Accepted Manuscript

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Xue-yan Li, Xue-mei Li, Xue-wei Li, He-ting Qiu

PII: S0378-4371(16)30827-5
DOI: http://dx.doi.org/10.1016/j.physa.2016.11.022
Reference: PHYSA 17678

To appear in: *Physica A*

Received date: 11 September 2016
Revised date: 28 October 2016

Please cite this article as: X.-y. Li, X.-m. Li, X.-w. Li, H.-t. Qiu, Multi-agent fare optimization model of two modes problem and its analysis based on edge of chaos, *Physica A* (2016), http://dx.doi.org/10.1016/j.physa.2016.11.022

Multi-agent fare optimization model of two modes problem and its analysis based on edge of chaos

Xue-yan Li Xue-mei Li* Xue-wei Li He-ting Qiu
School of Economics and Management Beijing Jiaotong University, Beijing, 100044, China

Abstract: This paper proposes a new framework of fare optimization & game model for studying the competition between two travel modes (high speed railway and civil aviation) in which passengers' group behavior is taken into consideration. The small-world network is introduced to construct the multi-agent model of passengers' travel mode choice. The cumulative prospect theory is adopted to depict passengers' bounded rationality, the heterogeneity of passengers' reference point is depicted using the idea of group emotion computing. The conceptions of "Langton parameter" and "evolution entropy" in the theory of "edge of chaos" are introduced to create passengers' "decision coefficient" and "evolution entropy of travel mode choice" which are used to quantify passengers' group behavior. The numerical simulation and the analysis of passengers' behavior show that (1) the new model inherits the features of traditional model well and the idea of self-organizing traffic flow evolution fully embodies passengers' bounded rationality, (2) compared with the traditional model (logit model), when passengers are in the "edge of chaos" state, the total profit of the transportation system is higher.

Key words: fare optimization; cumulative prospect theory; group emotion; passengers' behavior; complexity; edge of chaos;

1. Introduction

Fare planning & game of transportation system and passengers' choice have been the focus of a number of papers, the competition between two travel modes is a typical case. Si, B.F. (2007, 2009) [1][2], Zhao, X. (2013) [3] described the railway fare optimization under competition with a bi-level programming in which the operator pursues maximum profits in the upper level programming and the passengers pursue minimize generalized travel cost in the lower level programming. Clark, D.J. (2011) [4] analyzed equilibrium fares that arise from collusion, cournot, stackelberg, bertrand and sequential price competition when two profit maximizing transport firms produce symmetrically differentiable services. A duopoly model of high speed rail and airline is built by D'Alfonso T (2016) [5], in which the trade-off between the substitution effect of passengers is analyzed and a simulation study is conducted based on the London-Paris market. Óscar Álvarez-San Jaime (2015) [6] considered a transport market between two cities and presented a model of competition between high speed rail and air services, in which the changes in operators' objective functions is analyzed. A game approach was developed in Ref. [7] to model the airlines' operative decisions on fares and frequencies of service in a duopoly market. Borndörfer, R (2012) [8] proposed a nonlinear optimization approach to fare planning that is based on a detailed discrete choice model of user behavior, in which the maximization of demand, revenue, and social welfare were set as objectives respectively. The effect of rail travel time on

*Corresponding author
Email: gongye1632006@163.com; xmli@bjtu.edu.cn.
Address: Room 1215, No.3 Building, Xueyuan Apartment, No.18, Jiao Da East Road, Haidian District, Beijing.
Phone: +86-18811438978
Funding: This work was supported by the National Natural Science Fund of China (grant numbers: 71540010,71273023) and The science and technology research and development program of China Railway Corporation (grant number: 2015Z002).