Multi-agent Modelling of Freight Policies under Network Uncertainty

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Introduction

Urban freight transport is gaining more attention in many megacities of the world due to the movement of more population into urban areas as well as social and environmental problems that are related to urban freight transport. The government is constantly required to tackle problems in urban areas that include creating efficient urban freight transport systems with higher services and lower costs and to ensure a better environment, safer community and well-being of people who are living within. The concept of city logistics has been introduced[1)2)] for establishing efficient and environmentally friendly urban freight transport systems towards sustainable and liveable cities by balancing the above mentioned issues. The essential aspect of city logistics is that although the logistics activity is mainly carried out by private companies, the intervention of public authorities is required to achieve the goals of city logistics by implementing policy measures[3)]. Table 1 shows the typical city logistics measures that are possible for evaluation and implementation.

The UDC has been studied and encouraged as a promising concept, where carriers with common customer locations deliver their goods to a single facility. The goods are consolidated into neutral trucks operated by the facility and these trucks continue the last-mile journey to reach the final receivers. Such operation is said to increase the load factor of the trucks and to allow for easier time-windowed operations to avoid traffic congestion[4)].

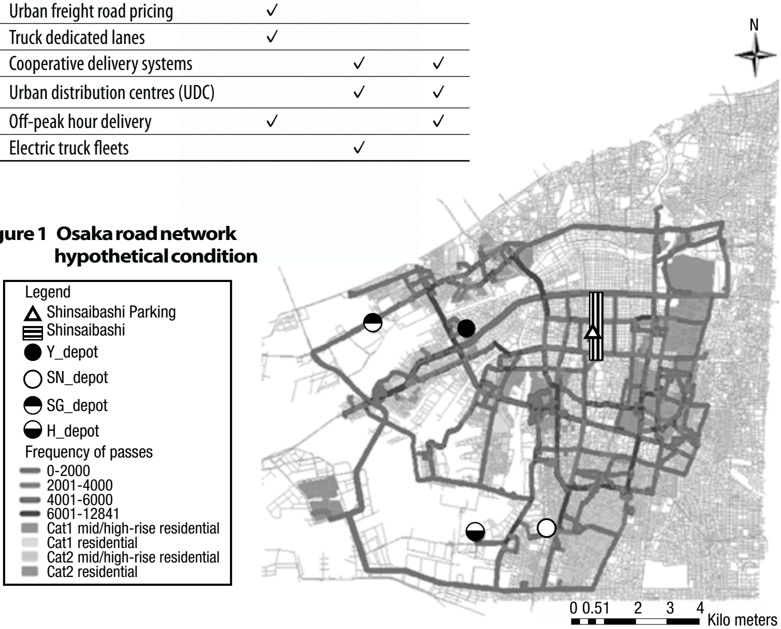
There are few but successful implementation of urban distribution centres around the world. One of them is the Cityporto case in Italy where the UDC is part of an initial public-private partnership among the Municipality, Province and Chamber of Commerce since 2004[5)]. Another case of successful UDC operation is Motomachi at Yokohama, Japan. The success factors for this UDC include good leadership, co-operative collaboration of stakeholders, good business model, use of CNG-powered trucks and pre-assigned parking locations for UDC operated trucks

Recent studies by researchers have considered urban freight logistics by using the multi-agent systems (MAS) modelling approach to evaluate urban distribution centre[6)7)]. This research will continue to explore the use of MAS with the support of

Table 1 List of Urban Freight Policy Measures

Types of Policy	Govern-ment Driven	Private Driven	PPP
1. Truck ban or access control	✓		
2. Junction improvement	✓		
3. New roads or additional lanes	✓		
4. Green routes	✓		
5. Quiet zones	✓		
6. Urban freight road pricing	✓		
7. Truck dedicated lanes	✓		
8. Cooperative delivery systems		✓	✓
9. Urban distribution centres (UDC)		✓	✓
10. Off-peak hour delivery	✓		✓
11. Electric truck fleets		✓	

Figure 1 Osaka road network hypothetical condition

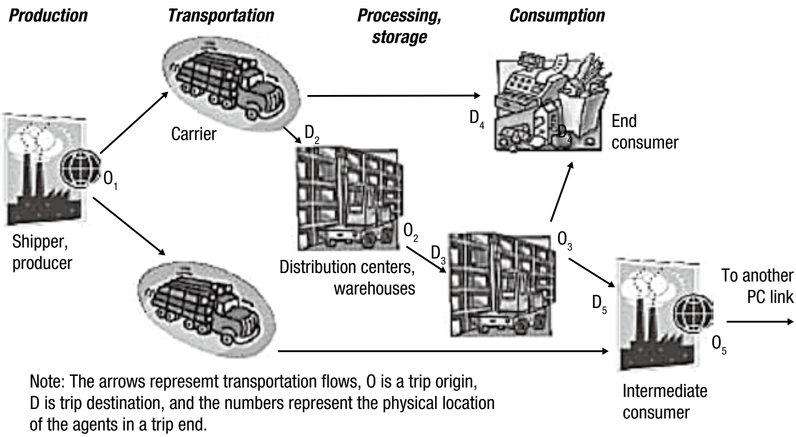


geographical information systems (GIS) to evaluate urban freight policies like UDC and the possibility of combining another freight policy in Osaka City in a real network environment (Figure 1) with uncertainty like the network travel time.

Network Uncertainty

Many studies were done on the reliability of road network. Reliability of transportation systems can be categorized into connection reliability, capacity reliability and travel time reliability[8]. The travel time reliability is a probability of the total travel time that is less than a pre-determined threshold. Reliability for post-seismic supply chain was studied by Peng et al.[9] where they introduced variations in transportation times during disaster based on the estimation by the United States Bureau of Public Roads, 1964. Although reliability and vulnerability are related, reliability focuses more on connectivity and probability whereas vulnerability is about network weakness and consequences of failure. Some game theoretic approaches have been used to deter-

Figure 2 Economic agents involved in freight generation[14)]



Note: The arrows represemt transportation flows, O is a trip origin, D is trip destination, and the numbers represent the physical location of the agents in a trip end.

mine the reliability of links or identifying critical links in the road network in the past while vulnerability research on road network has been different from the reliability research community where the potential risk is studied.

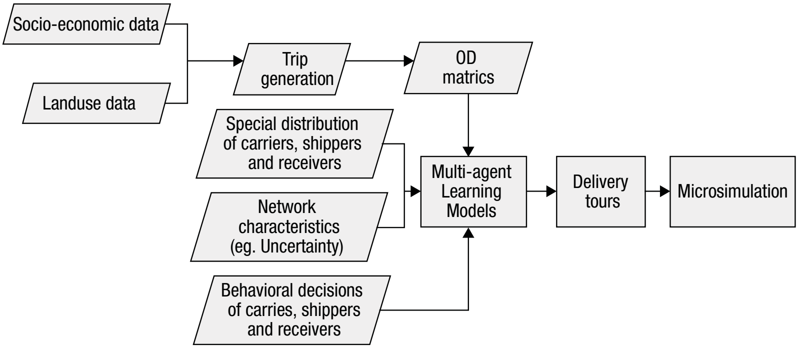
As defined by Berdica[10)], vulnerability can be considered as "a susceptibility to incidents that can result in considerable reductions in road network serviceability". Another concept of vulnerability, as quoted by Jenelius et al[11)] from Abrahamsson's working report in Swedish titled, "Characterization of vulnerability in the road transport system", has the "notion of little strokes fell great oaks". This concept explains the chain reactions that may incur on interconnected systems. Jenelius et al.[11)] identified the critical links by introducing importance and exposure metrics based on two measures. One measure represents the cost increase of a damaged link and another measure defines the unsatisfied demand of disconnected links. Therefore, when we consider urban freight logistics measures, it is also interesting to look at conditional vulnerability, i.e. the analysis of inoperability of the road network given that some uncertain events may occur.

Recent Trends in Modelling Freight Movement

Recent researches have attempted to model truck movements like the tour-based microsimulation by Hunt and Stefan[12)], a decision support systems named City Logistics Analysis and Simulation Support Systems (CLASS)[13)] that considered shopping demand models and urban restocking models by Nuzzolo et al.[13)] and freight trip generation based on land use proposed by Holguin-Veras et al.[14)]. The complexity of freight generation due to the multiple economic agents is shown in Figure 2.

Attributing to past findings that considered the uncertainty of travel times[15)] and the use of updated travel information from intelligent transport systems[16)], which

Figure 3 Proposed framework for tour-based urban freight multi-agent model with network uncertainty



can help to contribute to a more environmentally friendly urban living, the proposed modelling framework for a tour-based urban freight multi-agent model that considers the network uncertainty is shown in Figure 3. The proposed model is expected to be beneficial for short-term to medium-term freight policies evaluation as shown in Table 1.

Conclusion

Modelling freight movement has always been challenging due to the complexity of multiple economic agents involved. On top of that, events like man-made and natural disasters are evolving more often. As more data becomes available in addition to the cooperation from these agents to provide key information for modelling, the evaluation of urban freight policies will become more effective in the future and lead to not only a sustainable but resilient urban environment.

要約

行政は、効率的な都市物流システムの構築を含む多くの都市問題の解決と、安全なコミュニティと都市住民の福祉の実現をつねに求められている。本研究では、旅行時間に代表される不確実性を含む現実のネットワーク環境下における都市部の配送センターをはじめとした都市物流施策の評価に、地理情報システムを活用したマルチエージェントモデルが適用できるかを探求する。貨物流動のモデル化は、複数の経済主体が複雑に関係しているためにむずかしく、つねに挑戦を伴う。そのうえ、現実には人為災害や自然災害もたびたび起こる。本研究の目標は、持続可能なだけでなく、強靭な都市環境を実現するための都市物流施策を評価するためのツールを提供することである。

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