行政院國家科學委員會專題研究計畫　成果報告

含移動方程巨觀動態車流模式之建立

計畫類別：個別型計畫
計畫編號：NSC91-2415-H-009-003-
執行期間：91 年 08 月 01 日至 92 年 07 月 31 日
執行單位：國立交通大學運輸科技與管理學系

計畫主持人：卓訓榮

計畫參與人員：林杜寰　吳育婷　蔡昆廷

報告類型：精簡報告

處理方式：本計畫可公開查詢

中　華　民　國　92 年 10 月 31 日

含移動方程巨觀動態車流模式之建立

計畫編號：91-2415-H-009-003
執行期限： 91 年 08 月 01 日至 92 年 07 月 31 日
主持人：卓訓榮 教授 交通大學運輸科技與管理學系

一、 摘要

智慧型運輸系統為整合通訊電子科技以解決交通運輸問題之方法，然而除了硬體設備之配合外，軟體模式部分亦十分重要。車流理論描述與分析交通車流特性，供設計者進行系統服務水準評估，檢驗系統是否運作流暢、現行系統是否有其運作上之問題。所以交通車流理論在交通運輸之研究領域中佔有一重要地位。尤其在發展智慧型運輸系統的同時，許多及時控制均需要做及時交通資訊之預測，此為發展交通相關模式之重要課題。也因此，動態車流模式之角色更形重要。

Whitham、Lightwill、Richard 等人以連續方程式（continuity equation）為基礎發展的動態車流模式，可描述動態車流變化與車隊前進行為。若以一完整動態系統來看，需要以下兩個基本組成：

1．狀態方程（state equation）：描述各狀態時系統之狀況，如靜態模式。

2．移動方程（transient equation）：描述狀態與狀態間變化轉換之機制。

前述之動態車流模式以捕捉動態的轉換行為為主，但沒有同時發展適當的狀態方程描述狀態。如此一來雖然可以描述複雜的轉換行為，但整體來說仍有偏差。因此，本研究擬分析動態車流模式組成架構，分別討論狀態方程與轉換方程，並決定分析狀態方程中最重要的組成－移動方程（Mobility function），搭配守恆律構建具一般性的動態車流模式，作為推動智慧型運輸系統發展之基礎。

關鍵詞：狀態方程、移動方程、動態車流模式、守恆律

Abstract

Intelligent transportation system（ITS） combines communication and electronic technologies to solve traffic congestion problem. Except for the facilities, ITS still need traffic models to make the system intelligent. Traffic flow theory describes and analyzes traffic characteristics to build or modify traffic models and evaluate transportation system. By traffic flow theory, designers can evaluate traffic systems, and operators can check if there is something wrong in the system. It is why traffic flow theory be a fundamental topic of transportation research field. Especially, the trend of developing ITS, the necessity of real time control and real time information become more and more important, and so do the studies of dynamic traffic flow

theory. Therefore, it is more important to develop dynamic traffic flow models.

Whitham, Lightwill, and Richard develop a dynamic traffic flow model which can describe the dynamic movement of vehicles based on continuity equation. In a complete dynamic model, there are two basic equations：

1. State equation：Describes the system condition in all states, such as static models
2. transient equation：Describes the phenomena from a state change to another state.

Above LWL model focuses on transient equations, and state equations are not developed at the same time. Although LWL model can describe complicate behavior, there are still differences between real conditions. Therefore, the study tries to analyze the components of dynamic traffic flow models and separately discuss state equation and transient equation. Decides the most important component of state equation－mobility equation to build a general dynamic flow model with continuity equation so as to become the fundamental of the ITS development.

Keywords：state equation、mobility equation、dynamic traffic flow model、conservation law.

二、 研究目的

以車流模擬模式而言，早期交通模擬模式之探討與構建以提供研究無阻斷車流的路況為主，而後依據不同路況，車流組成等等影響逐步複雜化。但以一完整的動態系統而言，需有以下兩基本組成:

1. 狀態方程(state equation)：描述各狀態系統的情況，如傳統之靜態模式。
2. 轉換方程(transient equation)：描述狀態與狀態間的變化轉換的機制。

由國科會八十七年度"以波動方程探討汽機車混合車流之研究"，八十八年度"流量、動量與能量守恆之動態車流模式之研-模式構建、計算方法與應用之研究"與八十九年度"兼具巨觀與微觀行為動態車流模式之研究"中發覺，儘管構建的模式可捕捉動態的轉換行為，但若沒有適當的狀態方程描述狀態，所得到的結果仍會有所偏差。

由動態車流相關文獻可知，模式之構建越形複雜，雖然可將動態行為描述得更完全，但在最基礎的狀態方程部分，仍以傳統最簡單的假設如：Greenshield, Greenberg 等模式代入，使用的主要的理由不外忽計算簡單或由歷史資料配似而得，忽略了其模式假設與行為意義。本研究的目的在於回顧傳統狀態方程(或靜態模式)之假設與行為意義，並檢驗相關動態車流模式引用時之依據。分析決定狀態的影響因子與其間的相關性，進而構建具一般性的狀態方程。

三、 結論與建議

本研究推導之模式如下

$$k_t^i + q_x^i = In^i(x,t) - Out^i(x,t) \qquad \forall i = 1,\ldots,n$$
$$q^i = k^i u^i - v^i k_x^i \qquad \forall i = 1,\ldots,n$$
$$divE_{外} = constant$$
$$divE_{內} = f(k)$$
$$a = \mu E$$

其中 $$E = E_{外} + E_{內}$$

又 E 可看成加速度場，依密度不同分別為

$$\frac{du}{dt} = \varepsilon(\frac{\alpha}{k} - \frac{\alpha}{k_s}) + \frac{\varepsilon\beta}{k_s} \qquad if \quad k > k_s$$
$$\frac{du}{dt} = \frac{\varepsilon\beta}{k_s} \qquad if \quad k \le k_s$$

其中 $\varepsilon(\frac{\alpha}{k} - \frac{\alpha}{k_s})$ 為內場，$\frac{\varepsilon\beta}{k_s}$ 為外場，又

$$k_s = \frac{3600}{u_f \times t_r}$$

將機動力定義為一個向性，作用為修正加速度場讓車輛朝均衡速度變化，得到：

$$\mu = \begin{cases} 1 & if \quad (k - k_s)(u - u_f) > 0 \\ -1 & if \quad (k - k_s)(u - u_f) \le 0 \end{cases}$$

上述的 u_f 單位為公里/小時，t_r 為秒，k_s 為車/公里，t_r 定義為足夠完成變換車道與反應之時間，α、β、ε 為模擬而得知參數。

四、計畫結果自評

本研究完成部份：

1. 含行為意義的動態車流方程式
   本研究發展之模式最大差異在於不使用不具物理意義之參數，雖然仍含有 α 與 β 兩個參數，但這兩參數皆可由模擬結果求得，後續研究應可針

對α與β探討其與其他變數的關係式，應能解決需靠模擬求得的缺點。另外也推得鬆弛時間與密度之關係式，後續可試用此關係式帶入舊有車流模式判斷其正確性。

有待完成部份：

1. 模式之驗證比較
後續研究應與舊有模式比較，並利用現場資料對照本模式之合理性。
2. 縱向場的推導
由於缺乏機車橫向變換車道之資料，無法利用蒙地卡羅法模擬機車縱向移動行為，後續可針對這點調查現場資料，應可得到一縱向場之關係式。

五、文獻回顧

1. **Baker, R.G, 1981, "A Model Of Traffic Dispersion From A ongested Road", Transportation Research Part B, Vol. 15, No. 5, pp.319-327.Beltrami, E. J., Mathematics for Dynamic Modeling. San Diego, Academic Press Inc., 1987.**
2. **Cho, H. J., and S. C. Lo, "Numerical Simulation of Dynamic Drift-Diffusion Traffic Flow Model," *Applied Numerical Mathematics*, 2002a (submitted paper).**
3. **Cho, H. J., and S. C. Lo, "Modeling of Self-consistent Multi-class Dynamic Traffic Flow Model," *Physica A*, 2002c (accepted).**
4. **Cho, H. J., and S. C. Lo, "Monotone Iterative Simulation of Traffic Dispersion Model," *Computer Physics Communications*, 2002d (accepted).**
5. **Daganzo, C. F., "A Finite Difference Approximation Of The Kinematic Wave Model Of Traffic Flow", Transportation Research Part B, Vol. 29, No. 4, pp.261-276, 1995.**
6. **Daganzo, C. F., "A Continuum Of Traffic Dynamics For Freeways With Special Lanes" Transportation Research Part B, Vol. 31, No. 2, pp-83-102, 1997.**
7. **Daganzo, C. F., "The Cell Transmission Model: A Dynamic Representation Of Highway Traffic Consistent With The Hydrodynamic Theory", Transportation Research Part B, Vol 28, No. 4, pp.269-287, 1994.**
8. **Del Castillo, J. M., and F. G. Benitez, ,1995, "On The Functional Form Of The Speed-Density Relationship-I General Theory", Transportation Research Part B, Vol. 29B, No.5 pp.373-389.**
9. **Del Castillo, J. M., and F. G Benitez, 1995, "On The Functional Form Of The Speed-Density Relationship-II:Empirical Investigation", Transportation Research Part B, Vol. 29, No. 5, pp.391-406.**
10. **Gazis, D. C., R. Herman, and R. B. Potts, 1959, "Car-Following Theory Of Steady-State Traffic Flow", Operations Research, Vol. 7, pp.499-505.**
11. **Greenberg, H., "An Analysis Of Traffic Flow", Operations Research, Vol. 7,**

pp.79-85, 1959. Hanebutte, U, E. Doss, T. Ewing, and A. Tentner, "Simulation of Vehicle Traffic on An Automated Highway System", Mathematical Computing Modeling, Vol. 27, No. 9-11, pp.l29-141,1998.

12. **Johnston, C. M., and, A. T. Chronopoulos, "The Parallelization of A Highway Traffic Flow Simulation ", Proceedings of IEEE , pp. 192-199, 1999.**
13. **Lighthill, M. J., and Whitham, G. B., 1955, " On Kinematics Waves I. Flood Movement in Long Rivers ", London, Proceedings Royal Society, A229, pp.281-316.**
14. **Lighthill, M. J., and Whitham, G. B., 1955, " On Kinematics Waves II. A Theory of Traffic Flow on Long Crowded Road ", London, Proceedings Royal Society, A229, pp.317-345.**
15. **Lepper, J., U. Schnell, and K. R. G. Hein, "Parallelization of a Simulation Code for Reactive Flows on the Intel Paiagon", Computers Math. Applic., Vol. 3S, No. 7, pp.1O1-109, 1998.**
16. **Michalopoulos, P. G, G. Stephanopoulos, and V. B. Pisharody, "Modeling of Traffic Flow At Signalized Links", Transportation Science, Vol. 14, No. I, pp.9-41, 1980.**
17. **Michalopoulos, P. G., and V. Pisharody, "Plaoon Dynamics On Signal Controlled Arterial", Transportation Science, Vol. 14, No. 4, pp.365-396, 1980.**
18. **May, A. D., Traffic Flow Fundamentals. New Jersey, Prentice-Hall inc., 1990.**
19. **Newell, G, F,, "A Simplified Theory Of Kinematic Waves In Highway Traffic, Part 1: General Theory", Transportation Research Part B, Vol. 27, No. 4, pp.281-287, 1993.**
20. **Newell, G. F., "A Simplified Theory Of Kinematic Waves In Highway Traffic, Part II:Queueing At Freeway Bottlenecks", Transportation Research Part B, Vol. 27, No. 4, pp.289-303,1993.**
21. **Newell, G F., "A Simplified Theory Of Kinematic Waves In Highway Traffic, Part III: Multi-Destination Flows", Transportation Research Part B, Vol. 27, No. 4, pp.305-313, 1993.**
22. **Payne , H.J. ," Models of freeway traffic and control" ,Math. Models Publ. Sys. Simul. Council Proc. , 28 , 51-61.(1971).**
23. **Ross, P., "Traffic Dynamics", Transportation Research Part B, Vol. 22, No. 6, pp.421-435, 1988.Smoller, J., Shock Waves And Reaction-Diffusion Equation. New York, Springer-Verlag Inc., 1983.**