(t): The rate of passengers existing from the bottleneck

m(t): Passenger rate departing from the train at a time, t

C: Escalator capacity (Ped/s)

O-D pair: Origin-destination

M: metabolic rate (Watts)

CONTENTS

LIST OF FIGURES

LIST OF TABLES