MULTI-AGENT MODELING TO EVALUATE URBAN FREIGHT TRANSPORT POLICY MEASURES USING JOINT DELIVERY SYSTEMS

2014

WANG-A-PISIT ORNKAMON

PREFACE

This dissertation is submitted for the degree of Doctor of Philosophy at the Kyoto University. The research described herein was conducted under the supervision of Professor Taniguchi Eiichi in the Department of Urban Management, Logistics Management Systems Laboratory, Kyoto University, between October 2011 and September 2014.

Manuscript of this Ph.D. dissertation partly includes contents of the following conference papers.

Peer-Reviewed Conference Proceedings

- Wangapisit, O., Taniguchi, E., Teo, J.S.E. & Qureshi, A.G., 2014. Multi-agent Systems Modelling for Evaluating Joint Delivery Systems. *Procedia - Social and Behavioral Sciences, Eighth International Conference on City Logistics 17-19 June 2013, Bali, Indonesia*, Volume 125, pp. 472-483.

Conference Papers

- Wangapisit, O. & Taniguchi, E., 2012. Multi-Agent Modeling for Evaluating Urban Freight Policy Measures on Urban Distribution Centre. Presentation in *The 46th Infrastructure Planning Science Research Conference, Japan Society of Civil Engineers*, in Saitama, JAPAN, on November 3rd 2012.

- Wangapisit, O., Taniguchi, E. & Qureshi, A.G., 2013. Multi-Agent Modelling Systems for Evaluating Urban Freight Policy Measures on Parking Space Restriction. Presentation in *The 13th World Conference on Transport Research,* in Rio de Janeiro, BRAZIL, on July 15th -18th, 2013.

- TEO, J.S.E., Taniguchi, E., Qureshi, A.G. & Wangapisit, O., 2014. Practical Application of Multi-agent Models with GIS to Access City Logistics Measures in Osaka City. Presentation in *The 49th Infrastructure Planning Science Research Conference, Japan Society of Civil Engineers*, in Sendai, JAPAN, on June 7th -8th, 2014.

ACKNOWLEDGEMENT

The author wishes to express her sincere appreciation and heartfelt gratitude to her supervisor, Dr. Eiichi Taniguchi, Professor, Logistics Management Systems Laboratory, Graduate school of Engineering, Kyoto University, Kyoto, JAPAN for his excellent guidance, effective suggestions, efficient encouragement throughout the progress of the research study and especially for the knowhow and expertise of the subject matter to widen the author's views and knowledge of the study.

A great deal of appreciation is also extended to Dr. Nobuhiro Uno, Associate Professor and Dr. Ali Gul Qureshi, Associate Professor, for serving as members of the examination committee. They provided a wealth of knowledge and ideas, sharing some of their time for discussions, giving advises and most of all for their valuable support and recommendations. Without them, this dissertation would not have been completed.

The author would like to express her heartfelt thanks to all the Kyoto University, Graduate School of Engineering, Department of Urban Management, Logistics Management Systems Laboratory, and staffs for their help and for providing all the necessities needed for her dissertation.

Sincere gratitude is extended to the Japanese Government (Monbukagakusho: MEXT) Scholarship for providing the scholarship during her entire stay in Japan. Without this support she could not have been here where she meets people of diverse nationality and cultures and which she considers a great and once of a lifetime opportunity.

The author expresses her grateful to Dr. Joel S.E. Teo, Post-doctoral for his precious advice, unceasing encouragement, constant support and his friendship.

Finally the author wishes to say a million thank you to her parents who taught her that self-motivation is a positive personal attribute, to her sisters and brother who give her light and inspiration, to be strong and support throughout her life.

ABSTRACT

According to the increasing of shoppers and changeable shopping life style, the shopping centers and shopping streets are attached the shoppers into the urban areas. The area around the shopping center and shopping street might be crowded with pedestrians, private vehicles and freight trucks. Theses cause the environmental problems such as nuisance, truck emissions and suspended particular matter (SPM). Besides, illegal parking frequently occurs in shopping streets especially for the loading/unloading activities which affect the health of inhabitants who live around the shopping areas. The problem highlighted contributes to our interest to identify the possible policies to resolve the effects due to an increase in freight traffic and truck emissions. The Multi-Agent System (MAS) approach of modeling city logistics is widely recognized as a way of modeling individual agent behavior and interaction while gradually expanding the model to cover all agents within a system. This approach wishes to discover the evolving behavioral phenomenon among agents, which possible for other modeling approaches to accomplish. The multi-disciplinary nature of MAS approach provided a form of flexibility in terms of modeling as different theoretical model can be experimented to give a close to reality evaluation of problems. A modified MAS learning model is developed in this research which combine by two main modules. Firstly, the vehicle routing problem with soft time window model (VRPSTW) can determine the optimize routing using genetic algorithm and reinforcement learning model. Secondly, the Q-learning for shopping and home delivery is added to incorporate a decision making and the interaction of major stakeholders, including freight carriers, neutral carrier, residents, shop owners, administrator and shopping street association. The selected city logistics policies were evaluated to consider the economic and social effect from freight delivery due to the appearance of the Urban Distribution Center (UDC).

To evaluate the city logistics approach that aim to determine the behaviour of city logistics stakeholders such as freight carriers, residents, administrator and shipping were studied by several researchers. A number of papers have attempted to study on the MAS for logistic stakeholders' interaction. However, the gap still exists since most

researchers are attended on urban freight transport while less attention in city logistics research. Most of researchers focus and study on the point of view of administrator while less concern about other active stakeholders. None of them focuses on the stakeholders' behaviour by using the MAS modeling evaluate on join the joint delivery system (JDS) and parking space restriction policy measures. As a result, this proposed research aims to evaluate the city logistics policy and measures how it affects the stakeholder decision-maker in selecting to join the JDS.

In this research, the multi-agent system model was used as a tool to evaluate the transportation cost and environmental issues of using the UDC. It can be concluded that the presence of UDC and parking space restriction were identified as possible city logistics policy measures to decrease the environmental effect of the truck travelled from freight carrier depot to their customers. The MAS learning model was initially setup to include the JDS as representative of freight carriers and neutral carrier interaction to ensure that delivery cost was minimum. The reinforcement Q-learning model has been used in this research to test the developed MAS model and to perceive the freight carriers and neutral carrier interaction in the urban freight delivery. It is challenging to determine the agents learning objectives when each agent may be required to learn what other agents are learning or thinking. Therefore, the joint decision making and cooperate behavior can be attained.

The preliminary concluded that the reduction of the test road network operating cost reduction for implementing UDC and applying parking management as the additional supporting scheme showed the potential of reducing truck emissions level for example NO_x, CO_2 and SPM in the city when the freight carriers learnt and priced each link based on the outcome of past actions and future rewards. The parking space restriction policy was evaluated to have benefited the freight carrier' objective.

The preliminary results from the present the UDC the real situation of the Osaka road network could be concluded that the freight carrier delivery cost was not reduced because of the implemented UDC usage charge. To deal with this purpose, the discount service charge and the subsidy from the administrator can be fulfilled. The environmental impact for implementing UDC in Osaka city, the urban freight emissions reduction is achieved from the reduction in distance travelled resulting from the replacement of individual delivery to consolidated delivery with the presence of an UDC.

The idea of MAS modeling use to evaluate the interaction of stakeholders and behaviour changing is useful to measure beneficial when implementing the city logistics policy measures. This research is limited due to the availability of customer' demand, time window, the real data from the freight carriers and actual UDC service charge, which may be useful to analyze more realistic behavior of UDC participation for the further research.

Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

List of Tables

List of Figures

List of Figures (Continued)

List of Figures (Continued)

1

INTRODUCTION

1.1 General background

Presently, urban life style has changed throughout the world especially in the mega cities such as Tokyo, Yokohama and Osaka in Japan, United State of America, and Australia (Reimers & Clulow, 2004). The modern shopping centers (cited as shopping malls) and shopping streets (cited as high street in downtown) attract large number of local customers and tourists because the shopping centers become more useful and convenient to purchase different types of goods. The urbanization changes the way people live. Inhabitants in rural areas have immigrated into the urban areas for a better quality of life. Besides, the percentage of elderly people is certainly growing up as shown in Figure 1.1 and the foreign tourists are rising due to the initiative of visa waivers for tourists especially the South East Asian countries. Thai tourist is increasing rapidly after Japan government allows this policy in 2013 (The Embassy of Japan in Thailand, 2013).

City logistics aims to reduce the number of freight vehicles that access into the urban areas in order to avoid traffic congestion that produce negative environmental impacts. It introduces the economic and regulative measures to increase the efficiency of using freight vehicles. The examples of the development of this systems are the home delivery and the services to elderly people. These services are essential for the city's prosperity and city logistics schemes which can reduce the operating costs (Taniguchi, et al., 2001).

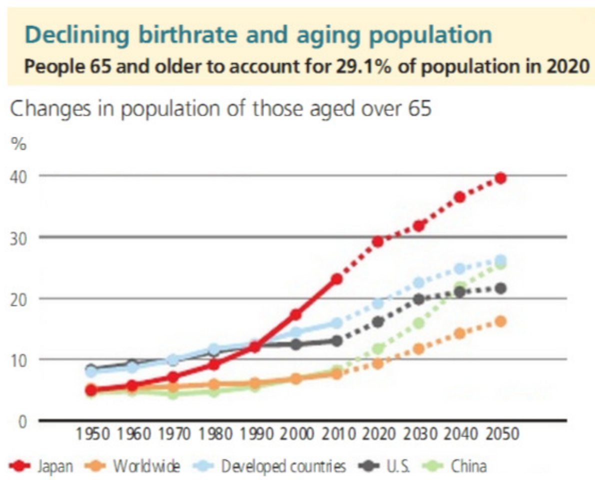


Figure 1.1 Declining birth rate and aging population

(*Source*: Statistical Handbook of the World, 2012)

However, the increasing number of shopping centers and shopping street causes environment problems for example nuisance, exhaust emissions and suspended particular matter (SPM) (Michon, et al., 2005). Moreover, illegal parking frequently occurred in shopping streets (van der Waerden & Timmermans, 2014) and (Spiliopoulou & Antoniou, 2012).

Recently, the shopping streets managements are introduced in Japan, including logistics transportation, parking areas, shop owners and providing loading/ unloading areas. It is a success in the Motomachi Shopping Street (MSS) in Yokohama and Ginza promenade shopping street in Tokyo with the cooperation among stakeholders. The model simulation of MSS is the pilot project that replicates into the other cities. The detail of planning and operation process of MSS is presented in the next section.

1.1.1 New logistics concept

Recently, the diversity of merchandise influences the communication networks and globalization of the economy. The new logistics systems have to design with capability to encounter with unpredicted and vary demands by the lowest number of heavy trucks in urban areas. It must improve the satisfaction of customers and environmentally friendliness.

The new logistics systems are essential to obtain the flexibility to cope with the disturbance of the new logistics setting. There are number of concepts that emphasize the activity of logistics systems in the city. Firstly, it is designed to decrease the obstacle of parking along the street for loading/ unloading activities. The study shows that the booking systems should be added to the delivery area in the urban logistics delivery. It increases the efficiency for sustainable development of the city with professional delivery operators which allows the dynamic adjustment of their booking by using information technology (Patier, et al., 2014). Secondly, the joint concept for delivery is encouraged (Department of Defense, 2010). The coordinated policy is achieved by scheduling single setup at the producer with multi-delivery to the buyer. The study shows the significant cost savings by implementing the proposed approach into the network optimization process (Lee & Fu, 2014). Moreover, Qu, et al., (2013) proposes the joint replenishment and delivery (JRD) model where a warehouse procures multi heterogeneous items from suppliers and delivers them to retailers. An adaptive hybrid differential evolution (AHDE) algorithm is designed in their research. The findings show that AHDE is more stable and robust in handling this complex problem. Finally, the Just In Time-Logistic (JIT-L) shows several benefits such as determination of waste sources, increasing delivery speed of goods to customers, improvement of processes by organizing business requirements and manpower plans for logistics, and increasing harmony among suppliers and customers (Ozalp, et al., 2010).

1.2 City logistics scheme

1.2.1 Urban Distribution Center (UDC)

An Urban Distribution Center (UDC) is designed by the same concept and usefulness with an urban consolidation center (UCC). The UDC is defined by Allen, et al., (2007) as,

> *"A logistic base located in the vicinity of the place of performing services (e.g. city centers, whole cities or specific locations like shopping malls) where numerous enterprisers deliver goods destined for the serviced area from which consolidated deliveries as well as additional logistic and retailed services are realized"*.

By this definition, a range of tasks of UDC can be clearly enumerated as basic tasks comprising, for instances, goods reception, sorting, storage, loading on other means of transport. Besides, additional tasks are setting prices and fees, reverse logistics, home delivery, and services of collecting wastes.

1.2.2 Joint Delivery Systems (JDS)

Motomachi Shopping Street (MSS) in Yokohama promotes the eco street campaign. This is the first project in Japan to collaborate between the Japanese government and private sectors. The purpose of the MSS is to reduce the delivery trucks that pass through the city significantly which causes environmental issues, such as exhaust gas and noise. In addition, it solves the limitation of pedestrian space and illegal parking problems. MSS started the collaboration among Yokohama's government including Kanagawa Prefectural Police Department, Traffic Regulation Division and Policy Division, Environmental Planning Bureau, the City of Yokohama in year 2004. Until now, it has carried out the corporate social responsibility experimental by considering the JDS.

The details of MSS are described as follows. The contents start from a joint delivery distribution center in Motomachi district neighborhood. The MSS freight delivery collects parcels in a joint delivery distribution center (called UDC) from the suppliers. MSS uses their own trucks for delivering the goods from UDC to shop owners. This system is called Joint Delivery Systems (JDS) as shown in Figure 1.2. In other words, JDS is an attempt to reduce the large delivery truck in MSS and try to encounter the environmental issues and transportation problems. The MSS have their own trucks that are called eco-truck that serve deliveries to shop owners. It also contributes to traffic safety. Nowadays, MSS is continuing to achieve the goal of urban development and environmentally friendliness.

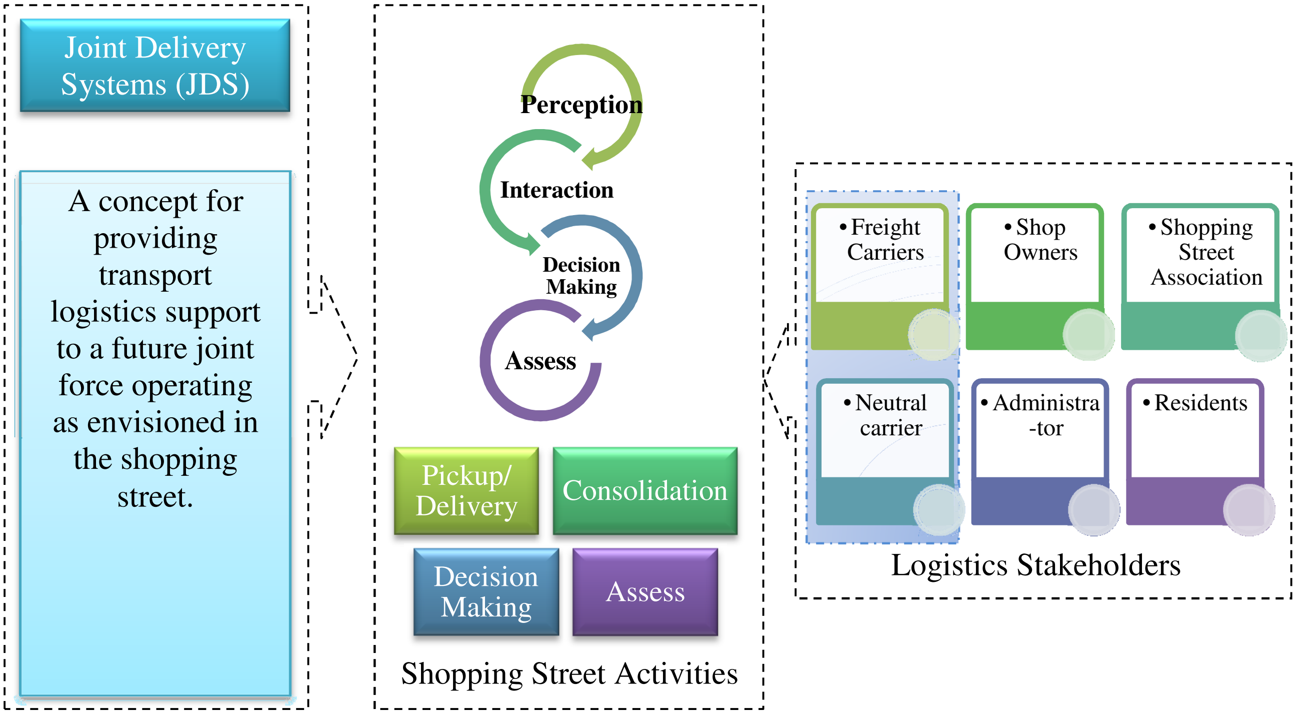


Figure 1.2 Concept of shopping street joint delivery system

1.2.3 Parking space restriction

Inside the regional shopping streets and residential areas, freight trucks need a parking space along roadside. This activity causes the road obstruction and illegal parking. The cost of parking component includes the searching time to find an available parking space, parking lots charge, and walking time from the parking space to the shop owners and residents (Bifulco, 1993). These might increase the congestion and reduce number of parking spaces in that area. The administrator issues the parking space policy for freight carriers and neutral carrier by given the parking space priority for neutral carrier and prohibited freight carrier's truck to go inside the shopping street area. Freight carriers are allowed to park the trucks further from the shopping area. For this reason, the freight carriers may not benefit over time.

From the above reasons, this research uses the lessons of MSS to study the uses of parking space restriction as one of the city logistics policy measures.

1.3 Motivation of research

Previous researches in city logistics have attempted to model and provide solutions to businesses and the community by ensuring optimum efficiency of goods delivery, reliability and customer service while reducing the negative environmental issues which are air pollution emissions, energy consumption and traffic congestion. One solution of improving and reducing the urban freight logistics problems is to introduce UDCs (Dablanc, 2007). The UDC is a promising concept where the loads of delivery trucks from different carriers are consolidated at a single facility and transferred to the new trucks. This concept increases the load factor and allows managing time-windowed operation to avoid traffic congestion (Quak & Koster, 2009). The main contributing factors to a successful of implementing the UDC are its location, subsidy collection, service cost of the UDC, shorter delay in delivery time and the collaborative relationship between the shippers and freight carriers. Furthermore, it is found that the most challenging factor is the collaboration between all involved stakeholders within the complex operation (van Duina, et al., 2012).

Several researches have studied on urban freight logistics by using the Multi-Agent Systems (MAS) modeling approach to evaluate city logistics measures, including road pricing, toll pricing, truck ban, time windows restrictions, load factor control, operation subsidies and UDC usage (van Duina, et al., 2012), (Vita & Janis, 2005), (Teo, et al., 2012), (Tamagawa, et al., 2010) and (Taniguchi, et al., 2007). However, the interaction between the stakeholders of the JDS and the consideration of illegally parked vehicles are intended to be comprehensively studied. The aim of this research is to explore whether the implementation of JDS and car parking management as the city logistics measures can improve an overall benefit by using the MAS model with reinforcement learning.

1.4 Proposes and objectives of research

The purpose of this research is to study the effects of city logistics measurements by the combination of the JDS, an UDC, and parking space restriction. To study the behavior of urban freight stakeholders and their interaction which is affected by the policy measures, the MAS modeling approach is used to represent their multi-objective environment.

The details of objectives are as follows:

1) To develop the MAS model with reinforcement learning to evaluate the implementation of JDS as the city logistics policy measurement that can lead to an overall benefit for all stakeholders.
2) To evaluate the MAS model in the context of city logistics measurement which aim to change the stakeholders' behavior. The performance measurements for evaluating include the truck emissions for instance carbon dioxide (CO_2), nitrogen oxide (NO_x) and suspended particulate matter (SPM).

1.5 Organization of the thesis

This research proceeds as follows; Chapter 2 presents the literature review of the previous related researches in MAS modeling approach particularly the urban freight transport and reinforcement learning especially Q-learning. This study is to review the current freight delivery policy measures on city logistics. The interaction among shopping street and objectives of each stakeholder in shopping street communities are also presented.

Chapter 3 addressed the model description of the mathematical formulation of the MAS to evaluate the policy measurements and the effect to stakeholder behaviors. Besides, this research is proposed to use Vehicle Routing Problem (VRP) to optimize the number of customers served from the proposed UDC central depot. Finally, to examine the optimal stakeholder decision making both action and selection, the author applies a reinforcement learning technique. Q-learning model ultimately provides the advantage of taking a given action in a given state and following the optimal policy thereafter.

Chapter 4 focuses on a hypothetical network at MSS. The two different city logistics schemes are presented here. The first scheme is to minimize the transportation cost when shop owners and residents request the freight carriers to use neutral carrier as their representative. The second scheme includes two measurements including parking space restriction (parking regulation and parking priority) and JDS as mention in chapter 2. From these two schemes, the details of their impacts on road traffic, economic, and environmental impacts are comprehensively described and concluded.

Chapter 5 applies the MAS modeling with the real world network in Osaka, Japan by implementing the JDS and parking restriction policy. The details on economic aspects and environmental effect are discussed.

Chapter 6 concludes an evaluation of the authorities' attitude concerning logistics and compares the real policy on urban freight transport and environment. Moreover, the recommendation to apply this concept in city logistics and the development for further studies are also presented. The flowchart of the thesis content is shown graphically in Figure 1.3.

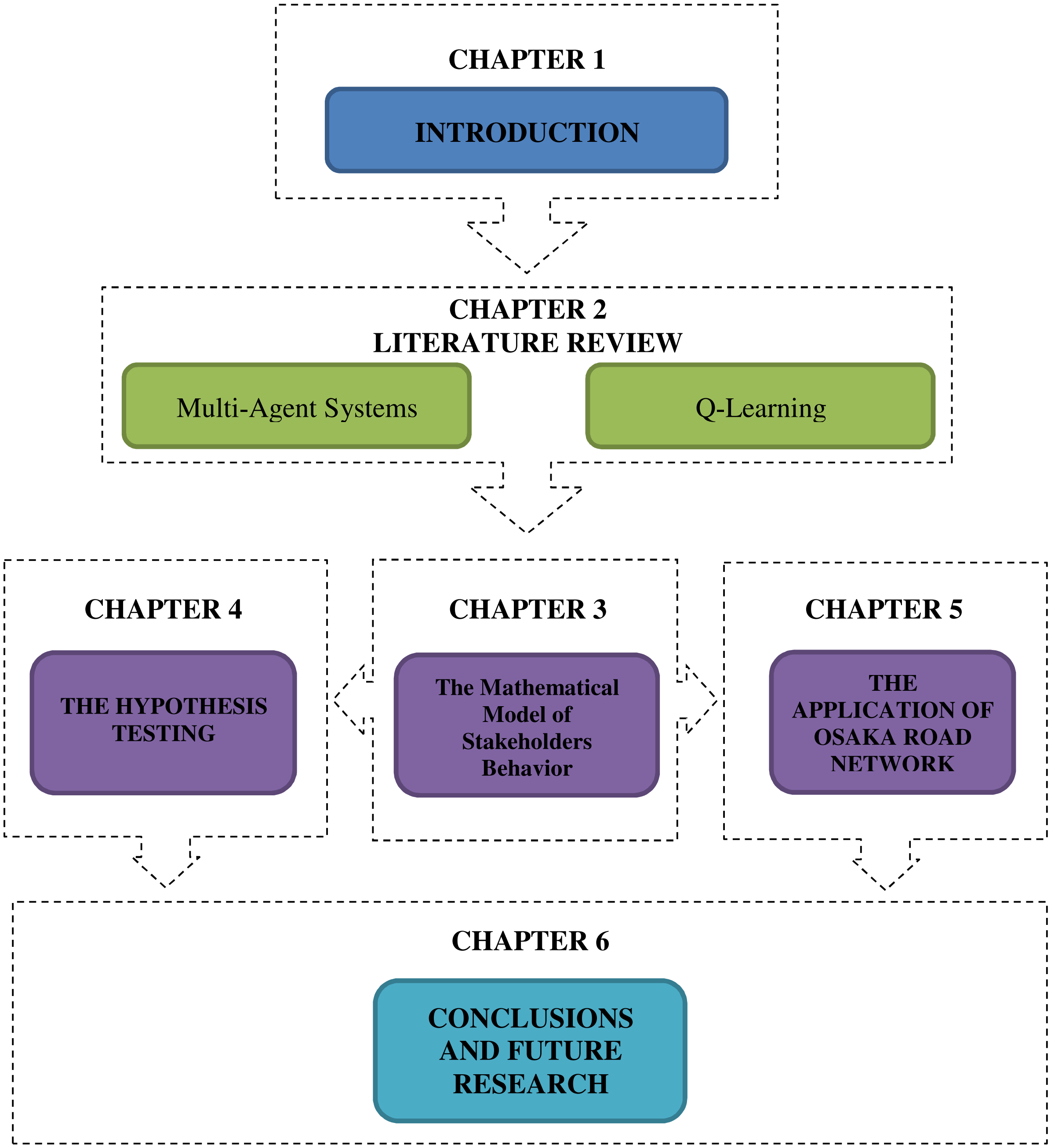


Figure 1.3 Flow chart of thesis structure

References

Allen, J., Thorne, G. & Browne, M., 2007. *BESTUFS Good practice guide on urban freight transport,* Brussels: BESTUFS EU Thematic Network.

Bifulco, G. N., 1993. A stochastic user equilibrium assignment model for the evaluation of parking policies. *European Journal of Operational Research,* 71(2), pp. 269-287.

Dablanc, L., 2007. Goods transport in large European cities: Difficult to organize, difficult to modernize. *Transportation Research Part A: Policy and Practice,* 41(3), pp. 280-285.

Department of Defense, U. S. o. A., 2010. *Joint Concept for Logistics.*

Lee, S. D. & Fu, Y. C., 2014. Joint production and delivery lot sizing for a make-to-order producer–buyer supply chain with transportation cost. *Transportation Research Part E,* Volume 66, pp. 23-35.

Michon, R., Chebat, J. C. & Turley, L. W., 2005. Mall atmospherics: the interaction effects of the mall environment on shopping behavior. *Journal of Business Research,* Volume 58, pp. 576-583.

Ozalp, I., Suvaci, B. & Tonus, H. Z., 2010. A NEW APPROACH IN LOGISTICS MANAGEMENT: JUST IN TIME-LOGISTICS (JIT-L). *International Journal of Business and Management Studies,* Volume 2, pp. 37-45.

Patier, D., David, B., Chalon, R. & Deslandres, V., 2014. A New Concept for Urban Logistics Delivery Area Booking. *Procedia - Social and Behavior Sciences.*

Quak, H. & Koster, M., 2009. Delivery Goods in Urban Areas: How to deal with urban policy restrictions and the environment. *Transportation Science,* Volume 43, pp. 221-227.

Qu, H., Wang, L. & Zeng, Y. R., 2013. Modeling and optimization for the joint replenishment and delivery problem with heterogeneous items. *Knowledge-Based Systems,* Volume 54, pp. 207-215.

Reimers, V. & Clulow, V., 2004. Retail concentration: a comparison of spatial convenience in shopping strips and shopping centres. *Journal of Retailing and Consumer Services,* Volume 11, pp. 207-221.

Spiliopoulou, C. & Antoniou, C., 2012. Analysis of illegal parking behavior in Greece. *Procedia - Social and Behavioral Sciences,* Volume 48, pp. 1622-1631.

Statistical Handbook of the World, 2012. *Statistical Handbook of the World.*

Tamagawa, D., Taniguchi, E. & Yamada, T., 2010. Evaluating city logistics measure using multi-agent model. *Procedia Social and Behavioral Sciences,* Volume 2, pp. 6002-6012.

Taniguchi, E., Thompson, R. G., Yamada, T. & van Duin, J. H. R., 2001. Network Modelling and Intelligent Transport Systems. In: *City Logisitics.,*The Netherlands: Elsevier Science Ltd.

Taniguchi, E., Yamada, T. & Okamoto, M., 2007. Multi-agent modelling for evaluating dynamic vehicle routing and scheduling systems. *Journal of the Eastern Asia Society for Transportation Studies,* Volume 7, pp. 933-948.

Teo, J. S. E., Taniguchi, E. & Qureshi, A. G., 2012. Evaluating city logistics measure in e-commerce with multi-agent systems. *Procedia Social and Behavioral Sciences,* Volume 39, pp. 349-359.

The Embassy of Japan in Thailand, 2013. *http://www.th.emb-japan.go.jp/.*

van der Waerden, P. & Timmermans, H., 2014. Car drivers' familiarity with the parking situation around regional shopping centres. *Procedia - Social and Behavioral Sciences,* Volume 111, pp. 292-300.

van Duin, J. H. R., van Kolck, A., Anand, N. & Tavasszy, L. A., 2012. Towards an agent-based modelling approach for the evaluation of dynamic usage of urban distribution centres. *Procedia - Social and Behavioral Sciences,* Volume 39, pp. 333-348.

Vita, G. & Janis, G., 2005. *Technologies and Multi-Agent System Architecture for Transportation and Logistics Support: An Overview.* Varna, pp. IIIA.6-1 - IIIA.6.6.

2

LITERATURE REVIEW

2.1 City logistics

The efficiency of freight transport lies on the function of logistics. The term ‘Logistics’ refers to the “planning, organisation, management, execution and control of freight transport operations. It integrates individual transport acts to door-to-door supply chains” (European Commission, 2010a). Logistics usually focuses on minimizing shipper costs, with little consideration of social costs such as congestion or pollution impacts. Taniguchi et al. (2001) defined ‘City logistics’ as “the process for totally optimizing the logistics and transport activities by private companies with support of advanced information systems in urban areas considering the traffic environment, the traffic congestion and energy consumption, the traffic safety and the energy savings within the framework of a market economy”.

However, the continuous growth of freight transport and especially the road mode aggravates its significant negative impacts on society and the environment. In cities, millions of people live and work in close vicinity with the road network, being largely exposed to the effects of road traffic. The growth of logistics activities implies an increase of their many negative effects. The U.K. Round Table on Sustainable Development has summarized these negative effects in Table 2.1.

Transport currently depends by 97% on fossil fuels (UK Roundtable on Sustainable Development, 1996). Unfortunately, diesel combustion products cause significant negative impacts on regional level. Gaseous components of diesel exhaust include carbon dioxide (CO_2), oxygen (O_2), water vapour, nitrogen (N_2), carbon monoxide (CO), nitrogen compounds, sulfur compounds and low-molecular-weight hydrocarbons. Particulate matter (PM) released includes a 10 central core of elemental carbon, absorbed organic compounds, as well as small amounts of sulfate, nitrate, metals and other trace elements (Sathaye, et al., 2006).

Nitrogen oxides (NO_x) and particulate matter (PM) tend to be the greatest concern, as they are related to a number of health-effects, such as irritation, neurophysiologic dysfunction, respiratory problems and even lung cancer. The combination of NO_x with volatile organic compounds (VOC) and sunlight can cause the formation of photochemical smog, which affects the air quality of many urban areas. In addition nitric acid (HNO_3) can cause paint deterioration, corrosion, degradation of buildings, and damage to agricultural crops.

CO_2 is a greenhouse gas (GHG) which has been found responsible for climate change. Global climate change is expected to severely affect the hydrological cycle, increase average temperatures, accelerate the melting of the ice in arctic areas and raise the sea level, literally changing the face of the earth. Road transport (passenger and freight) is a major contributor of CO_2 emissions (16.3% of the total CO_2 emissions in Europe in 2006). Especially in cities, urban freight transport accounts for 21% of the CO_2 emissions, while transiting heavy goods vehicles add another 10% of the CO_2 emissions (European Commission, 2007b).

Older heavy goods vehicles fitted with air conditioners and refrigerators may also release chlorofluorocarbons (CFCs), which cause stratospheric O_3 depletion, thus increasing the amount of harmful ultra-violet radiation penetrating the earth's atmosphere.

Table 2.1 Impacts of logistics systems (UK Roundtable on Sustainable Development, 1996)

Economic Impacts	Traffic Congestion
	Resource Waste
Ecological Impacts	Greenhouse Gases cause Climate Change
	The use of non-renewable fossil fuel
	The effects of waste products such as tires and oil
	Ecosystem destruction and species extinction
Social Impacts	Negative Public Health Impacts of Pollution
	Crop Destruction
	Injuries and deaths resulting from traffic accidents
	Noise
	Visual intrusion
	Congestion deterring passenger travel
	Loss of Greenfield sites and open spaces
	Deterioration of buildings/infrastructure

2.2 Multi-Agent Systems modeling (MAS)

The MAS consists of agents and environment which also includes the following elements: roles, interaction, environment resources and organizations (Zambonelli, et al., 2003). The roles are responsible for accomplishing the requirements and they are assigned to the agents in MAS (Nakagawa, et al., 2010).

In a MAS environment, there are numbers of agents that come together where they interact, cooperate, coordinate and negotiate with each other to reach their intended objectives. Figure 2.1 shows the idea of an intelligent agent interacting with an environment. Figure 2.2 also shows the basic idea of a MAS environment with multiple autonomous agents having the ability to sense, perceive and take action while incorporating the interactions other agents.

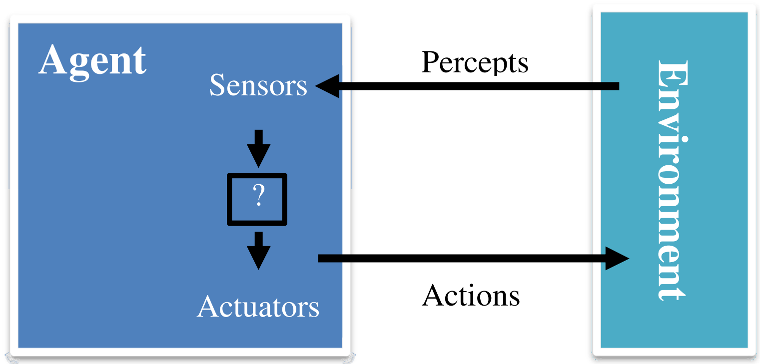


Figure 2.1 An agent interaction with the environment (*Source*: Russell & Norvig, 2010)

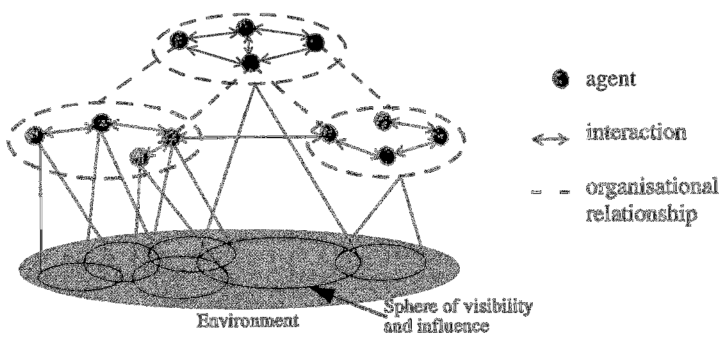


Figure 2.2 Common structures of MAS (*Source*: Jennings, 2000)

In a single agent environment as shown in Figure 2.1, the agent function is required to map the perceived information into action. In a multi-agent environment shown in Figure 2.2, it is essential to know the type of interaction that connects the different agents. It can determine what information is perceived by each agent and how the information leads to the final decision or actions of the agent (Teo, et al., 2012). Table 2.2 describe the characteristics of agent in the MAS.

Table 2.2 An overview of agency properties (*Source*: Garcia, et al., 2002)

Agency Property	Definition
Interaction	An agent communicates with the environment and other agents by means of sensors and effectors.
Adaptation	An agent adapts/modifies its mental state according to messages received from the environment.
Autonomy	An agent is capable of acting without direct external intervention; it has its own control thread and can accept or refuse a request message.
Learning	An agent can learn based on previous experience while reacting and interacting with its environment.
Mobility	An agent is able to transport itself from one environment in a network to another.
Collaboration	An agent can cooperate with other agents in order to achieve its goals and the system's goals.

Several researchers studied on the MAS in many fields, the followings are the examples related to transportation and city logistics approaches.

2.2.1 MAS in transportation approach

Nguyen, et al., (2012) studied on Multi-agent architecture with space-time components for the simulation of urban transportation systems. They implemented the prototype for movement of people in city of La Rochelle using GAMA that proved the feasibility of their choices for the design of their simulator. Lo, (2012) applied the features of information exchanged between ‘‘Multi-Agents’’ and mutual communication and collaboration mechanisms to intelligent transportation systems (ITS). A system framework and various types of dynamic data management systems to access the data were presented. It is proved to be more efficient with less cost than the traditional basic strategy. This study also proposed the algorithm which can solve the complexity of dynamic location. It brings the advantages that reduce the loading and latency of central server and increase the performance of communication effectively. Rieser, et al., (2009) and Grether, et al., (2010) show the agents consist of a mechanism for learning and choose the plan with the highest score. The policy measures and transport simulations are also examined using multi-agent modeling techniques in MATSim. In this algorithm, each agent are assigned a plan together with several information including the order, type location, duration, mode choice and other attributes related to travel plan. Bui, et al., (2012) presented the MAS dedicated to the chaotic traffic in Vietnam which has different traffic characteristics comparing with other countries. The user can carry out different experiments with different self-designed road systems as well as with different numbers of agents of different profiles.

2.2.2 MAS in city logistics approach

Basically, the supply-demand, transportation network and traffic are primarily deal in city logistic that urban goods are common entity (Van Duin & Quak, 2007). The main stakeholders in city logistic are carriers, shippers, customers and administrators. The stakeholders are interacted among each other learning and doing under diverse forces and different environment not only reactive but proactive, goal oriented and conflicting. The conventional modeling would not lead to achieve such a complex urban freight systems. Establishing each stakeholder as autonomous object can help exploring dynamics of interaction due to distributed decision making. This can be solved by improving number of functionally specific and nearly modular objects who can solve particular problem aspect. Combination of their interactive movement results into developing complex systems. This modular objects are called "Agent" in the artificial intelligence language (Anand & van Duin, 2010). A system consist of many different agents is MAS. It can be defined as a loosely coupled network of problem solvers that interact to solve problems that are beyond the individual capabilities or knowledge of each problem solver (Durfee, et al., 1989). The city logistic stakeholders are represented as the agent in MAS modeling. Each agent has own objective to achieve and certain rules. To evaluate of urban freight policy, the different business cases, settings, scenarios and regulations can be created and simulated for better representative of the city logistic systems.

The conceptual for urban freight decision making analysis referred from Anand & van Duin, (2010) in the RANDSTAD is shown in Figure 2.3. They presented the city logistics decision making using situated MAS. The cyclic process divide in three stages such specification, validation and analysis. Specification includes gathering information about decision structure of urban freight distribution and developing MAS. Validation part consists of validating developed model with base case (i.e. BESTUFS, Binnenstad service). After validation, with different settings, scenarios and regulations, different business cases (RANDSTAD specific) can be created and simulated for to understand city logistics related decision making processes and forces governing them. Finally knowledge gained from this analysis can be used to recommend some policy measures for sustainable urban freight transportation systems.

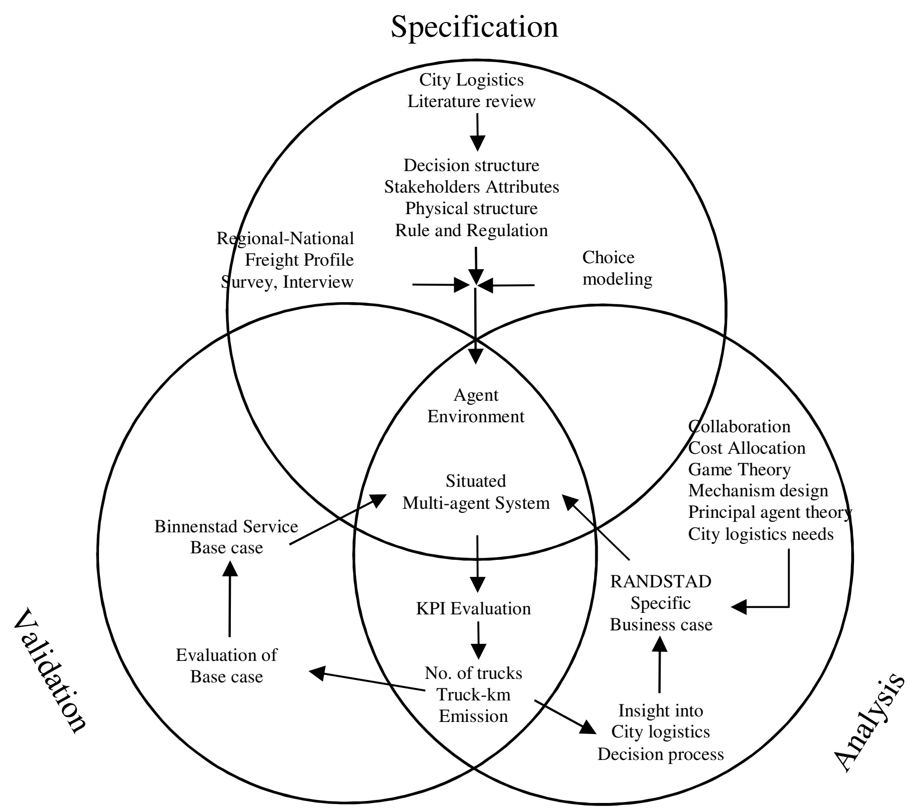


Figure 2.3 Conceptual for urban freight decision making analysis

(*Source*: Anand & van Duin, 2010)

Several researchers presented the MAS in various studies. A number of papers (Baykasoglu & Kaplanoglu, 2011), (Kolck, 2010), (Tamagawa, et al., 2010), (Taniguchi, et al., 2007) and (Teo, et al., 2012) have attempted to study on the MAS for logistic stakeholders interaction. However, the gap still exists since most researchers attended on urban freight transport while less attention in city logistics research (Anand, et al., 2012). As a result, this proposed research aims to evaluate the city logistics policy and measures how it affects the stakeholder decision-making to join the JDS. Most of researchers focus and study on the point of view of administrator while less concern about other active stakeholders (Teo, et al., 2012) and (Taniguchi & Tamagawa, 2005).

The unpredictable policy analysis problems could not solve with the conventional method as the urban freight transport is complex but it possible to solve the policy problems in various situation with the MAS (Anand & van Duin, 2010). The MAS modeling are developed for many different concerns and few attempts in city logistics. Additionally, none of them focuses on the stakeholders' behavior by using the MAS modeling evaluate on JDS and parking space restriction policy measures. Therefore, the author aims to use the MAS modeling to simulate the stakeholders' behavior and study their interaction among each other.

2.2.3 Urban freight transportation policy

The possible trends and gaps city logistics policy are introduced and summarized by (Anand, et al., 2012) as follow;

"Urban freight movement can be improved to make it more sustainable in various ways. van Duin, (2006) distinguishes two different groups of stakeholder who are capable of changing the urban freight systems. One is company-driven change where companies implement measures that can reduce the impact of their freight activities. These can be operated in more environmentally or socially efficient manner. Second, changes implemented by governing bodies–i.e. the introduction of policies and measures that force companies to change their actions to become more environmentally or socially efficient (e.g. changing the way in which they undertake certain activities (Ogden, 1992)). Policy perspective differs from planning as erstwhile concerns with planning new infrastructure (i.e. road, terminal, parking facilities etc.) or traffic planning to enhance urban goods movement and reduce externalities whereas latter (largely) concerns with introducing policy measures as rules, regulation or initiatives mainly to reduce negative externalities related to urban goods movement. Most common measures related to urban freight transportation is a vehicle restriction policy based on weight, size and time of delivery. Many times policy measures are implemented considering visible possible counter measures to the city logistics problems without any data evaluated or method used. Conclusively, urban freight policy mostly follows "Learning by doing" approach Visser, et al., (1999) that is not always effective. For example, Quak & De Koster, (2006) show that the time access restrictions does not decrease the pollutant CO_2 emissions. In contrary, it increases these emissions in many cases. In other modeling efforts considering policy perspective, Taniguchi & Tamagawa, (2005) simulate a test road network and implement policy measures such as truck ban and tolling of urban expressway. Figliozzi, (2007) analyzes the effects of variations in circuitry factor, delivery time, vehicle speed and payload. A model by Holguín, (2008) considers three combination policy of road pricing and financial incentive to estimate its impact on stakeholders' profit and consequently to get insight on their reaction. Reader can refer to other urban freight transportation models and their possible usage conducted by (Hensher & Puckett, 2005), (Gentile & Vigo, 2013) and (Muñuzuri, et al., 2010)."

In this research, the author proposes the UDC and parking space restriction policy measures to evaluate the city logistics which is described in the next section.

2.2.3.1 Urban Distribution Center (UDC)

The Urban Distribution Center (UDC) or urban consolidation center (UCC) have the similar concepts that aims to avoid the heavy freight trucks delivery goods into the urban areas. The potentiality for UDC is to relieve the environmental and traffic congestion within urban areas. The UDC is a logistic facility that is used for assortment, consolidation, re-packaging and transhipment of the goods. van Duina, et al., (2010) presented the urban consolidation center (UCC) is beneficial on the vehicle kilometre reduction and the average total load capacity of the vehicles performance indicator. The UCC consolidates the goods from various shippers into one truck and delivers to their customers. This concept can decrease the number of trucks that have to access into urban area. Moreover, UCC have to consolidate the goods and loading to the truck to maximize the truck capacity. Awasthi, et al., (2011) studied on multi-criteria decision making approach for location planning of UDC under uncertainty. They proposed the important criteria to measure the benefits of UDC as follows:

- Accessibility
- Security
- Connectivity to multimodal transport
- Costs
- Environmental impact
- Proximity to customers
- Proximity to suppliers
- Resource availability
- Conformance to sustainable freight regulations
- Possibility of expansion
- Quality of service.

van Duin et al. (2012) mentioned the successful of UDC in practical because the modeling approaches do not seem to predict well with respect to the feasibility of UDCs. The main policy measures that contribute to the successful of the UDCs are toll road pricing, operational subsidies and application of time windows inside the city. Therefore, author proposes to evaluate the benefit of UDC with parking space restriction policy measures.

2.2.3.2 Parking space restriction

The parking policies play an important role in transportation systems management (Bifulco, 1993). Spiliopoulou & Antoniou, (2012) presented that the various parking policies are vital nowadays for every developed city regardless of its size. To achieve the success of the parking measures, relevant enforcement must apply to ensure the compliance to the systems. Guo, et al., (2013) studied on the quantifying the environment cost of parking search in the university. This demonstrates the potential for effective parking management strategies. It aims to promote walking and taking the university shuttle bus for midday trips on campus to result in significant environmental benefits. The parking space restriction policy is also implemented at the MSS.

The parking space restriction that is implemented in this research is priority of parking space access and disallows the freight carriers to go through the shopping street. The neutral carrier gets priory to access the provided parking lots free of charges but the freight carriers have to find the parking space outside the shopping street that are quite far from the shop owners.

The parking cost can be calculated from the distance between parking lots and location of shop owners, and service time delay cost. In this research, the location of parking lots is random. The total service time calculated from the distance of cart delivery and service time window of each shop.

2.2.4 Joint Delivery Systems (JDS)

Joint Delivery Systems (JDS) were introduced by Taniguchi Eiichi. JDS is the cooperation of the freight carriers that aim to deliver the goods in the same area or destination such as shopping center and shopping street and other logistics stakeholders to reach the city logistics intentions and avoid the traffic congestion. Lee & Fu, (2014) studied on the coordination and the production and delivery. This research demonstrated that the total operating cost reduced significantly when the synchronized policy is implemented in the network optimization process. Qu, et al., (2013) presented that the joint replenishment and delivery is useful if the heterogeneous items are transported together. From the literature, the author applies the concept of cooperating the joint decision, coordinated operation, or integrated management in this research. The example of the JDS concept is shown in Figure 2.6.

2.3 Shopping street case study

2.3.1 General

Shopping streets activities have received criticism on their environmental, urban traffic and community impacts. Besides, there is an increasing pressure on the real estate sector to develop shopping street and centers, which contribute to urban renewal or revitalization. Shopping streets, including malls, strips and town centers, are increasingly managed and branded as complete entities. The shopping centers industry is characterized by increased competition

(Sardinha, et al., 2011). The increasing shopping centers and streets cause the traffic congestion in urban areas and also impact to residents' community located around. In this research, the author used the merits and benefits of JDS concept from MSS, Yokohama as a study for city logistics measure.

2.3.2 Motomachi Shopping Street (MSS), Yokohama

The MSS is the biggest shopping street in Yokohama, Japan. The total length of this narrow street is about 500 meters. Throughout the year, the MSS association arranges many events at this area. Therefore, it is crowded by the shoppers. It is difficult for the freight carriers to find the parking spaces for loading/unloading. Likewise, these activities obstruct the shopping street and also discharge the environmental impacts. Therefore, the administrator and shopping street association allow only neutral carrier to park the trucks at the provided parking spaces. The 3 parking spaces are located at parallel street as shown in Figure 2.4.

Freight carriers who prefer to join the JDS must drop their goods at UDC that located 600 meters far from the MSS as show in Figure 2.4 to Figure 2.7. Figure 2.6 shows the process and concept of the JDS. The manufacturers assign the freight carrier delivered goods to the jointly-owned collection and delivery center or UDC. All goods are assorted and transhipped from the UDC to the neutral carrier truck. The neutral carrier trucks deliver the goods to MSS and unload at allowable parking space and carry the goods by cart or dollies to shop owners. Likewise, they pick up some goods from shop owners for the return trip. The freight carriers need to pay the UDC service charges to the neutral carrier.

The MSS is selected as the case study for this research. To recognize the interaction between logistics stakeholders with their objectives, author examines results from customer demands, delivery schedule and time window at MSS. A JDS is established along this shopping street, which encompassed the freight carriers, a neutral carrier, shop owners, residents, administrators and shopping street association. Consequently, this research aims to study the benefit of the UDC with supporting city logistics measure. It aims to study and determine the effect of stakeholder's behavior on several service charges.

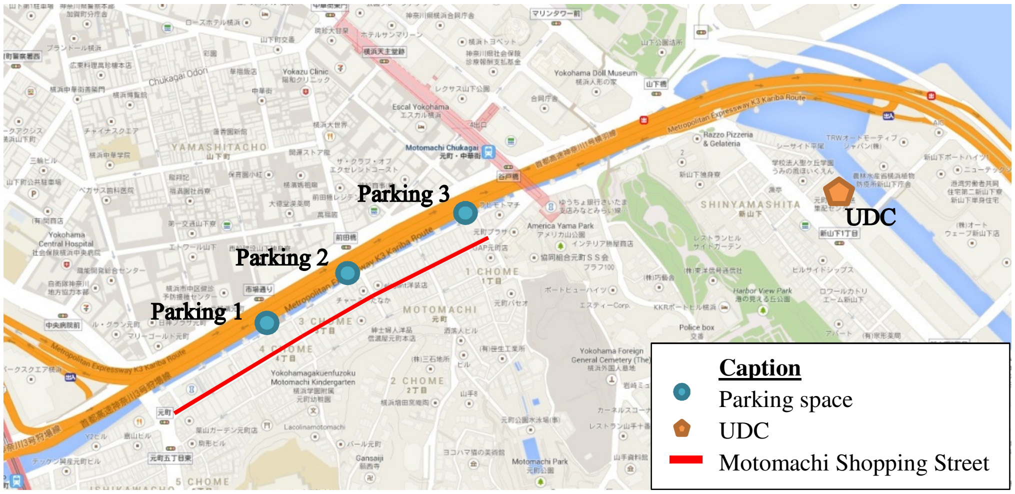


Figure 2.4 Motomachi shopping street location (*Source*: https://maps.google.com/)

Figure 2.5 Motomachi shopping street's UDC

(*Source*: https://maps.google.com/)

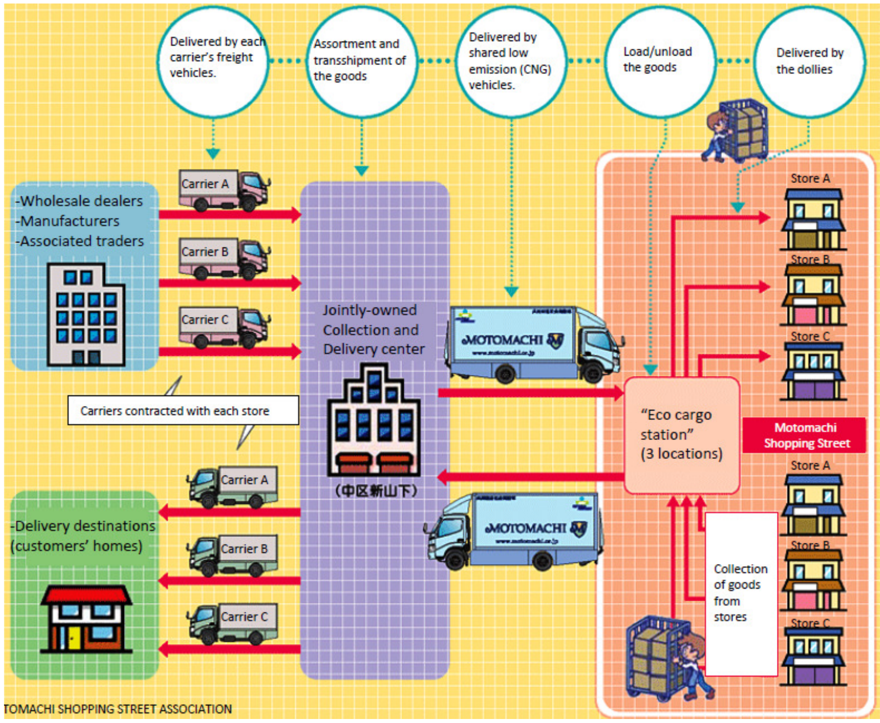
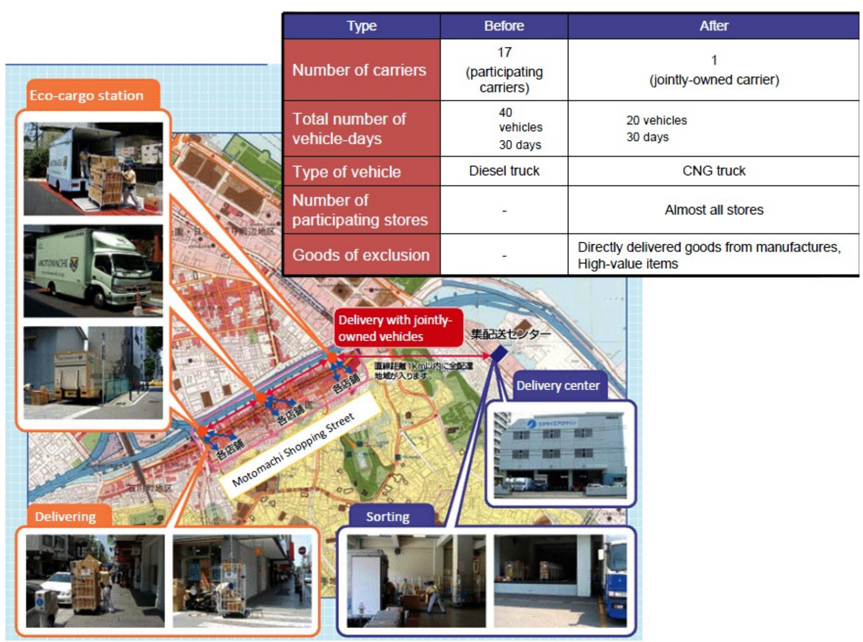


Figure 2.6 Motomachi shopping street's JDS

(*Source*: Motomachi Shopping Street, 2014)



Type	Before	After
Number of carriers	17 (participating carriers)	1 (jointly-owned carrier)
Total number of vehicle-days	40 vehicles 30 days	20 vehicles 30 days
Type of vehicle	Diesel truck	CNG truck
Number of participating stores	-	Almost all stores
Goods of exclusion	-	Directly delivered goods from manufactures, High-value items

Figure 2.7 Motomachi shopping street's map (*Source*: Motomachi Shopping Street, 2014)

2.4 Urban land use planning system

The urban land use planning systems in Japan is established by the City Planning Division and Regional Development Bureau, Ministry of Land, (2014) to support efficient urban activities, achieve a pleasant urban environment, and create townscapes with significant features. The system gives a set of rules concerning different types of land use, including residential, commercial, business and industrial use. The following described the urban land use planning systems in Japan.

2.4.1 Land use zones

- *Category I exclusively low-rise residential zone*

  This zone is designated for low rise residential buildings. The permitted buildings include residential buildings which are also used as small shops or offices and elementary/junior high school buildings.

- *Category II exclusively low-rise residential zone*

  This zone is mainly designated for low rise residential buildings. In addition to elementary/junior high school buildings, certain types of shop buildings with a floor area of up to $150m^2$ are permitted.

- *Category I mid/high-rise oriented residential zone*

  This zone is designated for medium to high residential buildings. In addition to hospital and university buildings, certain types of shop buildings with a floor area of up to $500m^2$ are permitted.

- *Category II mid/high-rise oriented residential zone*

  This zone is mainly designated for medium to high rise residential buildings. In addition to hospital and university buildings, the permitted buildings include certain shops and office buildings with a floor area of up to $1{,}500m^2$ to provide conveniences for the local community.

- *Category I residential zone*

  This zone is designated to protect the residential environment. The permitted buildings include shops, offices and hotel buildings with a floor area of up to 3,000m^2.

- *Category II residential zone*

  This zone is designated to mainly protect the residential environment. The permitted buildings include shops, offices and hotel buildings as well as buildings with karaoke box.

- *Quasi- residential zone*

  This zone is designated to allow the introduction of vehicle-related facilities along roads while protecting the residential environment in harmony with such facilities.

- *Neighbourhood commercial zone*

  This zone is designated to provide daily shopping facilities for the neighbourhood residents. In addition to residential and shop buildings, small factory buildings are permitted.

- *Commercial zone*

  Banks, cinemas, restaurants and department stores are constructed in this zone. Residential buildings and small factory buildings are also permitted.

- *Quasi- industrial zone*

  This zone is mainly occupied by light industrial facilities and service facilities. Almost all types of factories are permitted excepting those which are considered to considerably worsen the environment.

- *Industrial zone*

  Any type of factory can be built in this zone. While residential and shop buildings can be constructed, school, hospital and hotel buildings are not permitted.

- *Exclusive industrial zone*

  This zone is designated for factories. While all types of factory buildings are permitted, residential, shop, school, hospital and hotel buildings cannot be constructed.

2.5 Summary

The studies related to MAS for evaluating urban freight policy are quite limited. The literature shows that the result of its implementation is beneficial on the hypothetical test but less success in the practical projects. However, only one study considering MAS collaborate with genetic algorithm VRPTW and Q-learning decision making was found in literature. Moreover, the problem was considered only on freight carriers, administrator, residents, shipper and motorway operators. Therefore, development of MAS model representing the city logistic policies measures evaluating on JDS and parking restriction policy is a novel idea in this field. There is a strong need for logistics decision making in this sector, especially for implementing the developed model on a real road network which is described in chapter 5 of this thesis.

References

Anand, N., Quak, H., Tavasszy, L. & Tavasszy, L., 2012. City logistics modeling efforts: Trends and gaps - A review. *Procedia Social and Behavioral Sciences,* Volume 39, pp. 101-115.

Anand, N. & van Duin, J. H. R., 2010. *A SITUATED MULTI-AGENT SYSTEM FOR URBAN FREIGHT IN THE RANDSTAD.*

Awasthi, A., Chauhan, S. S. & Goyal, S. K., 2011. A multi-criteria decision making approach for location planning for urban distribution centers under uncertainty. *Mathematical and Computer Modelling,* Volume 53, pp. 98-109.

Baykasoglu, A. & Kaplanoglu, V., 2011. A multi-agent approach to load consolidation in transportation. *Advances in Engineering Software,* 42(7), pp. 477-490.

Bifulco, G. N., 1993. A stochastic user equilibrium assignment model for the evaluation of parking policies. *European Journal of Operational Research,* 71(2), pp. 269-287.

Bui, T. D., Ngo, D. H. & Tran, C., 2012. Multi-agent Based Simulation of Traffic in Vietnam. In: *Principles and Practice of Multi-Agent Systems: Lecture Notes in Computer Science.* pp. 636-648.

Durfee, E. H., Lesser, V. R. & Corkill, D. D., 1989. Trends in cooperative distributed problem solving. *IEEE Transactions on knowledge and data Engineering,* 1(1), pp. 63-83.

European Commission, 2007b. *Freight Transport Logistics Action Plan,* Brussels

Figliozzi, M., 2007. Analysis of the efficiency of urban commercial vehicle tours: Data collection, methodology, and policy implications. *Transportation Research Part B: Methodological 2007,* 41(9), pp. 1014-1032.

Garcia, A., Silva, V., Chavez, C. & Lucena, C., 2002. Engineering Multi-Agent Systems with Aspects and Patterns. *Journal of the Brazilian Computer Society,* Volume 8.

Gentile, G. & Vigo, D., 2013. Movement generation and trip distribution for freight demand modelling applied to city logistics. *European Transport,* Issue 54.

Grether, D., Kickhofer, B. & Nagel, K., 2010. Policy evaluation in mutiagent transport simulations. *Transportation Research Record: Journal of the Transportation Research Board,* Volume 2175, pp. 10-18.

Guo, L., Huang, S. & Sadek, A. W., 2013. A novel agent-based transportation model of a university campus with application to quantifying the environmental cost of parking search. *Transportation Research Part A,* Volume 50, pp. 86-104.

Hensher, D. A. & Puckett, S. M., 2005. Refocusing the modelling of freigh distribution: Development of an economic-based framework to evaluate supply chain behaviour in response to congestion charging. *Transportation,* 32(6), pp. 573-602.

Holguín-Veras, J., 2008. Necessary conditions for off-hour deliveries and the effectiveness of urban freight road pricing and alternative financial policies in competitive markets. *Transportation Research Part A: Policy and Practice 2008,* 42(2), pp. 392-413.

Jennings, N. R., 2000. On agent-based software engineering. *Artificial Intelligence,* Volume 117, pp. 277-296.

Kolck, A., 2010. *Multi-agent model for the urban distribution center: Master Thesis.* Delft University of Technology

Lee, S. D. & Fu, Y. C., 2014. Joint production and delivery lot sizing for a make-to-order producer–buyer supply chain with transportation cost. *Transportation Research Part E,* Volume 66, pp. 23-35.

Lo, S. K. C., 2012. A collaborative multi-agent message transmission mechanism in intelligent transportation system – A smart freeway example. *Information Sciences,* Volume 184, pp. 246-265.

Ministry of Land, 2014. *http : //www.mlit.go.jp/english/.*

Motomachi Shopping Street, 2014. *http://www.motomachi.or.jp.*

Muñuzuri, J., Cortés, P., Onieva, L. & Guadix, J., 2010. Modelling peak-hour urban freight movements with limited data availability. *Computers & Industrial Engineering,* Volume 59, pp. 34-44.

Nakagawa, H., Yoshioka, N., Ohsuga, A. & Honiden, S., 2010. A Framework for Validating Task Assignment in Multiagent Systems Using Requirements Importance. *Principles and Practice of Multi-Agent Systems,* pp. 443-458.

Nguyen, Q. T., Bouju, A. & Estraillier, P., 2012. Multi-agent architecture with space-time components for the simulation of urban transportation systems. *Procedia - Social and Behavioral Sciences,* Volume 54, pp. 365-374.

Quak, H. & de Koster, R., 2006. The impacts of time access restrictions and vehicle weight restrictions on food retailers and the environment. *EJTIR,* 6(2), pp. 131-150.

Qu, H., Wang, L. & Zeng, Y. R., 2013. Modeling and optimization for the joint replenishment and delivery problem with heterogeneous items. *Knowledge-Based Systems,* Volume 54, pp. 207-215.

Rieser, M., Grether, D. & Nagel, K., 2009. Addin mode choice to multiagent transport simulation. *Transportation Research Record: Journal of the Transportation Research Board,* Volume 2132, pp. 50-58.

Russell, S. & Norvig, P., 2010. *Artificial Intelligence: A Modern Approach.* 3rd ed. Upper Saddle River(New Jersey): Pearson Education.

Sardinha, I. D., Reijnders, L. & Antunes, P., 2011. Using corporate social responsibility benchmarking framework to identify and assess corporate social responsibility trends of real estate companies owning and developing shopping centres. *Journal of Cleaner Production,* Volume 19, pp. 1486-1493.

Sathaye, N., Li, Y., Horvath, A. & Madanat, S., 2006. *The Environmental Impacts of Logistics Systems and Options for Mitigation, Working Paper,* U.C. Berkeley.

Spiliopoulou, C. & Antoniou, C., 2012. Analysis of illegal parking behavior in Greece. *Procedia - Social and Behavioral Sciences,* Volume 48, pp. 1622-1631.

Tamagawa, D., Taniguchi, E. & Yamada, T., 2010. Evaluating city logistics measure using multi-agent model. *Procedia Social and Behavioral Sciences,* Volume 2, pp. 6002-6012.

Taniguchi , E. & Tamagawa, D., 2005. Evaluating city logistics measures considering the behavior of several stakeholders. *Journal of the Eastern Asia Society for Transportation Studies,* Volume 6, pp. 3062-3076.

Taniguchi, E., Thompson, R. G., Yamada, T. & van Duin, J. H. R., 2001. In: *City Logisitics: Network Modelling and Intelligent Transport Systems.,* The Netherlands: Elsevier Science Ltd.

Teo, J. S. E., Taniguchi, E. & Qureshi, A. G., 2012. Evaluating city logistics measure in e-commerce with multi-agent systems. *Procedia Social and Behavioral Sciences,* Volume 39, pp. 349-359.

UK Roundtable on Sustainable Development, 1996. *Defining a Sustainable Transport Sector, UK Roundtable on Sustainable Development.*

van Duin, J. H. R., 2006. Chaos in urban freight policies? A comparison between Dutch cities.

van Duin, J. H. R. & Quak, H., 2007. City logistics: a chaos between research and policy making? A review. *Urban Transport XIII-Urban Transport and the Environment in the 21st Century,* pp. 136-146.

van Duin, J. H. R., Quak, H. & Muñuzuri, J., 2010. New challenges for urban consolidation centres: A case study in The Hague. *Procedia Social and Behavioral Sciences,* Volume 2, pp. 6177-6188.

van Duin, J. H. R., van Kolck, A., Anand, N. & Tavasszy, L. A., 2012. Towards an agent-based modelling approach for the evaluation of dynamic usage of urban distribution centres. *Procedia - Social and Behavioral Sciences,* Volume 39, pp. 333-348.

Visser, J., van Binsbergen, A. & Nemoto, T., 1999. Urban freight transport policy and planning. *First International Symposium on City Logistics.*

Zambonelli, F., Jennings, N. R. & Wooldridge, M., 2003. Developing multiagent systems: The Gaia methodology. *ACMTransactions on Software Engineering and Methodology,* 12(3), pp. 317-370.

3

MODELING

3.1 General

A model, in the context of this chapter, can be descripted as a tool which may include a system of mathematical relationships that helps to explain the city logistics systems, study the effects that different components have on the systems, and make predictions about how freight movement will change when the system changes. With freight movement changes, we inclusively mean the changes in behavior of the various stakeholders, vehicle movement, commodity movement, infrastructure and related information. Models remain mere abstractions of reality itself. If models are to be useful in influencing decisions, they ought to be valid. This chapter considers the recent advances in city logistics modeling that resulted in models that are more valid. That is, model that are, a) better representations of reality in that they replicate what researcher observe and experience; and, b) are able to support improved decision-making. In other words, it may reveal unintended consequences that would otherwise have been missed.

A key challenge in city logistics modeling is that many modeling that are good representation of reality are not only complex, but also very complicated, resulting in decision-making avoiding them. Rather, the true challenge is to develop models that are simultaneously more scientifically valid and intuitive.

The chapter is structured as follow. It then considers the recent advances in agent-based modeling where city logistics stakeholders are represented as autonomous decision-making agents, opening a number of valuable opportunities in disaggregate models.

The understanding of freight movement and the associated behavior of freight stakeholders lag that of passenger travel. One reason is the increasing of complexity and diversity of products, and the behavior of the various stakeholders. When modeling city logistics, it challenges to address and represent the diversity of stakeholders, each acting autonomously pursing their individual and often completing objectives (Joubert, 2014).

3.2 Multi-Agent Systems modeling (MAS)

3.2.1 General

Multi-agent modeling techniques allow to be used in complicated urban freight transport systems with multiple actors to be investigated (Weiss, 1991; Wooldridge, 2009). Multi-agent models generally deal with the behavior and interaction among multiple agents, which are most suitable to understand and study the behavior of stakeholders in urban freight transport systems as well as their response to policy measures. Davidsson, et al., (2005) provided the survey of existing research on agent-based approaches in freight transport and note that agent-based approaches seem very suitable for this domain. van Duin, et al., (2012) presented a dynamic actor network analysis tool for investigating complex logistics problems. Ossowski, et al., (2005) described multi-agent approaches to provide decision support systems for traffic management. Jiao, et al., (2006) presented an agent based framework in a global manufacturing supply chain network. The literature shows number of interesting examples of multi-agent approaches to transport logistics problems while not directly focusing on urban freight transport systems.

Multi-agent models contain multiple and interacting agents, who take action for solving their own problems within the model. This chapter incorporates multi-agent learning models which assume that an agent pursues its own learning goal using their knowledge and communication with other agents. The important feature of multi-agent model is that more emphasis is put on the ability, characteristics and function of individual agents rather than system optimization. An agent in multi-agent models is an autonomous agent who can perceive the environment and make their own decision to act for satisfying their needs and attaining their objectives. These agents can communicate with each other and the interaction amongst agents is most interesting to observe during the simulation. Multi-agent learning model assumes that each agent take actions based on the reinforcement learning to maximize its action-value function (Sutton & Barto, 1998). It is interesting to examine the effects arise with other agent's actions through the interactions between agents.

Taniguchi et al., (2007) assumed three types of agents in the multi-agent models adopted in their paper; (a) freight carriers, (b) shippers and (c) administrators. The multi-agent models herewith allow communication between different agents such as shipper to freight carrier, freight carrier to administrator and administrator to shipper, but does not allow communication between same agent such as freight carrier to freight carrier, shipper to shipper and administrator to administrator. Each agent takes action to maximize its action-value function and does not consider collaboration among agents. Figure 3.1 shows the interaction among three agents.

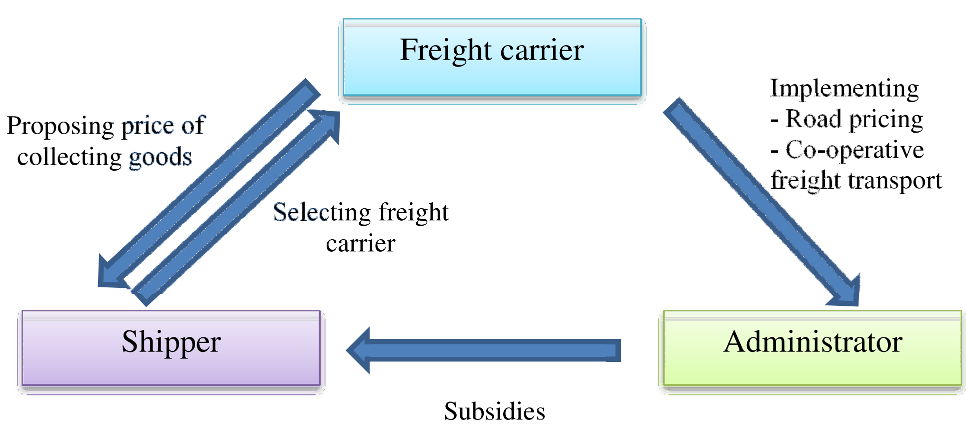


Figure 3.1 Interaction and actions of three agents (*Source*: Taniguchi et al., 2007)

Agents in this study are assumed to have a reinforcement learning mechanism. Very often learning agents with reinforcement learning are assumed in multi-agent modeling. Reinforcement learning is learning without supervision, where agents try to maximize (or minimize) their expected value which is feedback from an agent's action base on policy. Distributed learning is also adopted in modeling, which means each agent learns independently. Each agent needs to update their expected value after receiving feedback from action and iterations will go on. Taniguchi, et al., (2007) indicated that after implementing Multi-agent model on a large test road network, an introduction of the VRPTW-D (Vehicle Routing and Scheduling Problem with Time Window–Dynamic) (Taniguchi & Shimamoto, 2004) model generated a win-win situation by increasing profits for freight carriers and decreasing the cost for shippers. The result also shows that by implementing road pricing, NO_x emissions reduce but the cost for shippers may increase. To avoid such effects, cooperative freight transport systems must be introduced to help shippers reduce their costs.

Taniguchi & Tamagawa, (2006) modeled the behavior of numerous stakeholders including freight carriers, shippers, residents, administrators and toll road operators by stakeholder. The behavior of freight carriers and costs incurred for each stakeholder was simulated over time for variety of city logistics schemes.

An agent based micro-simulation framework for modeling commercial vehicle movements in Calgary using tour based approach was presented by (Stefan, et al., 2005). The model used Monte Carlo techniques to assign tour propose, vehicle type, next stop purpose, next stop location and next stop duration to grow tours (Taniguchi, et al., 2008).

3.2.2 Stakeholders perspectives

The different perspective of logistics stakeholders in regional shopping street should be integrated in city logistics. Each stakeholder has their own specific objectives and needs tends to behave in different manners. According to Taniguchi, et al., (2008), the significant stakeholders considered in this research are;

1. *Freight carriers*

The freight carriers service delivery goods to shop owners and residents. The objectives of freight carrier are to minimize the delivery cost while also expected to provide a high level of service. In this research, freight carriers were not allowed to park their truck in an area of shopping street. To deliver goods with low cost, freight carriers have to make a decision by go directly or decided to join the JDS that will assign the neutral carrier as a deputy to deliver goods to their customers (both of shop owners and residents).

2. *Neutral carrier*

Neutral carrier is representative of UDC service provider. Neutral carrier is required to consolidate the parcel of goods from freight carriers. Besides, neutral carrier aims to maximize the profit of delivery goods without delay. In this research, Neutral carrier gets the permission and priority from administrator to park their truck at specific parking lots inside the shopping street area. The neutral carrier gets paid by transporting goods charge from freight carriers and shop owners in case of residents asking home delivery from them.

3. *Shop owners*

Shop owners here mean the retailers. They have to decide to participate with the JDS in case of their delivery costs and service is inferior to freight carriers.

4. *Administrator*

The different policy measures are implemented by local government or municipality in attempt to minimize the negative impacts. Administrator attempts to enhance the economic development of city and interests in the reduction of congestion and environmental nuisances as well as in increasing safety of road traffic. They consider the urban transportation systems as a whole to resolve conflicts between the other stakeholders (Taniguchi, et al., 2001). In this research, the truck emissions discharge in the city and the complaints from residents are used as the main consideration in MAS model.

5. *Residents*

Residents or customers are individuals who live in neighbourhood area of shopping streets. Residents will express their discontent if the truck emissions exceeds some threshold level and will complain to administrator.

6. *Shopping Street Association (SSA)*

SSA is a representative of shopping street manager. SSA has to encourage and support other stakeholders to participate the JDS. SSA is enhanced to improve traffic congestion and environmental impacts to be sustainable shopping street.

3.2.3 Behavior perspectives

Behavior analysis attempts to understand, describe and predict the behavior under different situations. Behavioral models consider complexities of attribute and decision making ability of various stakeholders which cannot be captured in traditional four-step approach with the aggregate nature of the data. Urban freight transportation modeling lacks appropriate behavioral approach towards modeling related processes (Regan & Garrido, 2001). Planning or policy assessed under such circumstances does not guarantee anticipated results. Similar view is expressed by Tavasszy & Smeenk, (1998), Liedtke & Schepperle, (2004), de Jong & Ben-Akiva , (2007), Roorda, et al., (2010), Samimi, et al., (2009). In city logistics modeling, behavioral aspect of shipper is considered by Young, et al., (1983) in Elimination-by-Aspects mode choice model for regional freight mode choice. The Good Trip model by Boerkamps, et al., (2000) includes behavioral aspects of administrator, supplier, carrier and receiver to analyze urban freight systems. This model aims to help decision maker to assess new distribution systems and the impacts of changes in the freight distribution environment on infrastructure needs and usage, logistical performance, emissions, and energy use for planning and evaluation of freight distribution. The Tokyo model by Wisetjinda, et al., (2007) follows similar framework. Other models rich in behavioral context are Holguin-Veras, et al., (2007), Taniguchi & Tamagawa, (2005), Russo & Comi, (2010) and Anand, et al., (2012).

In the multi-agent model used in this research, the summary of stakeholder's objectives of the decision making agents are as follows;

Freight Carriers

Objective: Minimize operation cost.
(eg. Less truck used and distance travelled etc.)

⬇

Behavior: Propose the fee for transporting goods to shop owners and residents.

Neutral carriers

Objective: Maximize the profit of delivery goods.

⬇

Behavior: Propose the fee for transporting goods to freight carriers and delivery goods to shop owners without delay.

In this research, the fixed behaviour agents were also considered representing their objectives, indirectly. The indirect stakeholder's objectives are as follow;

Shop Owners

Objective: Minimum delivery cost.

⬇

Behavior: Their behaviour is affected from the freight carrier's operation cost. Therefore, it is indirectly represented by optimal solution cost of the carrier.

Administrator

Objective: Minimum environmental emissions

⬇

Behavior: Fixed behaviour is considered indirectly as environmental emissions (NOx) is considered in the evaluations. Also it is considered that they provide parking spaces and regulations to improve the environment.

Residents

Objective: Minimum emissions by trucks and minimum number of truck in their area.

⬇

Behavior: Their behaviour is indirectly modeled from the freight carrier's optimization process which seeks for minimum number of vehicles and also when they intended to join the joint delivery systems.

Shopping Street Association (SSA)

Objective: Enhanced shopping street environment and less frequent deliveries.

⬇

Behavior: Their behaviour is modelled by the UDC participation of the freight carrier.

Urban Distribution Center or Urban Consolidation Center Benefits/Costs

The benefits or costs of logistics stakeholders when UDC were implemented are as follow;

Benefits	Costs
1. Freight carrier	
• More delivery per day • Opportunity for night delivery • Avoid slow traffic in downtown • Avoid parking problem	• Security • Loss of control on delayed deliveries • Perceived damage due to extra handling
2. Shop owner/ Resident/ Customer	
• Improved delivery reliability • Fewer (consolidated) delivery • Just in Time deliveries (less inventory requirement) • More selling space • Better shopping environment • Possible reverse logistics • Off-site value added activities • Direct delivery to customers from UDC	• Additional step in tracking late delivery • Degraded environment/ congestion/ safety
3. Administrator	
• Less congestion • Less emissions • Pedestrian benefit • Attraction to tourism	• Monitoring of freight movement
4. UDC operator	
• Profit making business	• Pressure of timed deliveries • Responsibility for identifying loss/damage of inbound goods • Paper work

3.2.4 Behavioral decision making models

The MAS model for evaluating the JDS requires the identification of stakeholders, which include the logistics communities or logistics associations. Stakeholders are individuals, who belong to various identified "communities" and whose lives or businesses are affected by particular policies. Similarly, the policies may also affect the environment and transportation costs, which may ultimately affect the end consumers. The stakeholders identified in a JDS include the freight carriers, a neutral carrier, shop owners, residents, administrators and logistics association that consolidate goods from various freight carriers and load it onto a neutral carrier to dispatch to shop owners by considering operation cost, truck assignment and time window. The urban freight logistics experts have emphasized the importance of engagement of the stakeholders in terms of greater Urban Distribution Center (UDC) usage, environmental issues as well as the potential of the JDS. The MAS model framework consists of the vehicle routing problem with soft time window (VRPSTW) (Qureshi, 2008) and the behavioral interaction among stakeholders with reinforcement learning model. The interaction among the stakeholders can be described with the MAS interaction model as shown in Figure 3.2. Figure 3.2 shows a modified MAS model framework with vehicle routing and scheduling problem with time windows from Tamagawa, et al., (2010), which consists of two sub-models; one is the learning model for stakeholders, and the other is the model for vehicle routing and scheduling problem with soft time window (VRPSTW). The learning model evaluates the behavior of stakeholders, learns and selects the behavior with their associated objective value. The purpose of VRPSTW in the MAS model is to plan and implement delivery schedules of trucks for each freight carrier and neutral carrier. These two models are executed sequentially.

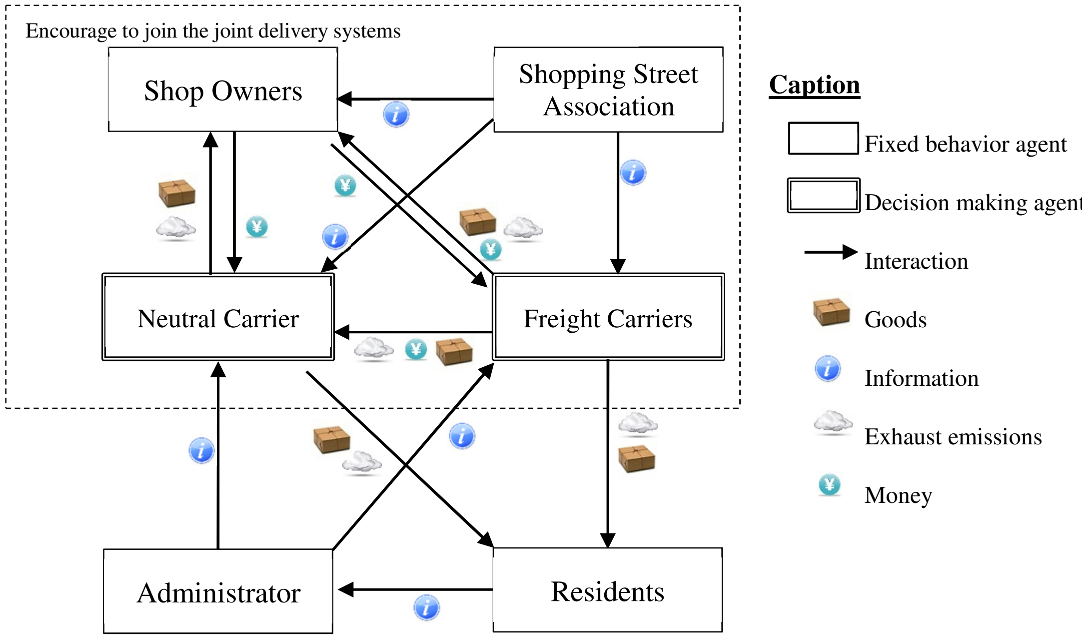


Figure 3.2 Shopping street stakeholders' interaction within the MAS model

The rational model of decision making where goals, objectives and criteria are defined and a thorough evaluation of alternatives is assumed does not seem to represent the actual decision making process used within many organizations. The rational model is highly structured and data intensive decision making process. There is a need to develop urban freight models that incorporate satisficing, incremental, organizational and political bargaining decision making process (Meyer & Miller, 1984).

The satisficing model involves sequential examination of alternatives against a set of minimally acceptable levels, where the first alternative found with acceptable levels for attributes is selected. This is a non-optimal, search process where the order of alternatives examined is important.

Within organizations decisions are often made on basis of marginal differences in their consequences. A small number of alternatives that differ marginally from the status quo are only considered. The incremental model is conservative but is common in remedial and reactionary environments.

The organizational process model recognizes that decisions are outputs from organizations with distinct cultures. Values and goals determine perspectives and a culture that manifests itself as operating procedures.

The political bargaining model recognizes that there are many players in the decision making process. Groups within organisations can have diverse and conflicting goals. Here, the need for bargaining and compromises arises.

There is a need to identify and describe the decision support systems used by organisations in their evaluation processes. This includes how contemporary management principles such as triple bottom line, corporate social responsibility and total quality management are incorporated in organizations involved in urban freight.

Multi-criteria decision making techniques provide a tool for incorporating a range of factors (quantitative and qualitative) into the evaluation process. The Analytical Hierarchy Process (AHP) has been used to aid management decisions relating to supplier selection incorporating a range of criteria (Choi & Hartley, 1996), (Ghodsypour & O'Brien, 1998) and (Lee, et al., 2003). The AHP also provides a method for estimating the relative importance of factors. A decision support system was developed to aid project selection of urban freight projects for a road authority based on determining a set of goals, objectives and criteria (Thompson & Hassall, 2006).

Russo & Carteni, (2006) developed a tour based model that simulates the dependencies between successive trips of the same distribution channel. Random utility models (e.g. nested logit) were used to represent the hierarchical structure that considers many choices between procurement and sale. This allows the decision making process of several actors, including, retailers, manufacturers, suppliers, shippers and carriers to be modelled considering a range of choices relating to the market, timing, load unit and freight services.

Hensher & Puckett, (2005) present a framework to investigate how agents in retail supply chains may be able to interact more efficiently. An interactive agency choice method allowed the preferences of participants in the supply chain to support congestion charging policy initiatives to be investigated.

Holguin-Veras, (2000) developed a discrete-continuous choice model to understand the factors influencing the choice of vehicle type and shipment size as joints decisions of shippers and freight transport companies. A two steps process involving the estimation of multi-nomial logit models and heteroscedastic extreme value models was used to estimate key variables.

Holguin-Veras, et al., (2006a) presented analysis of the effectiveness of policies for encouraging freight to avoid peak periods in Manhattan considering the receivers and carriers using game theory. Stated preference techniques were used to investigate the effects of financial incentives and segment the market according to the type of goods being delivered. Discrete choice models are including logit and mixed-logit model were used to investigate a number financial policy incentives for carriers to switch to off-peak deliveries Holguin-Veras, et al., (2006b) and Holguin-Veras, et al., (2006c).

3.3 Vehicle routing problem with time window (VRPTW)

The VRP with Time Windows (VRPTW) is the extension of the CVRP in which capacity constraints are imposed and each customer i is associated with a time interval $[a_i, b_i]$, called a time window (Toth & Vigo, 2002). The time instant in which the vehicles leave the depot, the travel time, t_{ij} , for each arc $(i, j) \in A$ and an additional service time s_i for each customer i are also given. The service of each customer must start within the associated time window, and the vehicle must stop at the customer location for s_i time instants. Moreover, in case of early arrival at the location of customer i, the vehicle generally is allowed to wait until time instant a_i , i.e., until the service may start.

Normally, the cost and travel-time matrices coincide, and the time windows are defined by assuming that all vehicles leave the depot at time instant 0. Moreover, observe that the time window requirements induce an implicit orientation of each route even if the original matrices are symmetric. Therefore, VRPTW normally is modeled as an asymmetric problem.

VRPTW consists of finding a collection of exactly K simple circuits with minimum cost, and such that;

i. each circuit visits the depot vertex;
ii. each customer vertex is visited by exactly one circuit;
iii. the sum of the demands of the vertices visited by a circuit does not exceed the vehicle capacity, q; and
iv. for each customer i, the service starts within the time window, $[a_i, b_i]$, and the vehicle stops for s_i time instants.

VRPTW is NP-hard in the strong sense, since it generalizes the CVRP, arising when $a_i = 0$, $b_i = +\infty$, for each $i \in V \setminus \{0\}$. Moreover, the so-called TSP with Time Windows (TSPTW) is the special case of VRPTW in which $q \geq d(V)$ and $K = 1$.

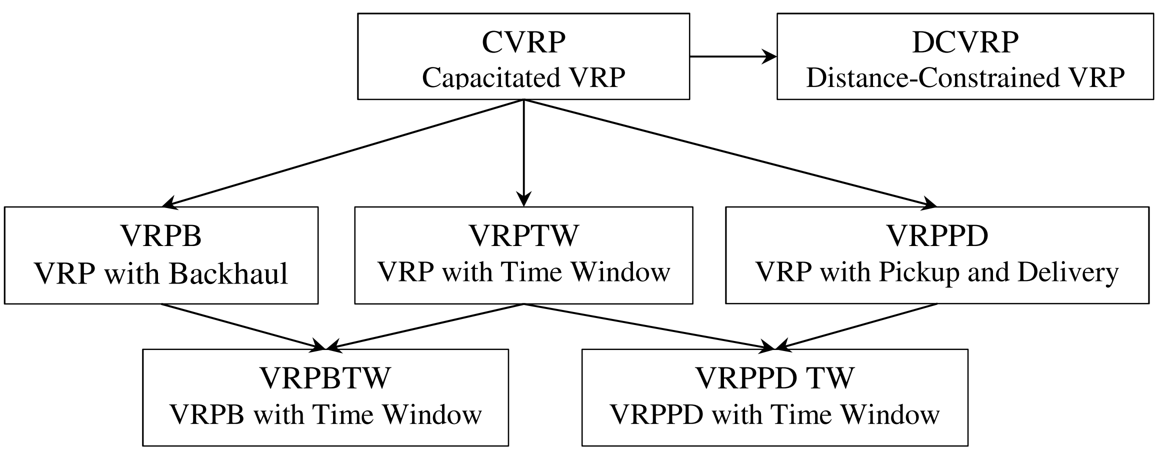
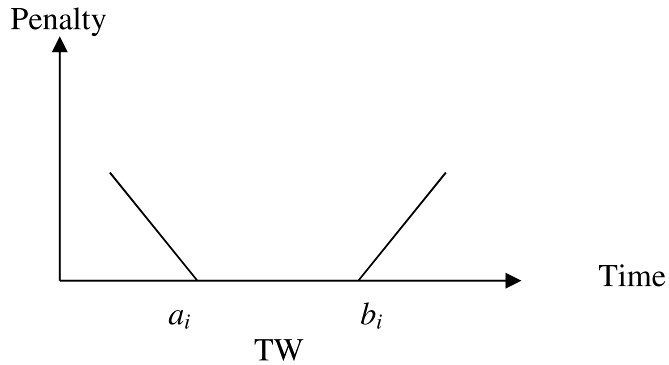


Figure 3.3 The basic problems of VRP class and interconnections (*Source:* Toth & Vigo, 2002)

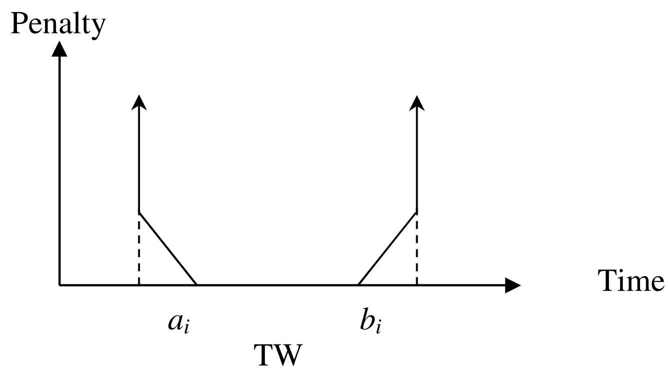
Two typical types of soft time window definitions, which have been used by some researchers, are given in Figure 3.4. In Figure 3.4 a), it deal with the VRPSTW in which no waiting is permitted either it is early arrival or timely arrival or late arrival, thus the vehicle needs to start service immediately once it arrives at customer location, and to leave immediately once the service is completed (Lu & Yu, 2012) and (Tas, et al., 2013). In addition to Figure 3.4 a), some related works such as Calvete, et al., (2007), Chiang & Russell, (2004), Figliozzi, (2010), and Ioannou, et al., (2003) have given the maximum allowable violations of hard time windows, which were based on assumptions, as illustrated in Figure 3.4 b).

The work of Liberatore, et al., (2011) followed the soft time windows as in Figure 3.4 a), but the authors in turn allowed all vehicles to wait without penalty at any time over the routes. While the work of Xu, et al., (2011) also described the soft time windows as in Figure 3.4 b), but the authors considered the satisfaction level of customer instead of penalty cost. Indeed, level of customer satisfaction goes down when the service is given beyond customer's hard time window. Figure 3.5 illustrates the soft time windows of Xu, et al., (2011).

VRPTW model plans and implements delivery routing and schedules of trucks for each freight carrier. This research includes the study of delivery activities to the shop owners at shopping streets by planning and implementing delivery routing and schedules of trucks for neutral carrier (UDC truck operation). Likewise, this research seeks to modify the MAS model framework for vehicle routing and scheduling problem with time window-forecasted (VRPTW-F) (Tamagawa, et al., 2010) as shown in Figure 3.6.



a) Without maximum allowable violations



b) With maximum allowable violations

Figure 3.4 Typical soft time window settings

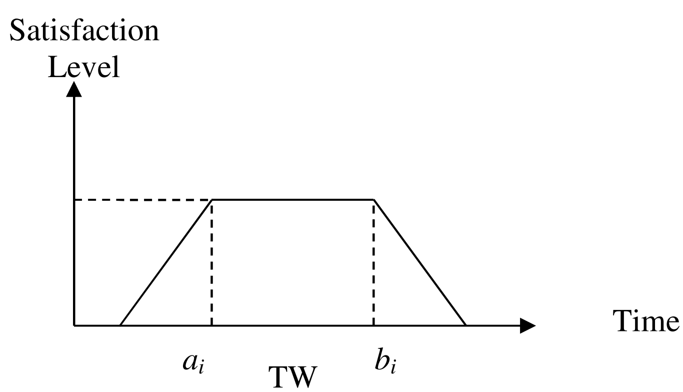


Figure 3.5 Satisfaction levels of Xu, et al., (2011)

To determine the optimal solution by minimizing the total transport cost of freight carriers and neutral carrier, this research has applied the vehicle routing and scheduling problem with soft time windows (VRPSTW) model by Qureshi, (2008) to study the delivery and pickup goods activities.

The model can be formulated as follows:

$$\min \sum_{k \in K} \sum_{(i,j) \in A} c'_{ij} x_{ijk} \tag{3.1}$$

subject to

$$\sum_{k \in K} \sum_{j \in V} x_{ijk} = 1 \qquad \forall i \in C \tag{3.2}$$

$$\sum_{i \in C} d_i \sum_{j \in V} x_{ijk} \leq q \qquad \forall k \in K \tag{3.3}$$

$$\sum_{j \in V} x_{0jk} = 1 \qquad \forall k \in K \tag{3.4}$$

$$\sum_{i \in V} x_{ihk} - \sum_{j \in V} x_{hjk} = 0 \qquad \forall h \in C, \forall k \in K \tag{3.5}$$

$$\sum_{i \in V} x_{i0k} = 1 \qquad \forall k \in K \tag{3.6}$$

$$a'_i \leq s'_{ik} \leq b'_i \qquad \forall i \in V, \forall k \in K \tag{3.7}$$

$$a_i \leq s_{ik} \leq b'_i \qquad \forall i \in V, \forall k \in K \tag{3.8}$$

$$s_{ik} + t_{ij} - s_{jk} \leq (1 - x_{ijk}) M_{ijk} \qquad \forall (i,j) \in A, \forall k \in K \tag{3.9}$$

$$x_{ijk} \in \{0,1\} \qquad (i,j) \in A, \forall k \in K \tag{3.10}$$

The two decision variables in the VRPSTW are the service start time, s_{jk} of truck $k \in K$ at vertex $j \in C$, that will determine the arrival time at vertex $j \in C$ and travel cost of arc (i, j), and x_{ijk}, where $x_{ijk} = 0$ when arc (i, j) is used and $x_{ijk} = 1$ when arc (i, j) is not used in the solution. The objective function equation (3.1) minimizes the sum of delivery costs that consist of the fixed vehicle utilization cost, travel cost on arcs and the penalty costs. Constraint equation (3.2) ensures that each customer is serviced only once and constraint equation (3.3) makes sure that the load carried by the vehicle is within the limit of the vehicle's capacity. Constraints equation (3.4) and (3.6) determine that the vehicle shall start and end at the depot while constraint equation (3.5) ensures that the vehicle entering vector h must also leave from vector h. Constraint equation (3.7) restricts the arrival time to be within the relaxed time window of a_i' and b_i' and constraint equation (3.8) ensures that the service start time is within a_i and b_i'. Constraint equation (3.9) shows that if a vehicle travels from i to j, the service at vector j can only start after service at vector i is completed. The last constraint, equation (3.10) is the integrality constraint, which completes the model formulation.

The problem described here is a NP-hard (Non-deterministic Polynomial-hard) combinatorial optimization problem. Thus, some heuristic genetic algorithms are required to provide good and fast solutions for MAS model. The model described here uses heuristics genetic algorithm to solve the VRPSTW.

3.4 Parking cost

The location parking lots around the shopping street is randomly. The distance is between 500 to 1,000 meters. The parking rate is 300 yen per 30 minutes. The walking time is equal to time requiring for carrying goods by cart from parking space to the shop owners. The average speed is 5 kilometer per hour. The parking cost can be calculated from this follow equation;

$$r_k = \sum_{i \in C_s} (p_i + w_i) \qquad \forall k \in K \qquad (3.11)$$

where;

r_k is the additional parking and walking cost for a vehicle k that serves a customer in the shopping street.

p_i is the additional parking cost for a customer in the shopping street, given by the randomly generated parking time multiplied by the unit parking cost.

w_i is the additional walking time cost for a customer in the shopping street, given by the randomly generated distance between shopping street and the parking lot location multiplied by the unit walking time cost.

C_s is set of all customers belonging to shopping street.

3.5 Reinforcement learning

In reinforcement learning (RL), an autonomous agent learns an optimal policy π :→ A, that outputs an appropriate action $a \in A$, given the current state $s \in S$, where A is the set of all possible actions in a state and S is the set of states. The available information to the agent is the sequence of immediate rewards $\gamma(s_i, a_i)$ for all the possible actions and states i = 0; 1; 2;… Given this kind of training information, it is possible to learn a numerical evaluation function defined over state-action pairs (Q(s,a)), and then implement the optimal policy in terms of this evaluation function.

One of the most important breakthroughs in RL was the development of the temporal difference algorithm known as Q-learning (Watkins, 1989). Q-learning evaluation functions updating equation, is defined by:

$$Q(s,a) \leftarrow Q(s,a) + \alpha\,[r + \gamma\, max\, a' Q(s',a') - Q(s,a)] \qquad (3.12)$$

where, Q(s,a) is the action value function of taking action a in state s, Q(s',a') is the state-action value function in the resulting state (s') after taking action a, α is the step-size parameter [0,1], r is the reward, and γ is a discount rate. The state-action value function is updated using information from the current value, the associated reward, and the best next action value function. Q-Learning and other RL algorithms have been reported in the literature for multiple agent settings, e.g., (Craig, 1999), (Michael, 1994) and (Ming, 1993), among others. However, such work is focused on the selection of rules for the coordination of actions between agents. In the following section, a simple approach for the coordination of agents to perform a common goal, called DQL, is described.

3.5.1 Q-learning

Q-learning is a reinforcement learning technique that works by learning an action-value function that gives the expected utility of taking a given action in a given state and following a fixed policy thereafter. One of the strengths of Q-learning is that it is able to compare the expected utility of the available actions without requiring a model of the environment. A recent variation called delayed Q-learning has shown significant improvements, bringing probably approximately correct learning (PAC) bounds to Markov decision processes (Alexander, et al., 2006). A typical learning algorithm for the freight carriers and neutral carrier or UDC operator can be represented by equation (3.13) to (3.14).

The freight carrier learning model is

$$Q(s_t, a_t) \leftarrow (1-\alpha)Q(s_t, a_t) + \alpha\left[r_{s_t,a_t} + \gamma\, min\, Q(s_{t+1}, a_{t+1})\right] \quad (3.13)$$

where ,

$Q(s_t, a_t)\mathrm{Q}(\mathrm{s_t}, \mathrm{a_t})$: Q-value in state *t* due to action in state *t*.

$Q(s_{t+1}, a_{t+1})\mathrm{Q}(\mathrm{s_{t+1}}, \mathrm{a_{t+1}})$: Q-value in state *t+1* of all actions

γ : discount rate for agent (0 < γ < 1)

α : learning rate for agent (0 < α < 1)

r_{s_t,a_t} : $\begin{cases} UDC\ fee * No.of\ parcel; if\ a_t\ join\ JDS\ in\ s_t \\ VRPSTW\ cost + Parking\ cost; if\ \ a_t\ does\ not\ join\ JDS\ in\ s_t \end{cases}$

r_{s_t,a_t} : is transportation cost and unexpected additional costs such as parking costs at the shopping street.

Furthermore, the pressure of truck drivers from finding the parking lots might interest to consider in this research.

The neutral carrier learning model is

$$Q(s_t, a_t) \leftarrow (1-\beta)Q(s_t, a_t) + \beta\left[p_{s_t,a_t} + \gamma\, min\, Q(s_{t+1}, a_{t+1})\right] \quad (3.14)$$

where ,

$Q(s_t, a_t)Q(s_t, a_t)$: Q-value in state *t* due to action in state *t*.

$Q(s_{t+1}, a_{t+1})Q(s_{t+1}, a_{t+1})$: Q-value in state *t+1* of all actions

γ : discount rate for agent ($0 < \gamma < 1$)

β : learning rate for agent ($0 < \beta < 1$)

p_{s_t, a_t} : is profit of the UDC that come from the revenue of the service charge from freight carrier after deduction of the operating cost from the UDC to the customers.

The learning rate of 1 means that the agent will consider the most current information while 0 means agent does not learn. Discount rate set at 1 means that the agents will consider the long term reward while 0 means that the agents concerns only on the current rewards.

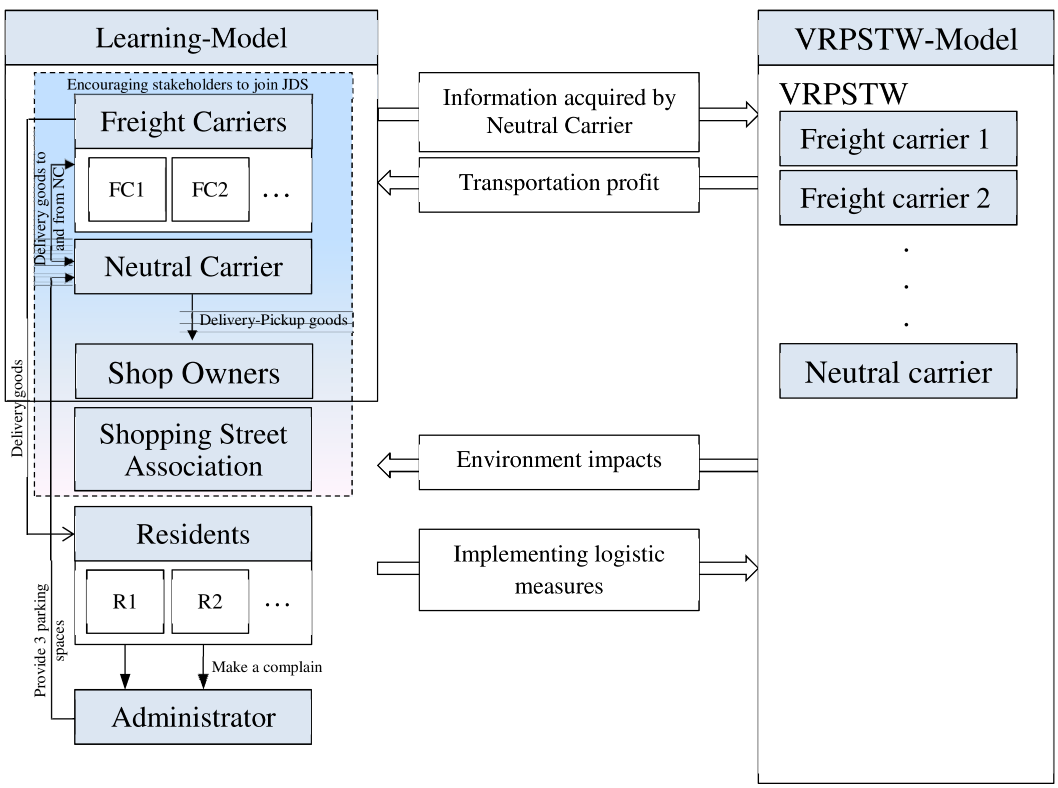


Figure 3.6 Proposed MAS model framework with vehicle routing and scheduling problem with time window (modified from Tamagawa, et al., 2010)

3.6 Environmental truck emissions

Truck emissions are considered as the negative effect of city logistic scheme to evaluate the benefit of using UDC which aspect to be used the JDS and parking management as the policy measures. The oxides of nitrogen (NO_x), carbon di-oxide (CO_2) and suspended particulate material (SPM) equations are used to estimate the truck emissions.

The oxides of nitrogen (NO_x), carbon di-oxide (CO_2) emissions and suspended particulate material (SPM) are estimated using equation (3.15), equation (3.16) and equation (3.17) respectively (NILIM, 2003) assuming delivery truck vehicles use diesel fuel.

$$NO_x = l_{ij}\left(1.06116 + 0.000213v_{ij}^2 - 0.0246v_{ij} + \frac{16.258}{v_{ij}}\right) \quad (3.15)$$

$$CO_2 = l_{ij}\left(278.448 + 0.048059v_{ij}^2 - 5.1227v_{ij} + \frac{2347.1}{v_{ij}}\right) \quad (3.16)$$

$$SPM = l_{ij}\left(0.03442 + 0.000039391v_{ij}^2 + 0.0036777v_{ij} + \frac{1.2754}{v_{ij}}\right) \quad (3.17)$$

where,

NO_x : expected nitrogen oxide emissions in grams

CO_2 : expected carbon oxide emissions in grams

SPM : expected suspended particulate matter in grams

l_{ij} : length of road link between nodes *i* and *j* in kilometres

v_{ij} : speed of vehicle travelling on road link between nodes *i* and *j in kilometres per hour*

3.7 Summary

Table 3.1 is the recommended checklist that this research is using to evaluate the stakeholder behavior when implemented the city logistics policy measures. Table 3.2 show the briefly of research work using MAS approach related to evaluating of city logistics policy for urban freight transport. This research aims to contribute further to the list of work done previously as described in the following chapters.

Table 3.1 Checklist for modeling agent based systems (Modified from Teo, et al., 2012)

No.	Information regarding agent-based systems modeling
1	Describe the purpose of application and intended users.
2	Indicate the size of the simulated systems including number of agents.
3	Describe the characteristics of each agent type in the model.
4	Describe whether the agents are static or if they can be added or removed.
5	State which software or programming language was used.
6	Describe how the agents were implemented.
7	Indicate if the model was used by user or for laboratory experiment. State if real data or hypothetical data were use in case of laboratory.
8	Describe the validity with the real network.

Table 3.2 MAS model for evaluating city logistics schemes (Modified from Teo, et al., 2012)

	Purpose of application and intended users	Type of schemes tested	Type of agents	Programming language, models of software used	Validity model
(Taniguchi, et al., 2007)	*Administrators*- Evaluation of city logistics measures *Carriers*– Comparison of VRPTW-Dynamic and VRPTW-Forecasted models	- Road pricing - Subsidies to shippers for choosing environment friendly carriers - Implement cooperative freight transport systems	- Administrators - Shippers - Carriers	- VRPTW-D and VRPTW-F models with genetic algorithm - Monte Carlo learning model	Non-cooperative game theory for 2-player game.
(Davidsson, et al., 2008)	*Administrators*- Investigate impact of governmental controls on different stakeholders	- Fuel taxes - Road tolls - Vehicle taxes	- Shippers - Carriers - Customers	- 2 layered Transport and Production Agent-based Simulator (TAPAS) - Economic order quantity (EOQ) - Shortest path problem - JAVA 1.4 - JADE	- Interview with expert in policy issues and transportation and logistics. - Comparison with similar studies.

	Purpose of application and intended users	Type of schemes tested	Type of agents	Programming language, models of software used	Validity model
(Tamagawa, et al., 2010)	*Administrators*- Evaluation of city logistics measures *Motorway operators*- Evaluating impact of discounts to toll fee.	- Road pricing - Truck ban - Discounted toll fee	- Administrators - Shippers - Carriers - Residents - Motorway operators	- VRPTW-F model with GA - Monte Carlo learning model - Q-learning model - Fortan	- Comparison of Monte Carlo learning model and Q-learning model
(Kolck, 2010)	*UDC operators* - Evaluating the impact of dynamic usage fee, congestion rate, toll setting, subsidy and UDC delivery scheme	- Dynamic usage of Urban Distribution Center (UDC)	- Carriers - UDC - Trucks - Retailers - Roads	- VRPTW-F model with GA - Netlogo	- Future research plans

	Purpose of application and intended users	Type of schemes tested	Type of agents	Programming language, models of software used	Validity model
(Baykasoglu & Kaplanoglu, 2011)	*Consolidation center*- Proposed approach the load consolidation decisions for the less-than-truckload orders	- Load consolidation	- Consolidation center - Belief-Desire-Intention : BDI - Order agent - Truck agent	- Multi-agent based load consolidation system (MABLCS) - VRPTW	- Evaluation of the performance of MABLCS with some static VRPTW
(Teo, et al., 2012)	*Administrator*- Evaluation the city logistic measures the rising trend of e-commerce and home delivery.	- Road pricing in e-commerce	- Carriers - Shippers - Administrators - Residents	- VRPTW - Second price auctioning - Q-learning	- Comparative second-price auction and Q-learning

	Purpose of application and intended users	Type of schemes tested	Type of agents	Programming language, models of software used	Validity model
(Anand, et al., 2013)	*Stakeholders*- Explore into the characteristics of city logistic decision making process	- City logistic decision making process	- Shipper - Shopkeeper - Logistic service monitoring - Truck - Road network - Municipality	- Decision making model	- Validate the practice case (RANDSTAD) with the BESTUFS, base case project.

References

Alexander, L. S., Lihong, L., Eric, W. & John, L., 2006. Pac model-free reinforcement learning. *Proceedings of the 23 rd International Conference on Machine Learning,* p. 881–888.

Anand, N., Quak, H., van Duin, J. R. H. & Tavasszy, L., 2012. City logistics modeling efforts: Trends and gaps - A review. *Procedia Social and Behavioral Sciences,* Volume 39, pp. 101-115.

Boerkamps, J. H. K., van Binsbergen, A. J. & Bovy, P. H. L., 2000. Modeling behavioral aspects of urban freight movement in supply chains. *Transportation Research Record: Journal of the Transportation Research Board,* Volume 1725, pp. 17-25.

Calvete, H. I., Gale, C., Oliveros, M. J. & Sánchez-Valverde, B., 2007. A goal programming approach to vehicle routing problems with soft time windows. *European Journal of Operational Research,* 177(3), pp. 1720-1733.

Chiang, W. C. & Russell, R. A., 2004. A metaheuristic for the vehicle-routing problem with soft time windows. *Journal of the operational Research Society,* Volume 55, pp. 1298-1310.

Choi, T. Y. & Hartley, J. L., 1996. An exploration of Supplier selection parctices across the supply chain. *Journal of Operations Management,* Volume 14, pp. 333-343.

Craig, B., 1999. Sequential Optimality and Coordination in Multiagent Systems. *Procedia IJCAI-99.*

Davidsson, P. et al., 2005. An analysis of agent-based approaches to transport logistics. *Transport Research Part C,* Volume 13, pp. 255-271.

de Jong, G. & Ben-Akiva , B., 2007. A micro-simulation model of shipment size and transport chain choice. *Transportation Research Part B: Methodological,* Volume 41(9), pp. 950-965.

Figliozzi, M. A., 2010. An iterative route construction and improvement algorithm for the vehicle routing problem with soft time windows. *Transportation Research Part C,* Volume 18, pp. 668-679.

Ghodsypour, S. & O'Brien, C., 1998. A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. *International Journal of Production Economics,* Volume 56-57, pp. 199-212.

Hensher, D. A. & Puckett, S. M., 2005. Refocusing the modelling of freigh distribution: Development of an economic-based framework to evaluate supply chain behaviour in response to congestion charging. *Transportation,* 32(6), pp. 573-602.

Holguín-Veras, J., 2000. *A framework for an integrative Freight market simulation.* pp. 476-481.

Holguín-Veras, J., Silas, M., Polimeni, J. & Cruz, B., 2006a. An Investigation on the Effectiveness of Joint Receiver-Carrier Policies to Increase Truck Traffic in the Off-Peak Hours. Part I: The Behavior of Recievers. *Networks and Spatial Economics.*

Holguín-Veras, J., Silas, M., Polimeni, J. & Cruz, B., 2006b. An Investigation on the Effectiveness of Joint Receiver-Carrier Policies to Increase Truck Traffic in the Off-Peak Hours. Part II: The Behavior of Carriers. *Networks and Spatial Economics.*

Holguín-Veras, J., Silas, M., Polimeni, J. & Cruz, B., 2006c. On the Effectiveness of Financial Incentives to Off Peak Deliveries to Manhattan Restaurants. *Transportation Research Record 1966,* pp. 51-59.

Holguín-Veras, J., Thorson, E. & Ozbay, K., 2007. Preliminary results of experimental economics application to urban goods modeling research. *Transportation Research Record: Journal of the Transportation Research Board,* Volume 1873/2004, pp. 9-16.

Ioannou, G., Kritikos, M. & Prastacos, G., 2003. A problem generator-solver heuristic for vehicle routing with soft time windows. *Omega: The International Journal of Management Science,* Volume 31, pp. 41-53.

Jiao, J., You, X. & Kumar, A., 2006. An agent-based framework for collaborative negotiation in the global manaufacturing supply chain network. *Robotics and Computer-integrated Manufaturing,* Volume 22, pp. 239-255.

Joubert, J. W., 2014. Modelling.

Lee, M., Lee, Y. & Jeong, C. S., 2003. A High quality supplier selection model for supply chain management and ISO 9001 system. *Production Planning and Control,* Volume 14(3), pp. 225-232.

Liberatore, F., Righini, G. & Salani, M., 2011. A column generaation algorithm for the vehicle routing problem with soft time windows. *4OR: A Quarterly Journal of Operations Research ,* 9(1), pp. 49-82.

Liedtke, G. & Schepperle, H., 2004. Segmentation of the transportation market with regard to activity-based freight transport modelling. *International Journal of Logistics Research and Applications,* Volume 7(3), pp. 199-218.

Lu, C. C. & Yu, V. F., 2012. Data envelopment analysis for evaluating the efficiency of genetic algorithms on solving the vehicle routing problem with soft time windows. *Computers & Industrial Engineering,* Volume 63, pp. 520-529.

Meyer, M. D. & Miller, E. J., 1984. *Urban Transportation Planning, A Decision Orientated Approach.* New York: McGraw Hill.

Michael, L., 1994. *Markov Games as a Framework for Multi-agent Reinforcement Learning.* New Brunswick, NJ, pp. 157-163.

Ming, T., 1993. *Multi-agent Reinforcement Learning: Independent vs. Cooperative Agents.* Amherst, MA, pp. 330-337.

NILIM, 2003. Qualitative appraisal index calculations used for basic unit for computation of CO_2, NOx and SPM (in Japanese).

Ossowski, S. et al., 2005. Decision Support for Traffic management based on organisational and communicative multiagent abstractions. *Transportation Research Part C,* Volume 13C, pp. 272-298.

Qureshi, A. G., 2008. *A column generation based exact solution for vehicle routing and scheduling problem with soft time windows.*

Regan, A. & Garrido, R., 2001. Modelling freight demand and shipper behaviour: State of the art, future directions. *Travel Behaviour Research.*

Roorda, M., Cavalcante, R., McCabe, S. & Kwan, H., 2010. A conceptual framework for agent-based modelling of logistics services. *Transportation Research Part E: Logistics and Transportation Review,* 46(1), pp. 18-31.

Russo, F. & Carteni, A., 2006. *Application of a tour-based model to simulate freight distribution in a large urbanized area.* Langkawi.

Russo, F. & Comi, A., 2010. A modelling system to simulate goods movements at an urban scale. *Transportation 2010,* Volume 37, pp. 987-1009.

Samimi, A. & Mohammadian, A., 2009. *Behavioral freight movement modeling.* Jaipur, Rajasthan India.

Stefan, K. J., McMillan, J. D. P. & Hunt, J. D., 2005. *An urban commercial vehicle movement model for Calgary.* Washington DC.

Sutton, R. S. & Barto, A. G., 1998. *Reinforcement learning - An introduction.* Massachusetts: The MIT Press, Cambridge.

Tamagawa, D., Taniguchi, E. & Yamada, T., 2010. Evaluating city logistics measure using multi-agent model. *Procedia Social and Behavioral Sciences,* Volume 2, pp. 6002-6012.

Taniguchi, E. & Shimamoto, H., 2004. Intelligent Transport System besed dynamic vehicle routing and scheduling with variable travel times. *Transportation Research Part C,* Volume 12C(3-4), pp. 235-250.

Taniguchi, E. & Tamagawa, D., 2005. Evaluating city logistics measures considering the behavior of several stakeholders. *Journal of the Eastern Asia Society for Transportation Studies,* Volume 6, pp. 3062-3076.

Taniguchi, E., Thompson, R. G., Yamada, T. & van Duin, J. H. R., 2001. In: *City Logisitics: Network Modelling and Intelligent Transport Systems,* The Netherlands: Elsevier Science Ltd.

Taniguchi, E., Yamada, T. & Okamoto, M., 2007. Multi-agent modelling for evaluating dynamic vehicle routing and scheduling systems. *Journal of the Eastern Asia Society for Transportation Studies,* Volume 7, pp. 933-948.

Tas, D., Dellaert, N., van Woensel, T. & de Kok, T., 2013. Vehicle routing problem with stochastic travel times including soft time windows and service costs. *Computers & Operations Research,* 40(1), pp. 214-224.

Tavasszy, L. & Smeenk, B., 1998. A DSS for modelling logistic chains in freight transport policy analysis. *International Transactions in Operational Research,* Volume 5(6), pp. 447-459.

Teo, J. S. E., Taniguchi, E. & Qureshi, A. G., 2012. Evaluating city logistics measure in e-commerce with multi-agent systems. *Procedia Social and Behavioral Sciences,* Volume 39, pp. 349-359.

Thompson, R. G. & Hassall, K., 2006. A methodology for evaluatingurban freihgt projects. In: *Recent Advances in City Logistics,* pp. 283-292.

Toth, P. & Vigo, D., 2002. An overview of vehicle routing problems. In: *The Vehicle Routing Problem,* Society for Industrial and Applied Mathematics., pp. 1-26.

van Duin, J. H. R., van Kolck, A., Anand, N. & Tavasszy, L. A., 2012. Towards an agent-based modelling approach for the evaluation of dynamic usage of urban distribution centres. *Procedia - Social and Behavioral Sciences,* Volume 39, pp. 333-348.

Watkins, C. J. C. H., 1989. *Learning from Delayed Rewards,* Cambridge University.

Weiss, G., 1991. *Multiagent Systems: A modern approach to distributed artificial intelligence.* Cambridge, Massachusetts: The MIT Press.

Wisetjinda, W., Sano, K., Matsumoto, S. & Raothanachonkun, P., 2007. *Micro-simulation model for modeling freight agents interactions in urban freight movement.* Washington D.C.

Wooldridge, M., 2009. *An introduction to multiagent systems.* 2nd ed. West Sussex, United Kingdom.

Xu, J., Yan, F. & Li, S., 2011. Vehicle routing optimization with soft time windows in a fuzzy random environment. *Transportation Research Part E,* Volume 47, pp. 1075-1091.

Young, W., Richardson, A. J., Ogden, K. W. & Rattray, A. L., 1983. An inter-Urban freight mode choice model. *Transportation Planning and Technology,* 8(1), pp. 61-80.

4

APPLICATION FOR HYPOTHETICAL TEST ROAD NETWORK

4.1 General

The previous chapters have introduced the development of the Multi-Agent Systems (MAS) modeling approach in several traffic engineering, transportation, and supply chain problems. It has been used to monitor and evaluate the city logistics measures recently. This section describes the application of MAS modeling approach to evaluate the UDC measure, parking space restriction measure and its impact on the stakeholders, including the freight carriers, neutral carrier, shop owners, residents, shopping street association (SSA) and the administrator. The VRPSTW model on heuristic genetic algorithm is used to evaluate the carriers on their optimized routes while the Q-learning algorithm is performed to determine the rate of service charge for each parcel of the neutral carrier based on the cost and emissions level of the oxides of nitrogen (NO_x), carbon dioxides (CO_2) and suspended particulate matter (SPM).

The main objective is to study the effect of city logistics measures by implementing the Joint Delivery Systems (JDS), an Urban Distribution Center (UDC), and time windows restriction. To study the behavior of urban freight stakeholders and their interaction, which is affected by the policy measures, the MAS modeling approach is a useful methodology to represent their own objective. This research discusses the MAS in the context of city logistics measures aiming at the diversity of the stakeholders' behavior and reducing the environment impacts.

4.2 Experiment setup

The hypothetical test road network is shown in Figure 4.1. Nodes 2 to 18 represent the residents while nodes 19, 20 and 21 are the locations of shop owners. Four freight carriers are named as carriers A, B, C and D.

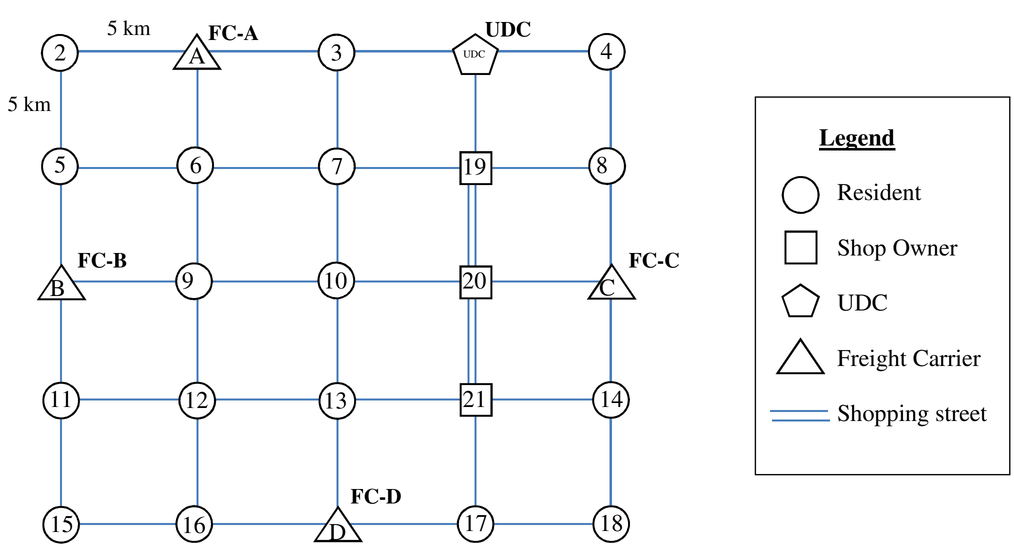


Figure 4.1 Test road network

The MAS model is iterated for 360 days representing a year. The differences of experiment of with/without the UDC operations are described as following;

Without UDC case (Base case)

(Step 1) Freight carriers deliver goods to residents and shop owners.

(Step 2) Repeat step 1.

With UDC case

(Step 1) Neutral carrier offer the UDC' service charge to freight carriers.

(Step 2) Freight carriers make a decision to join the JDS by comparing the direct delivery cost and UDC cost.

(Step 4) Repeat step 1 and 3 for the next day.

Table 4.1 Modeling assumptions

Modeling assumption
<u>General assumption</u>
Service time for delivery is from 8 AM. until 8 PM.
There is only one type of truck.
There is only one type of goods.
The dynamically assigned quantities of delivery goods are fixed throughout the year.
The dynamically assigned time window of delivery goods is fixed throughout the year.
Model illustrates a hypothetical city.
The total demand per day is 1440 parcels per day.
<u>UDC</u>
Access to the UDC is closed to the freight carriers.
The UDC can have an early delivery, fixed time deliveries or full truck delivery scheme.
UDC usage charge is free, 10, 50 and 100 yen per parcel.
<u>Freight carriers and neutral carrier trucks</u>
Vehicular costs are fixed.
Truck capacity is 200 parcels.
Service time window 60 minutes
Trucks travel with an average velocity at 20 kph.

Table 4.1 Modeling assumptions (Cont.)

Modeling assumption
Freight carriers and neutral carrier trucks
Penalty charge for early delivery is 1 yen/minute.
Penalty charge for delay delivery is 5 yen/minute.
Parking fee is 100 yen for 10 minutes.

4.2.1 Experiment scenario

In this section, the distribution activities are divided into four scenarios to evaluate the benefit of entire distribution activities:

1. *Scenario I*		
	Base case:	all freight carriers intended to direct deliver the goods to their customers by themselves.
2. *Scenario II*		
	Implemented UDC:	all freight carriers intended to drop all the goods at the UDC and assign the neutral carrier to deliver the goods.
3. *Scenario III*		
	Role of MAS: no parking policy	freight carriers make a decision to participate the JDS by learning the benefit from history.
4. *Scenario IV*		
	Role of MAS:with parking policy	freight carriers make a decision to participate the JDS by considering the total delivery cost include transportation cost and parking cost.

4.3 MAS evaluating city logistics measures

4.3.1 MAS for Urban Distribution Center (UDC)

The impact of truck emissions from the hypothetical test road network is estimated using equation (3.13) and the oxides of nitrogen (NO_x) emissions are shown in Figure 4.2.

Figure 4.2 shows the reduction of the oxides of nitrogen due to the UDC utilization. It was found that the UDC usage reduced the distance travelled, which otherwise will be greater if each carrier delivers the goods separately. Air pollutants have also decreased with the reduced distance travelled. The use of UDC reduced the NO_x effects by almost 53 percent for resident delivery activity and 54 percent for shop owner delivery activity. In addition, the benefit NO_x for entire system decreased 54 percent.

Table 4.2 The performance of UDC benefits of scenario I & II

Urban Distribution Usage	Distribution Activities	Number of Trucks (veh)	Delivery Cost (yen)	Average Distance Travelled (km)	Load Factor (%)
Scenario I	Residential	14	484,997	1,497.14	58.42%
	Commercial	9	250,966	613.06	31.47%
	Total	23	735,963	2,110.20	47.88%
Scenario II	Residential	11	297,375	693.42	74.35%
	Commercial	3	180,713	281.08	94.42%
	Total	14	478,088	974.50	78.65%
Benefit Comparison	Residential	-21.43%	-38.69%	-68.45%	+27.27%
	Commercial	-66.67%	-27.99%	-90.21%	+200.00%
	Total	-39.13%	-35.04%	-74.77%	+64.29%

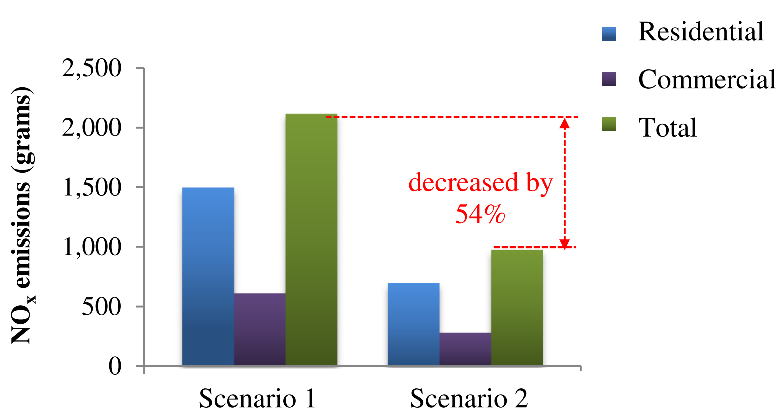


Figure 4.2 NO_x emissions level of implementing UDC comparison

Table 4.2 The performance of UDC benefits shows the number of trucks, delivery cost, total distance travelled and load factor for one year. The results show similar trend of reducing the number of trucks by 40 percent, total cost by 35 percent and total distance travelled by 75 percent when UDC is implemented. In addition, the truck load factor increased by 36 percent with the presence of UDC. Moreover, the total benefit comparison of all distribution activities shows that the UDC has numerous benefits which can potentially be city logistic policy measure.

The behavior changing of stakeholders in scenario III with the various service charge of the UDC were evaluated using equation (3.13) and the comparisons of the benefits of UDC usage are shown in Figure 4.3 to Figure 4.5. Figure 4.3 shows the trend of UDC frequency usage is declined when the service charge increases. It occurred because the freight carriers intended to deliver the goods directly to their customers.

The cost comparison of UDC usage is shown in Figure 4.4. The UDC can reduce the delivery costs with free of charges. In contrast, if the UDC charges some service fees, freight carriers avoid using the UDC because their delivery costs are higher. Similarly, the trend of NO_x emissions increases due to the UDC service charge because of the delivery cost is high. Therefore, freight carriers prefer to delivery by themselves. However, if the UDC promoted free of charge, it can reduce the NO_x emissions as shown in Figure 4.5.

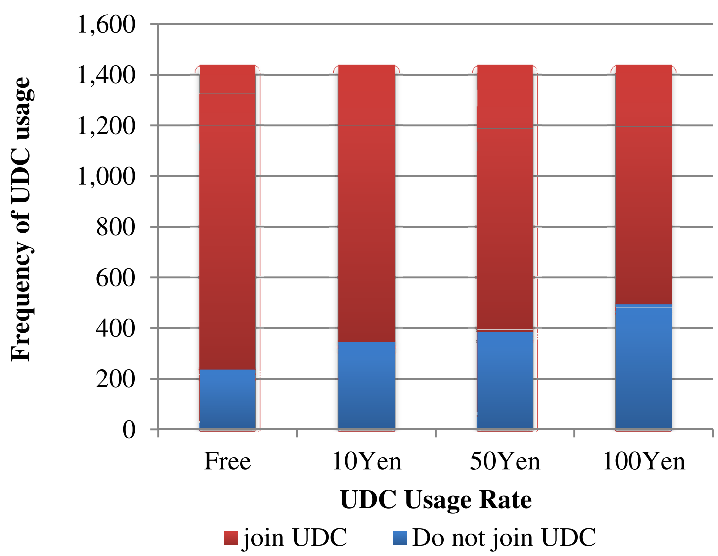


Figure 4.3 Frequency of UDC usage

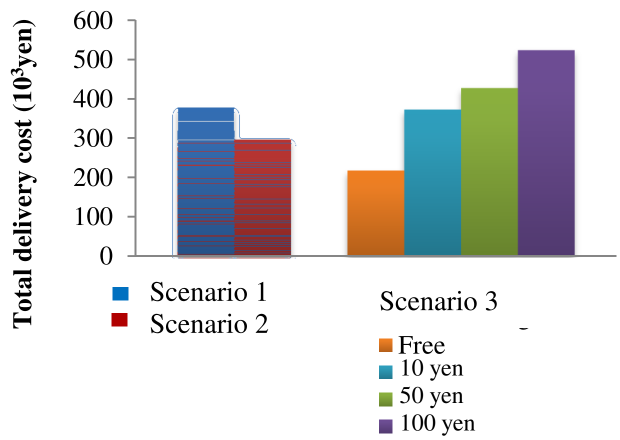


Figure 4.4 Cost comparison of UDC usage

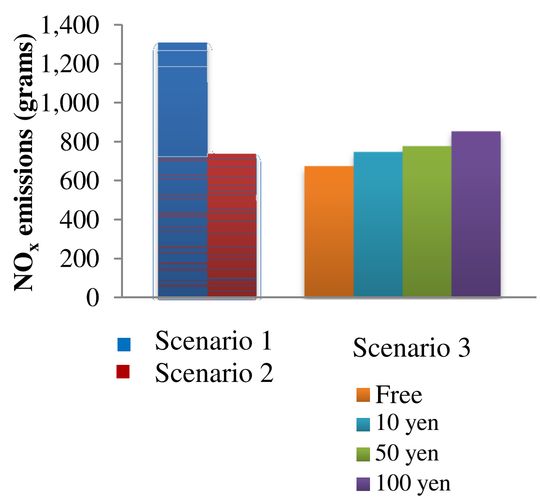


Figure 4.5 NO_x emissions comparison of UDC usage

The initial findings of operating cost reduction and minimized environmental impact for implementing UDC are encouraging and more work will be done to include additional schemes to evaluate the effectiveness of the UDC. The urban freight emission reduction is achieved from the reduction in distance travelled resulting from the replacement of individual delivery to consolidated delivery with the presence of an UDC. The effect of distance and emission reduction is, therefore, dependent on the number of carriers who used the UDC. To attract more carriers to use UDC, it is important to consider the reasonable price for charging the use of UDC and should not be based solely on profit earning objective.

4.3.2 MAS for JDS measure on parking space restriction (Scenario IV)

The objective of this research is to study the effect of city logistics measures consisting of the JDS, an UDC, and parking space restriction. To study the behavior of urban freight stakeholders and their interaction, which is affected by the policy measures, the MAS modeling approach is used to represent their multi-objective environment. This research discusses the MAS in the context of city logistics measures that change the stakeholders' behavior. In addition, the performance measures including the truck emissions and other costs of the stakeholders are also evaluated.

The MAS model for evaluating the JDS requires the identification of stakeholders that include the logistics communities or logistics associations. Stakeholders are individuals, who belong to various identified "communities" and whose lives or businesses are affected by particular policies. Similarly, the policies may also affect the environment and transportation costs, which may ultimately affect the consumers. The stakeholders identified in a JDS include the freight carriers, a neutral carrier, shop owners, residents, administrators and shopping street association. The UDC have to consolidate goods from various freight carriers and load it onto a neutral carrier to dispatch to shop owners by considering operation cost, truck assignment and time window. The urban freight logistics experts have emphasized the importance of engagement of the stakeholders in terms of greater UDC usage, environmental issues as well as the potential of the JDS. The MAS model framework consists of the vehicle routing problem with soft time window (VRPSTW) (Qureshi, 2008) and the behavioral interaction among stakeholders with reinforcement learning model. The interaction among the stakeholders can be referred the MAS interaction model with Figure 3.2 Shopping street stakeholders' interaction within the MAS model. A modified MAS model framework with VRPTW from Figure 3.6, which consists of two sub-models; one is the learning model for stakeholders, and the other is the model for VRPSTW. The learning model evaluates the behavior of stakeholders, learns and selects the behavior with their associated objective value. The purpose of VRPSTW in the MAS model is to plan and implement delivery schedules of trucks for each freight carrier and neutral carrier. These two models are executed sequentially.

The hypothetical test road network is represented by Motomachi Shopping Street (MSS) in Yokohama, Japan. The four freight carriers are named as carriers A, B, C and D and neutral carrier is representative of UDC. Nodes 19, 20 and 21 are the locations of shop owners while the rest are the residents. This network is assumed to be an urban area with congested traffic conditions and crowded shopping street. The four freight carriers have their own depot. The assumption and city logistic measure policies that are used in this study are described in Table 4.1 and Table 4.3 respectively. The MAS model is iterated for 360 days, which is equivalent to a yearly basis. The delivery demand and time window are different as compared to the data used in the scenario III due to the parking space restriction scheme implementation. The experiment flow of without/with the UDC operations is described as following;

Without UDC case

(Step 1) Freight carriers deliver goods to residents and shop owners.

(Step 2) Iterate delivery activities of step 1.

With UDC case

(Step 1) Freight carriers decide to join the JDS by comparing the transportation cost.

(Step 2) Freight carriers decide whether to join the JDS deliver goods to the UDC.

(Step 3) The delivery can divide into two scenarios. Firstly, the freight carriers whom decided to join the JDS deliver goods directly to shop owners and residents. Secondly, other trucks from neutral carrier deliver goods to shop owners and residents.

(Step 4) Repeat step 2 and 3 for the next day.

The experiment evaluates the based case where no learning has taken place within the MAS model. In addition, the comparison of the performance measures by implementing the JDS and car parking management is also examined.

Table 4.3 Condition of policy measure

Policy Measure	Affected Agent	Condition
Parking Management	- Neutral carrier - Freight Carriers	- Neutral carrier has the first priority of parking space without any charge. - Parking truck at normal car park with 100 yen charged per 10 minutes and continuation of delivery to shop owners on foot with additional service charge of 100 yen per minute.

Figure 4.6 shows the delivery cost of freight carriers when the UDC is implemented with different charges. In the first month, the trends remain the same because there is no learning process for the freight carriers. They decided not to join the UDC. In the second month, UDC usage charged at 50 and 100 yen rise precipitously because of most of the freight carriers attended to use the UDC. In the third month onward, the trends declined because of the freight carriers learned through their experiences which decision can maximize their profit. Some chose to join UDC continuously, some did not.

In contrast, the environmental issues show the dissimilarly trend. The truck emissions with UDC are lower than without UDC even though the UDC service charge is increased as shown in Figure 4.7 to Figure 4.9.

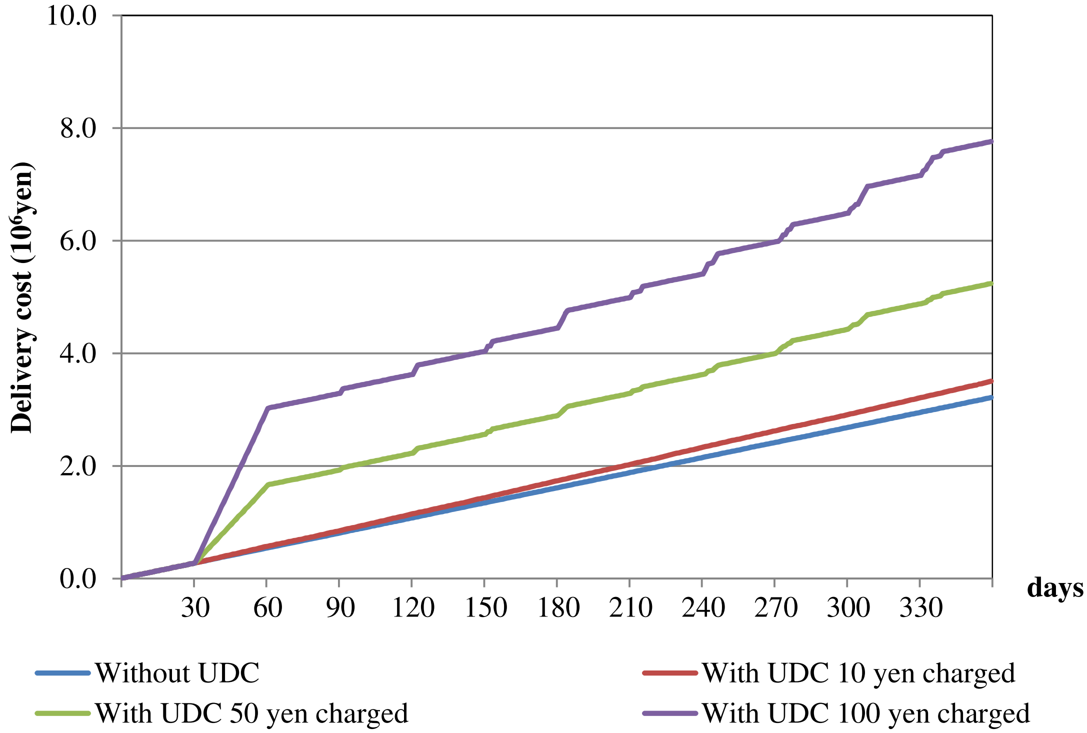


Figure 4.6 Cumulative delivery cost of various UDC service charged for 360 days in scenario IV

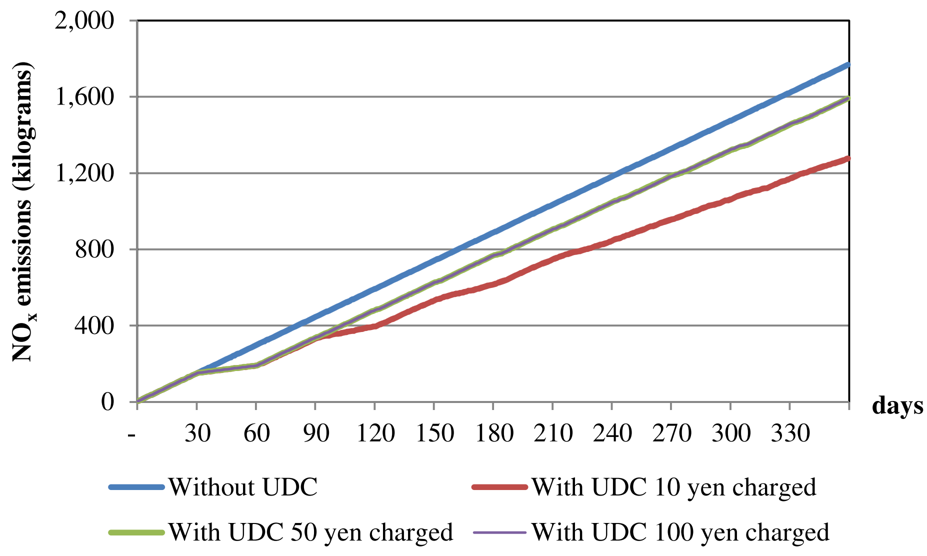


Figure 4.7 Cumulative NO_x emissions of various UDC service charged for 360 days in scenario IV

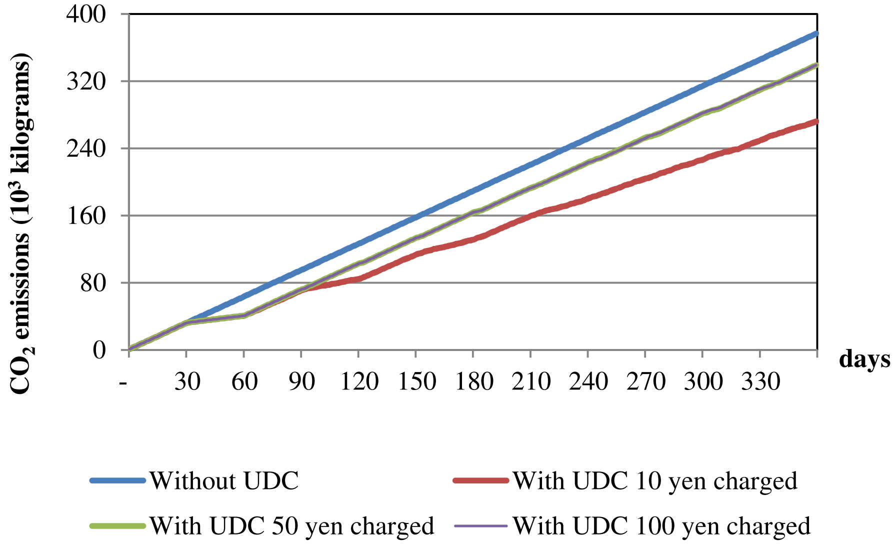


Figure 4.8 Cumulative CO_2 emissions of various UDC service charged for 360 days in scenario IV

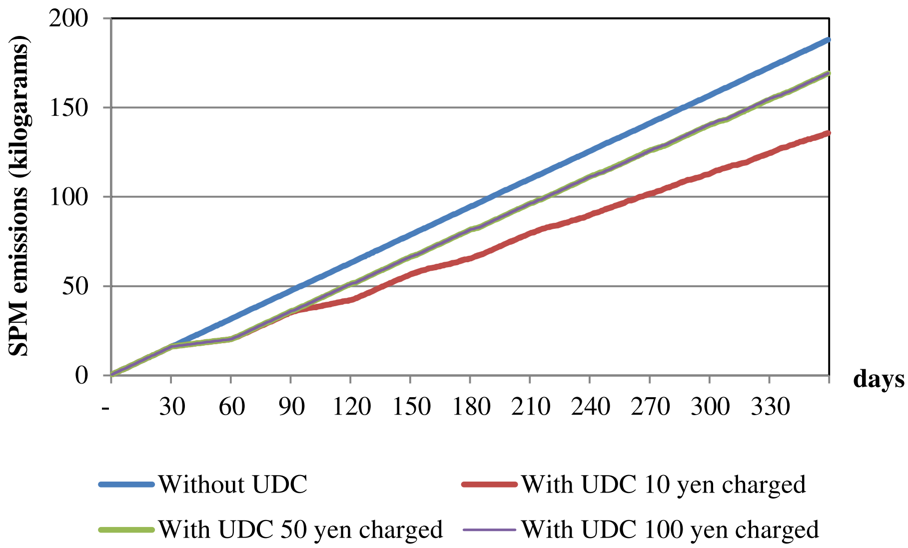


Figure 4.9 Cumulative SPM emissions of various UDC service charged for 360 days in scenario IV

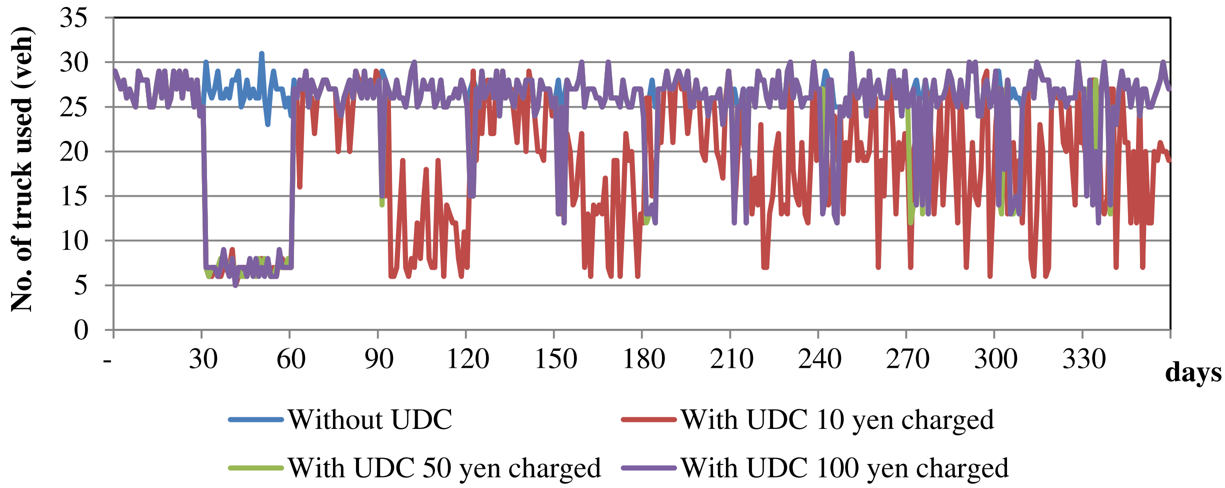


Figure 4.20 Number of truck used in scenario IV

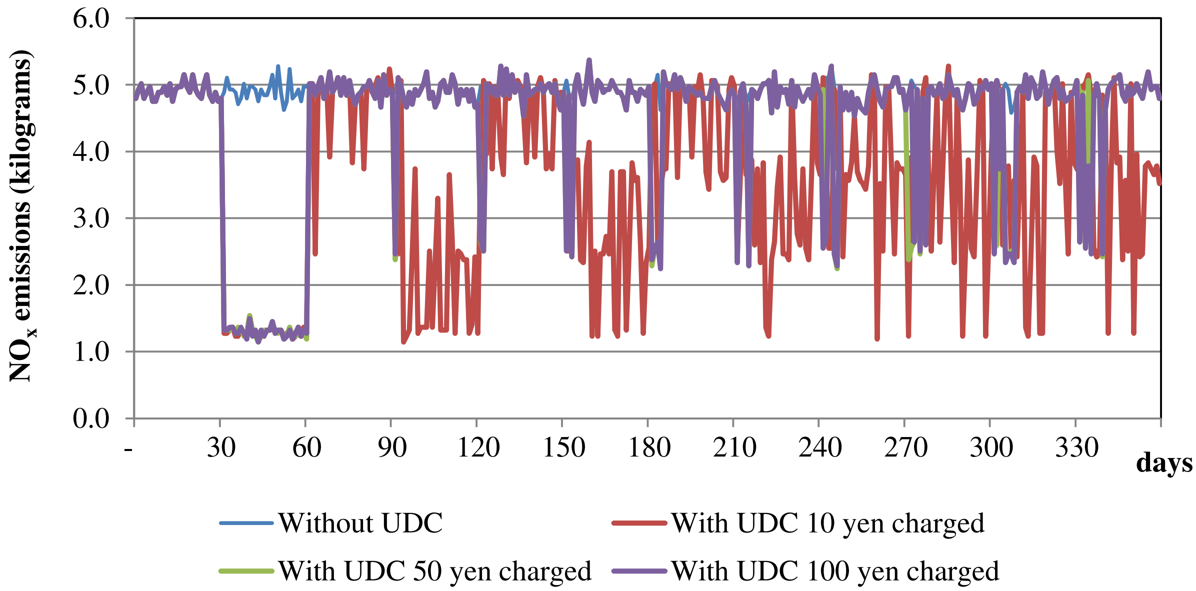


Figure 4.31 NO_x emissions level in scenario IV

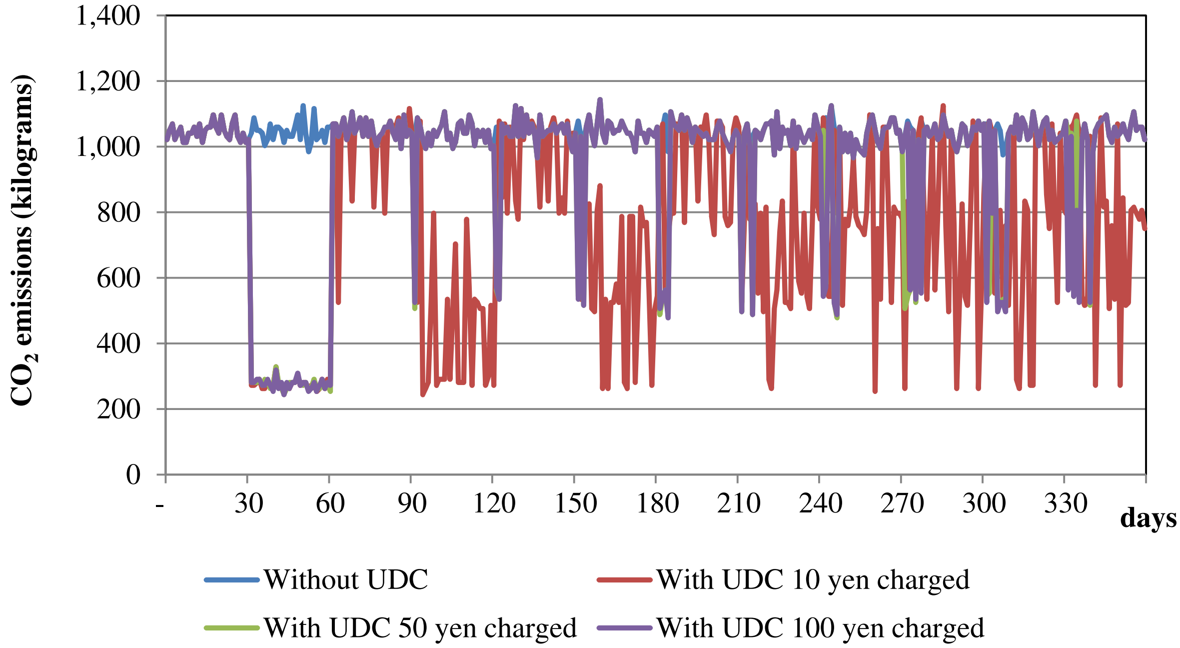


Figure 4.42 CO_2 emissions level in scenario IV

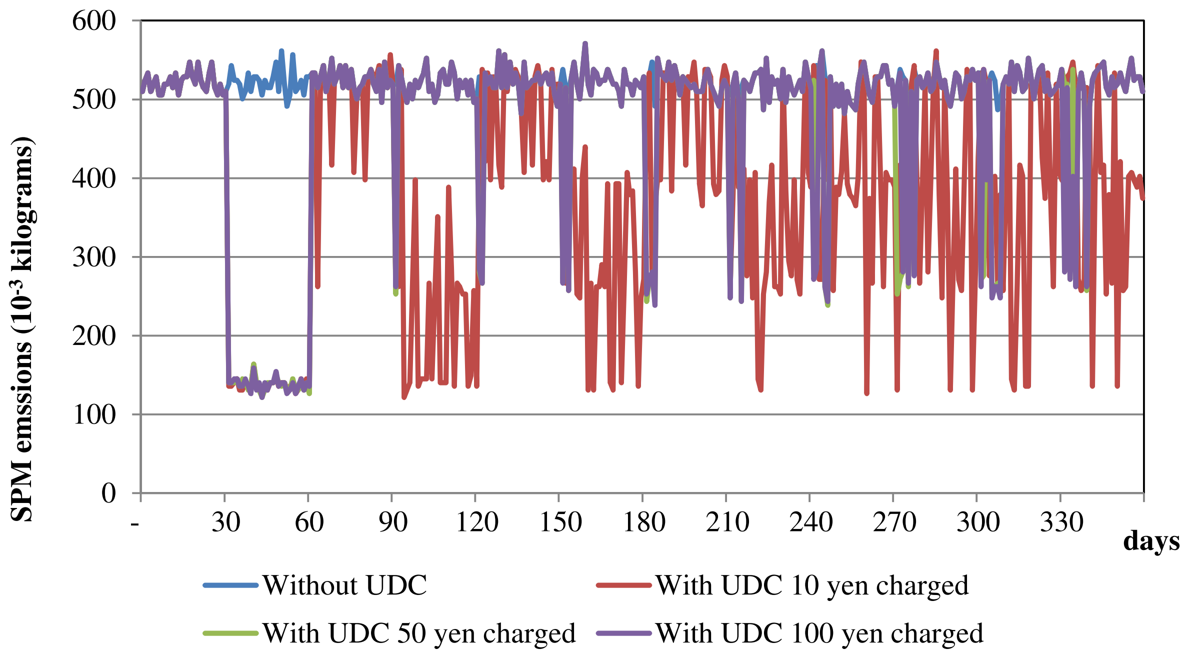


Figure 4.53 Suspended particulate matter emissions (SPM) in scenario IV

The MAS modeling evaluates the environmental impact and the truck utilization as shown in Figure 4.10 to Figure 4.13. The graphs show the outcome of truck used and emissions when

UDC is presented and is charged at different rates. The initial 30 days show similar trend of truck usage and emissions since the freight carriers desire direct delivery of the goods to their customers. The period immediately after 30 days shows an immediate decrease in truck usage and emissions because of the carriers' preference to use the UDC. The time after 60 days shows the effect of carriers' learning behavior and UDC operator's learning of charging 10yen, 50yen and 100yen. It is observed that the price of 10yen, which coincidentally is the lower price option, provides lower truck used in the environment and more emissions reduction. These results show that if the UDC charge is more than 10yen, the freight carriers will decide not to join the JDS. However, if the UDC usage charge is lower than 10yen, the freight carriers' behavior may change to use the UDC.

Figure 4.64 shows the declination of frequency of UDC usage when the service charge increases. Figure 4.15 shows the performance measures of using JDS and parking space policy with various service charges compared to the base case when freight carriers make a decision to join JDS. The manner to interpret the radar plot is to consider the performance measures of "Without UDC" case having the value of one. Any value higher than one is considered beneficial. This observation is reversed when the UDC charge is more than 50 yen. The frequency of UDC usage decreased when the service charge rises but the benefit of UDC usage dropped because freight carriers decided to deliver directly to their customers. However, for the environmental friendly viewpoint, the JDS is beneficial in any circumstances even when the UDC service charge increases.

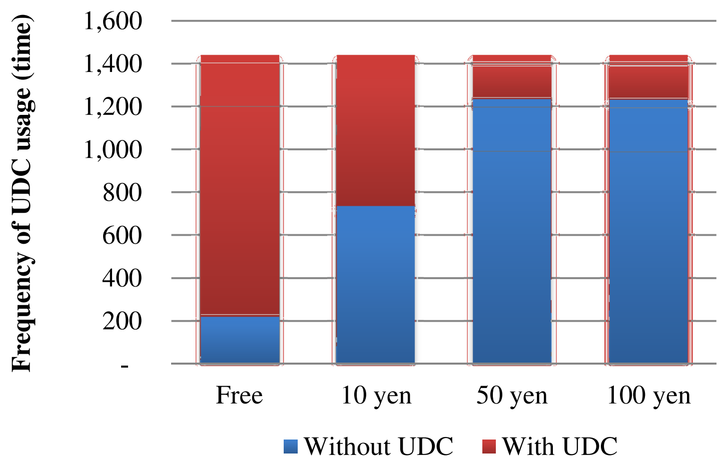
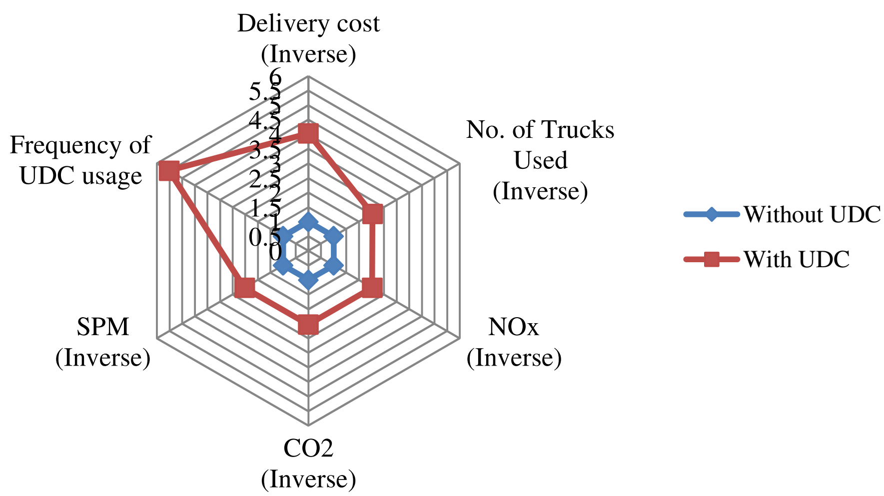
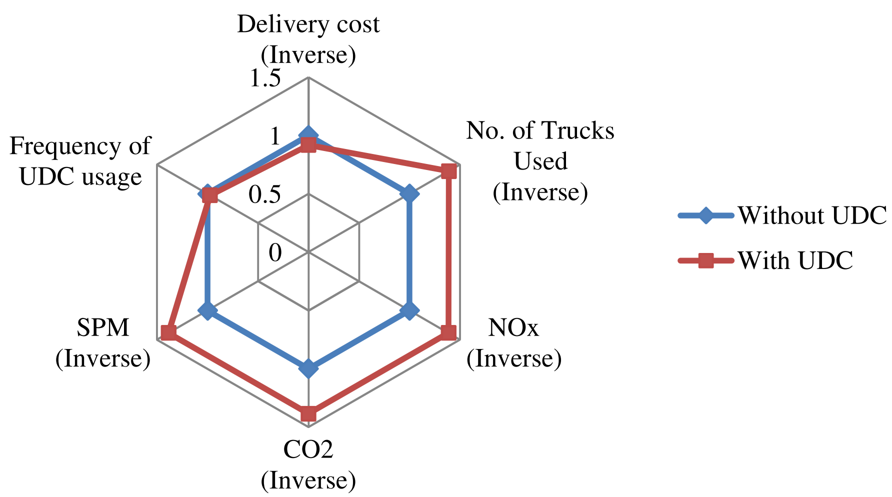


Figure 4.64 Frequency comparison of various UDC usage rates in scenario IV

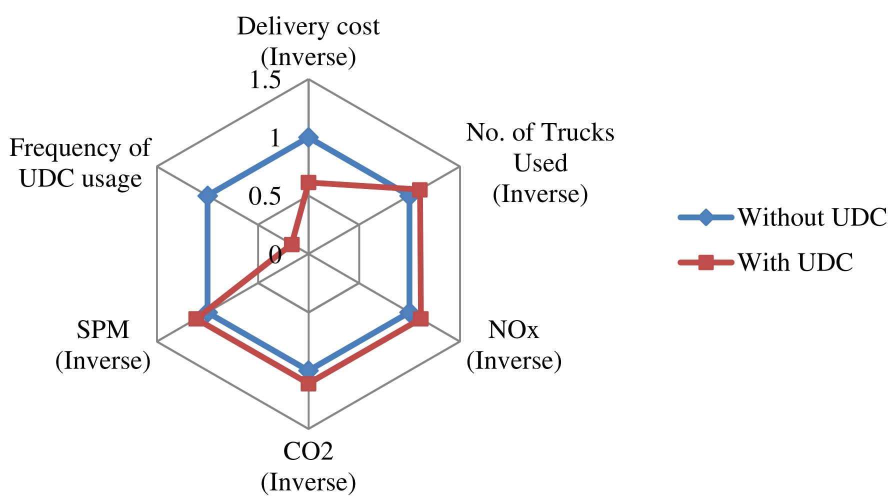


a) The comparison between "With UDC" and "Without UDC" with subsidy by administration

Figure 4.75 Performance of using UDC with various charging in scenario IV

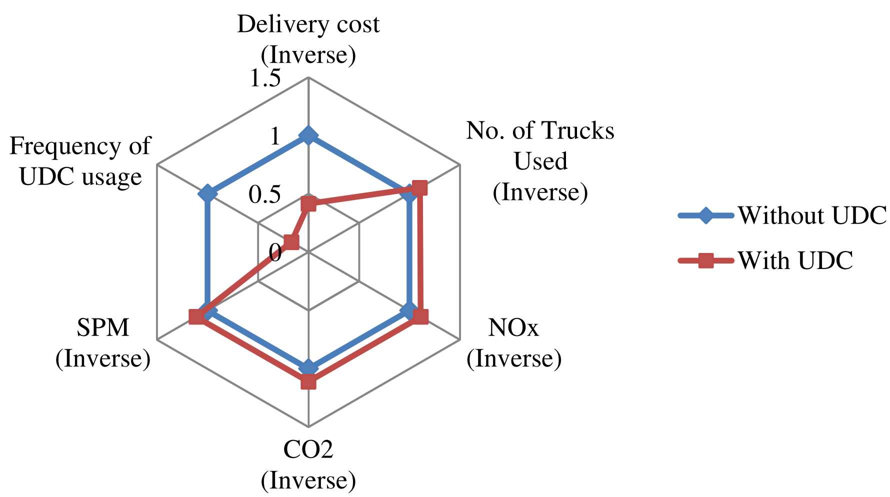


b) The comparison between "With UDC" and "Without UDC" with 10yen charged per parcel



c) The comparison between "With UDC" and "Without UDC" with 50yen charged per parcel

Figure 4.15 Performance of using UDC with various charging in scenario IV (Cont.)



d) The comparison between “With UDC” and “Without UDC” with 100yen charged per parcel

Figure 4.15 Performance of using UDC with various charging in scenario IV (Cont.)

4.4 Summary

In this research, the MAS model was used as a tool to evaluate the transportation cost and environmental issues of using the UDC on the hypothetical road network.

It can be concluded that the reduction of operating cost reduction for implementing UDC and applying parking management as the additional supporting scheme improve the overall effectiveness of city logistics. The urban freight emission reduction is achieved from the reduction in distance travelled resulting from the replacement of individual delivery to consolidated delivery with the presence of an UDC. However, it is found that a lower charge of 10 yen per parcel eventually led to an overall benefit except for the delivery cost.

References

Qureshi, A. G., 2008. A column generation based exact solution for vehicle routing and scheduling problem with soft time windows, Ph.D. Dissertation.

5

APPLICATION FOR OSAKA ROAD NETWORK

5.1 General

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 the better environment, safer community and well-being of people who are living within. The concept of city logistics has been introduced Taniguchi, et al., (2001) and Crainic, et al., (2009) 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 are required to achieve the goals of city logistics by implementing policy measures (Technical committee, 2012). In the procedure of public private partnerships for identifying current problems, discussing appropriate approaches and measures as well as evaluating them and feedback are important. Sharing data and information among stakeholders and assessing the policy measures before implementing them would also be essential. In this procedure, modeling city logistics policy measures, including truck ban, access control, road pricing, setting Urban Distribution Centers (UDC), off-peak hour delivery, load factor controls and new highway locations play a crucial role for the evaluation.

Osaka city have two largest shopping districts, Umeda in the north and Namba in the south. The Umeda area is served by JR Osaka Station and Umeda Station, while the Namba area is served by Namba Station. Both areas have large concentration of department stores, shopping arcades and some of Japan's most extensive underground shopping malls. Between Umeda and Namba is the covered shopping arcade Shinsaibashi Suji, one of Osaka's oldest and busiest shopping destinations which run about 600 meters in length. Shinsaibashi Suji's collection of brand name shops, chain stores, independent boutiques and variety of restaurants makes it popular with nearly every kind of shopper.

This research evaluates the prospects of UDC in Osaka City based on the experience of successful implementations like Motomachi Shopping Street (MSS) in Yokohama, Japan. The study case location is at Shinsaibashi Suji shopping street. The location is shown in Figure 5.1.

Figure 5.1 Location of Shinsaibashi shopping street (*Source:* cruiseportwiki.com)

5.2 Methodology

This research follows the Multi-Agent Systems (MAS) framework as shown in Figure 5.2 MAS simulation framework. This framework utilises the similar Q-learning method employed for the agents in past study (Wangapisit, et al., 2014) with an additional UDC learning agent.

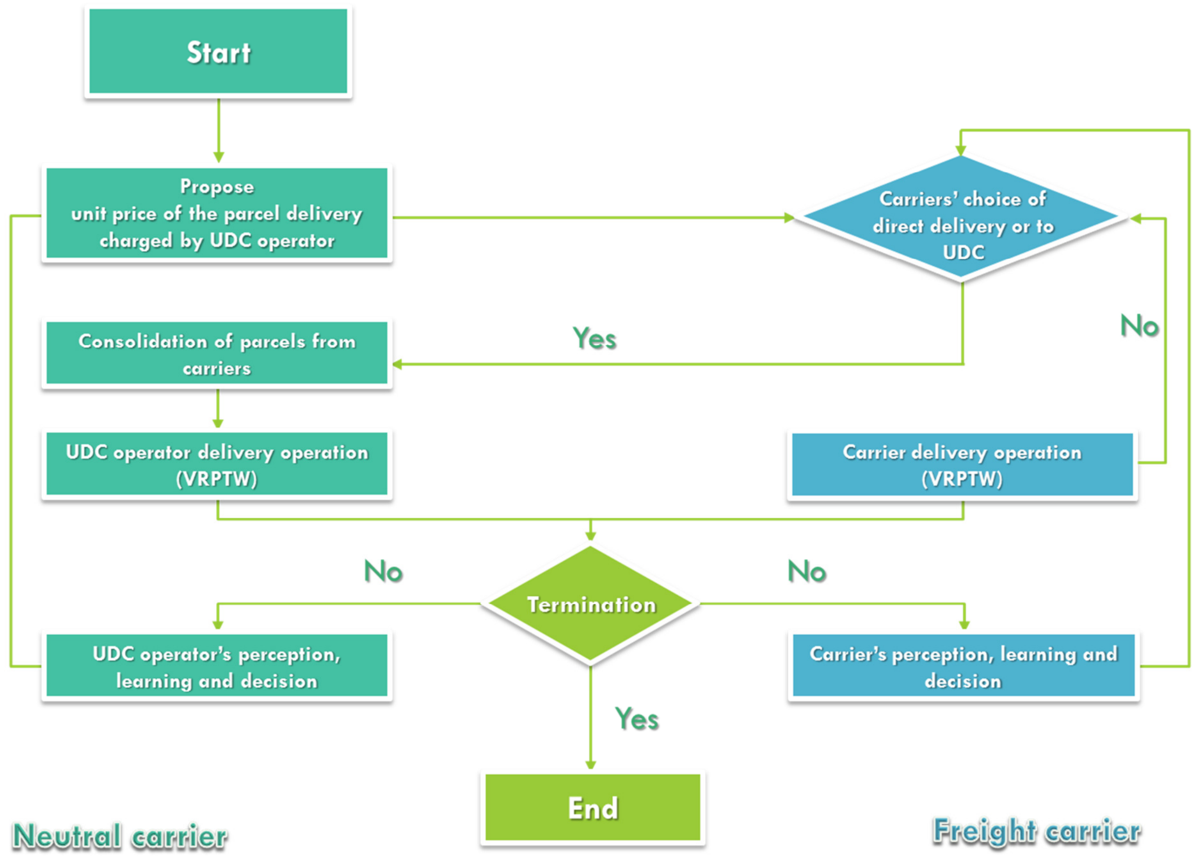


Figure 5.2 MAS simulation framework

Table 5.1 Application assumptions

Modeling assumption
General assumption
Service time for delivery is from 8 AM. Until 8 PM.
There is only one type of truck.
There is only one type of goods.
The dynamically assigned quantities of delivery goods are fixed throughout the year.
The dynamically assigned time window of delivery goods is fixed throughout the year.
Model illustrates an Osaka city, JAPAN.
UDC
Access to the UDC is closed to the freight carriers and highway.
The UDC can have an early delivery, fixed time deliveries or full truck delivery scheme.
UDC usage charge in various rates.

Table 5.1 Application assumptions (Cont.)

Modeling assumption
<u>Freight carriers and neutral carrier trucks</u>
Vehicular costs are fixed.
Truck capacity is 500 parcels.
Trucks average is dependent on the number of lanes in the network (e.g. 3 lanes = 30km/h)
Penalty charge for early delivery is 1 yen/minute.
Penalty charge for delay delivery is 5 yen/minute.

5.3 Experiment setup

The source of Osaka road network is based on the GIS data. Since there is no data collected for the network, it is assumed that the trucks travel at 10km/h on single lane road links up to 60km/h on six lanes road links. Four actual private carriers are located on the road network as shown in Figure 5.3. The location of UDC is selected at a parking facility called Nishinari managed by Urban Infrastructure Technology Centre Foundation. The layout of this parking facility is shown in Figure 5.4. In this chapter, the parking space restriction policy does not implement at Shinsaibashi shopping street due to the very narrow parallel street; therefore, the administrator allows the freight carriers can park their truck at “Ripark". A parking location, “Ripark”, for delivery trucks of both private carriers and UDC is located near the middle of Shisaibashi street as shown in Figure 5.5.

Figure 5.3 Osaka road network with carrier depots and UDC location (Nishinari)

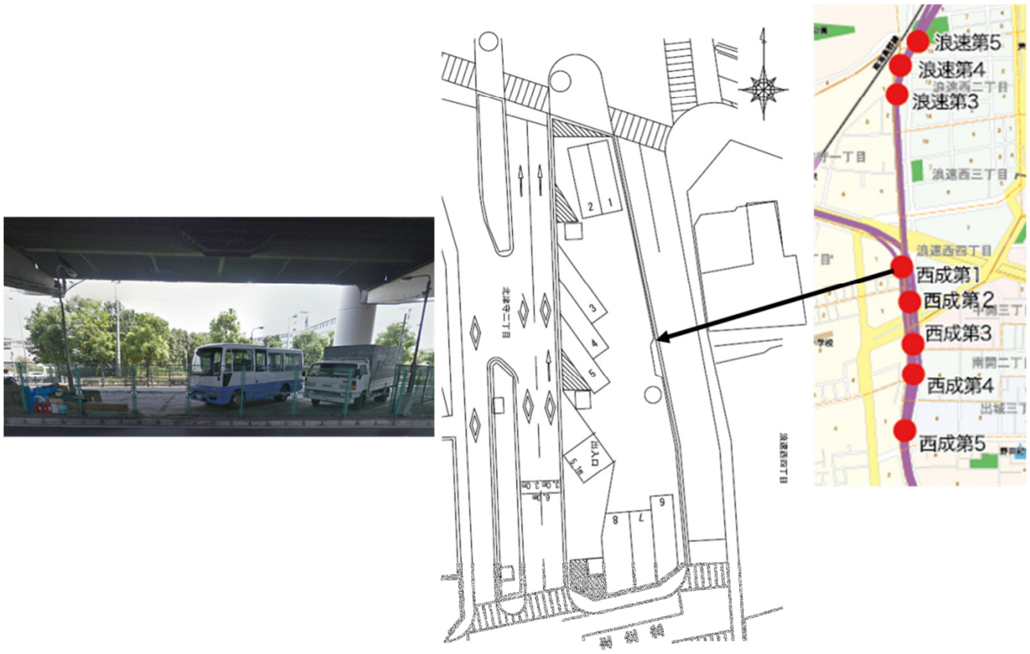


Figure 5.4 Nishinari (UDC) parking facility

Figure 5.5 “Ripark” parking facility near Shinsaibashi (Shopping street parking)

Figure 5.6 shows the land use over the road network for analysis. This land use information is used for the demand generation. For simplicity, the customer demand is generated only from the residential zones and Shisaibashi street represents the only commercial demand for this analysis. The simplified residential zonal demand and Shinsaibashi demand network is shown in Figure 5.7. This simplified map has a total of 139 residential locations and one Shinsaibashi commercial zone for analysis.

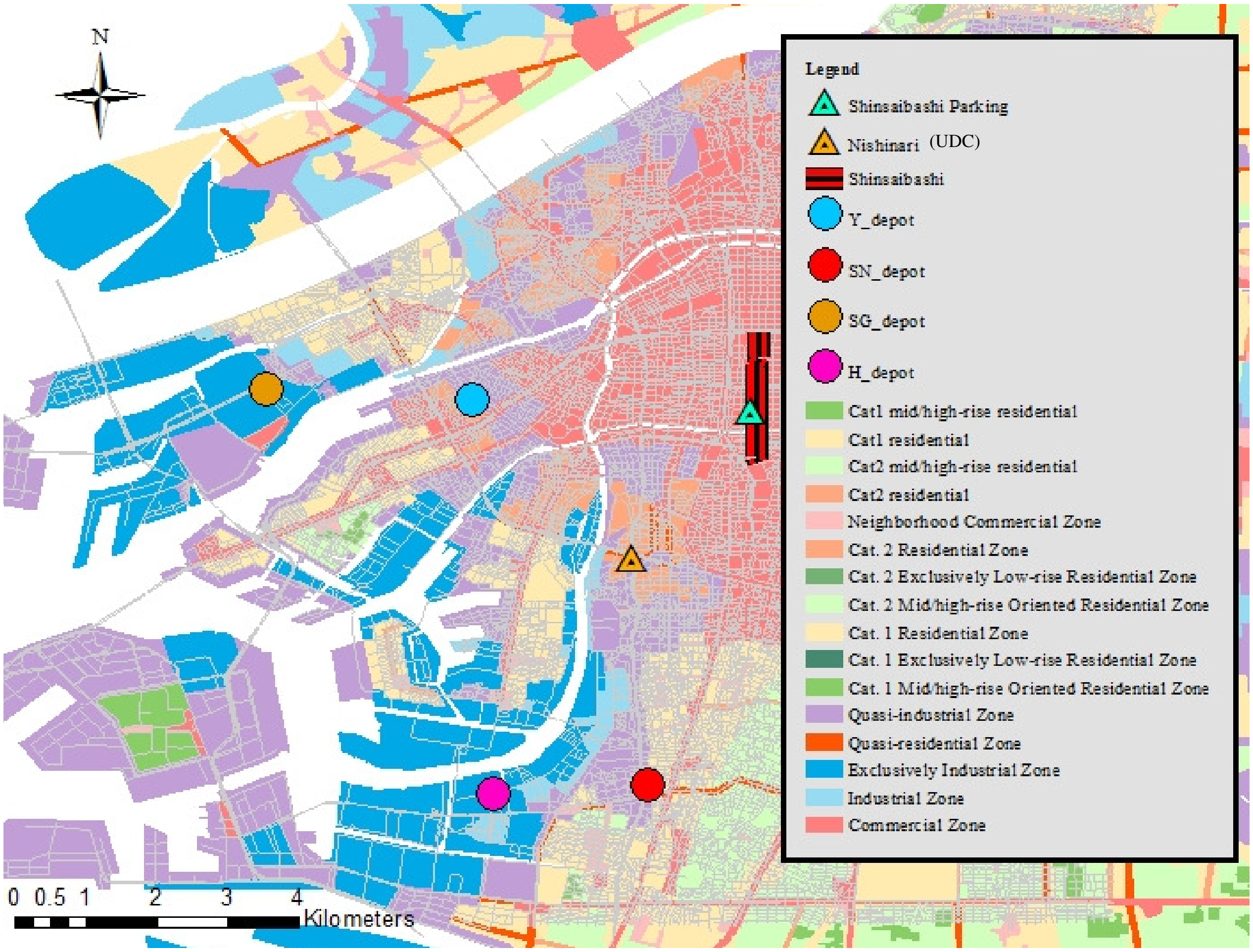


Figure 5.6 Osaka network with land use information

The demand and time window of the 140 customers are dynamically generated every day. It is also assumed that the demand and time window of the customers are the same for all carriers. The initial setup of this experiment is evaluated with the MAS model and iterated for 60 days to test the performance of the environment with UDC and without UDC.

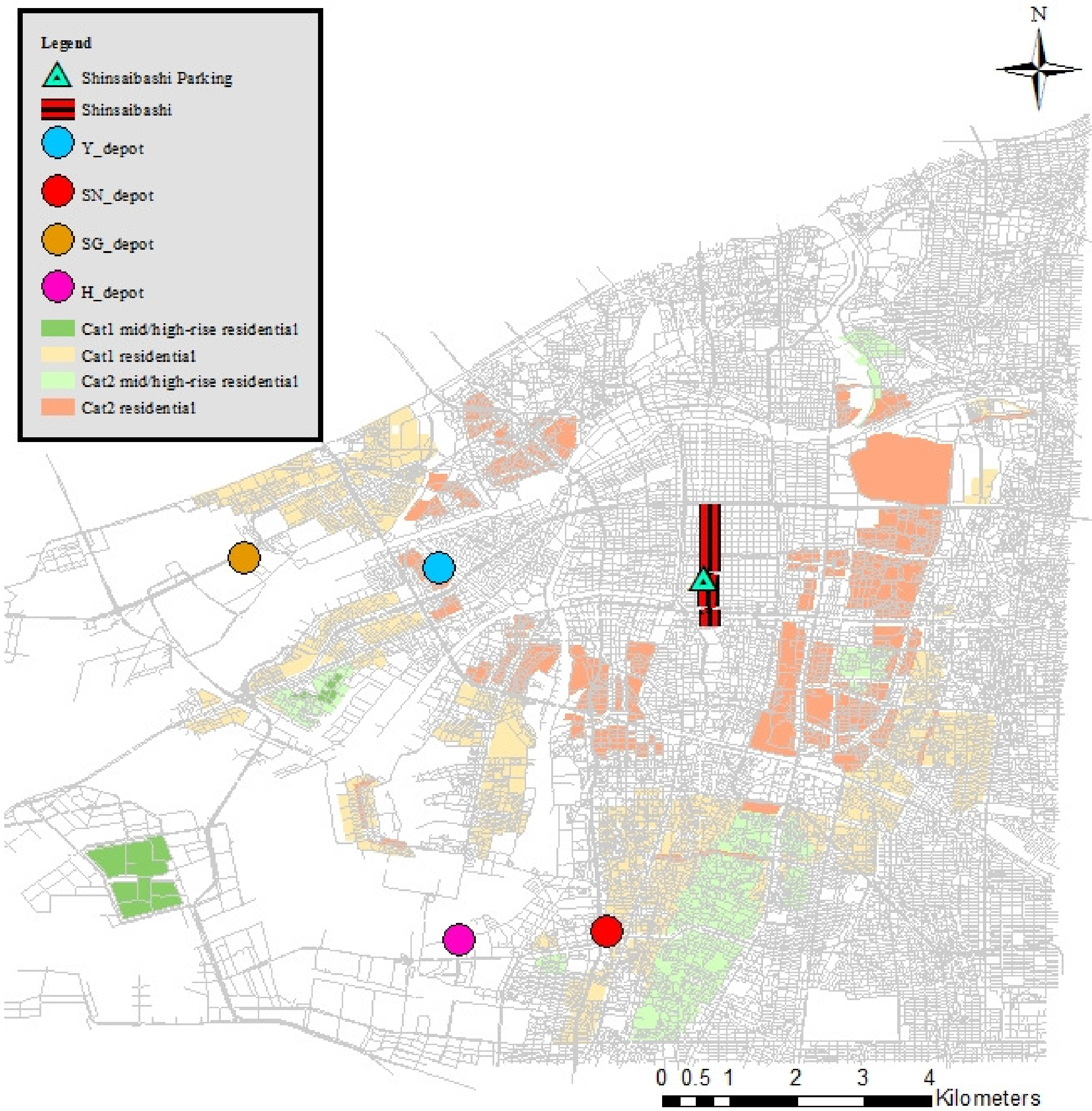


Figure 5.7 Final network with residential zonal demand and Shinsaibashi demand

5.4 Results and discussion

The bar graphs from Figure 5.8 to Figure 5.10 show the benefits of having UDC reducing the emissions of NO_x, SPM and CO_2. The number of trucks in the environment is more when UDC is introduced as seen in Figure 5.11 but the total distance travelled is reduced as shown in Figure 5.12. The cost to the private carriers increased when all of the carriers used the UDC as seen in Figure 5.13. The bulk of the cost of the carriers is the result of the rate charges by the UDC operator as shown in Figure 5.14. As shown in Figure 5.15, the overall benefits of the UDC are mainly the reduction of emissions and number of trucks used. However, the charges by the UDC operator have to be adjusted for longer term analysis in order to reduce the cost to the carriers, which might affect the consumers if the carriers pass on the cost to them.

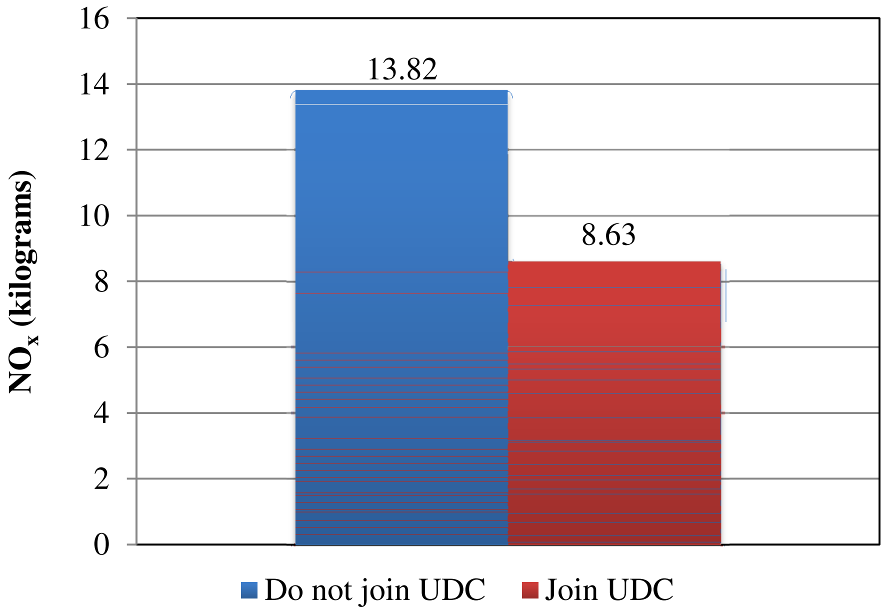


Figure 5.8 NO_x emissions comparisons

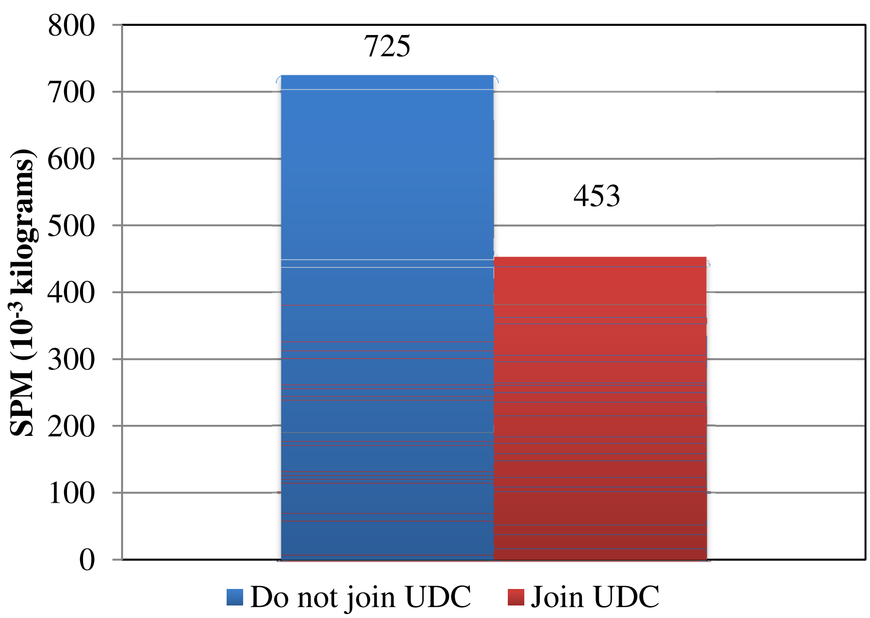


Figure 5.9 SPM emissions comparisons

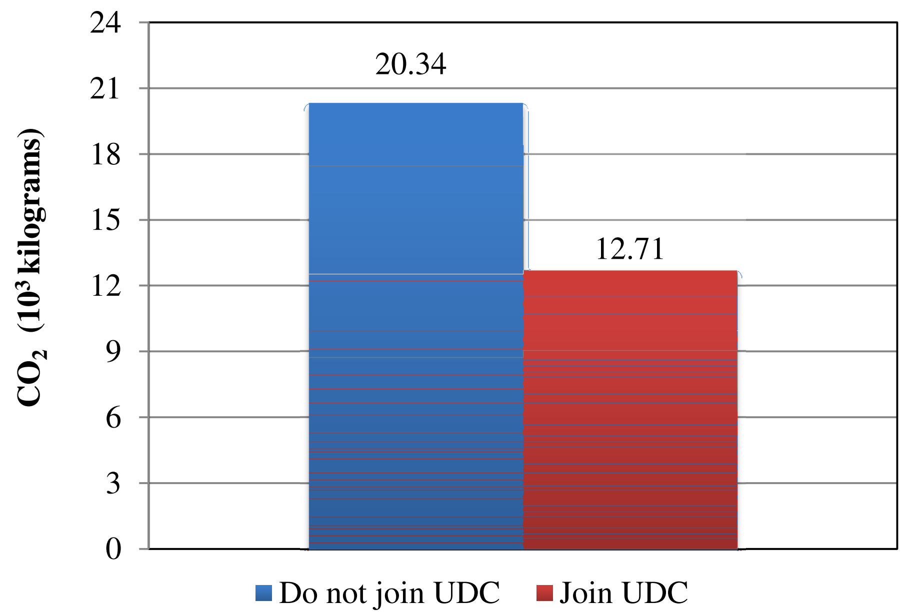


Figure 5.10 CO_2 emissions comparisons

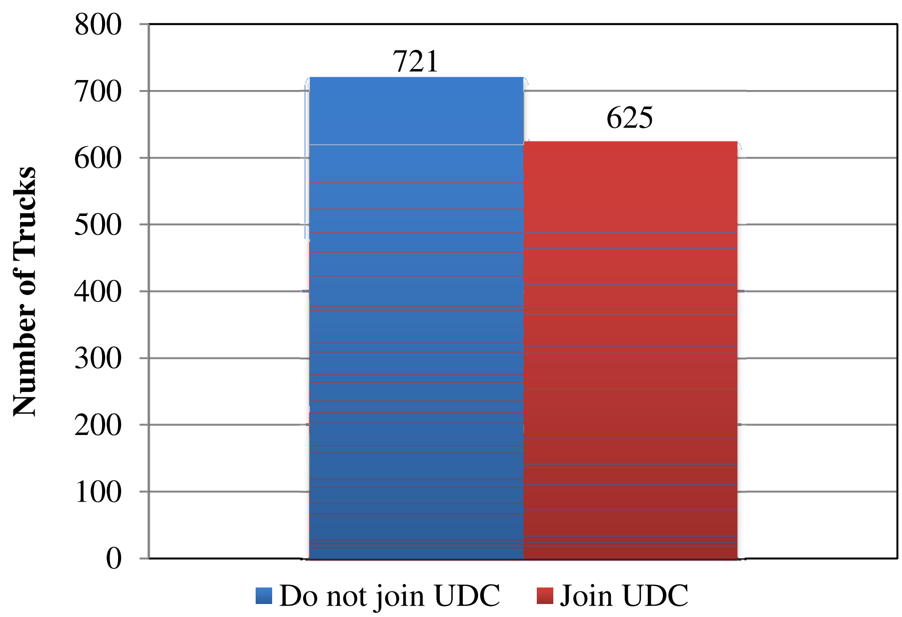


Figure 5.11 Number of trucks comparisons

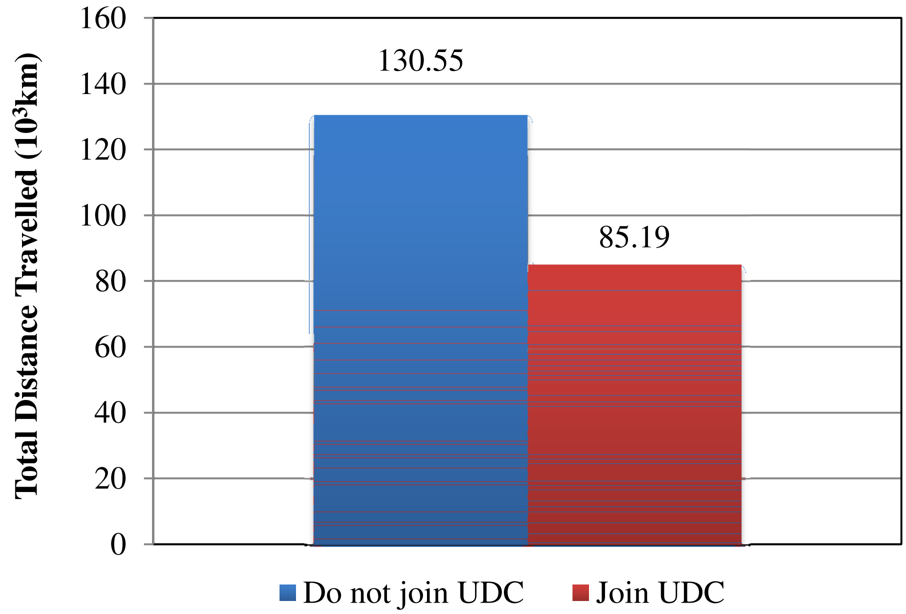


Figure 5.12 Total distance travelled comparisons

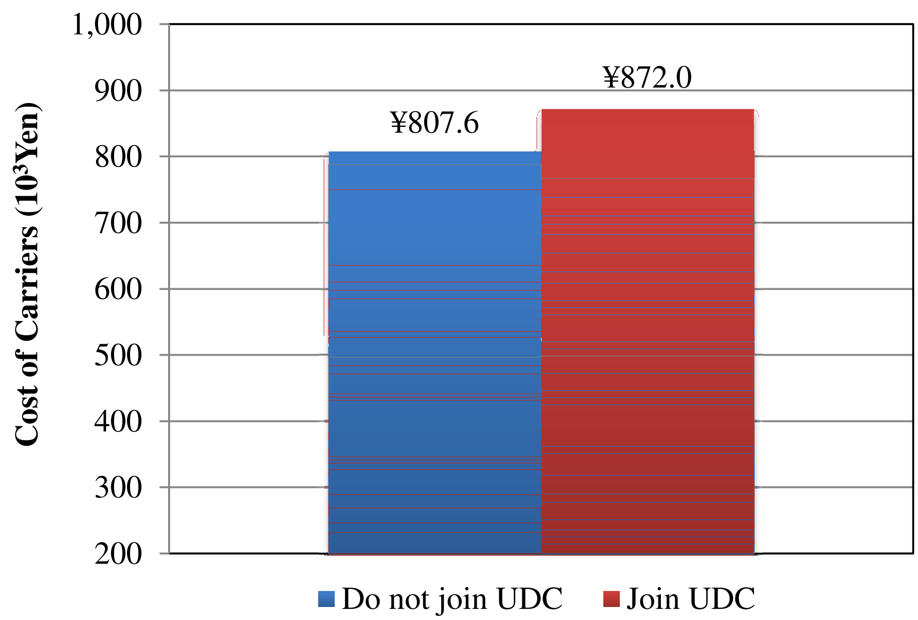


Figure 5.13 Cost of freight carriers

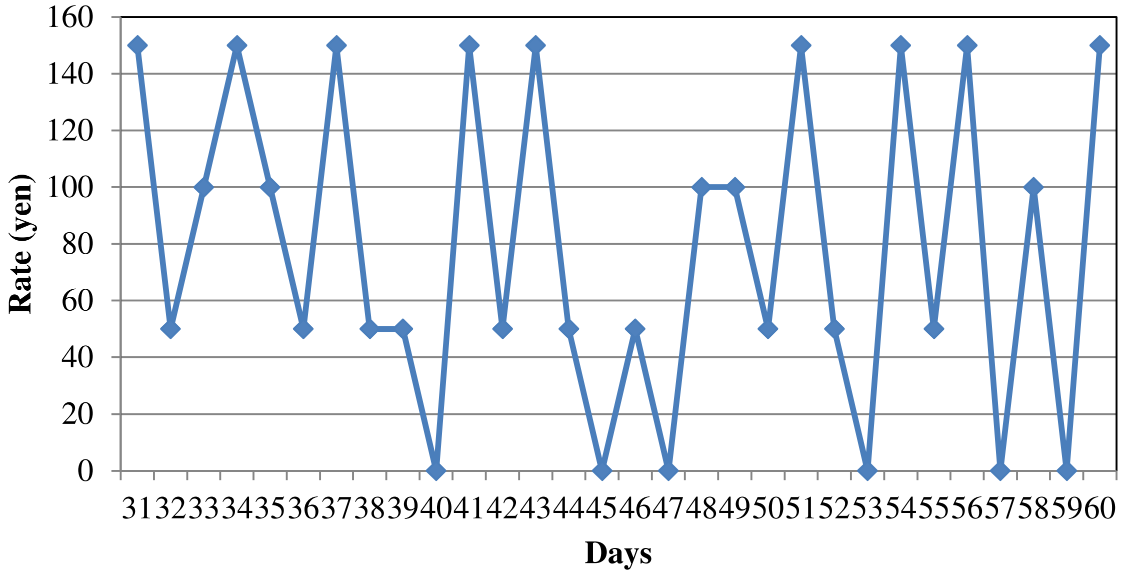


Figure 5.14 Rate charges by UDC operator

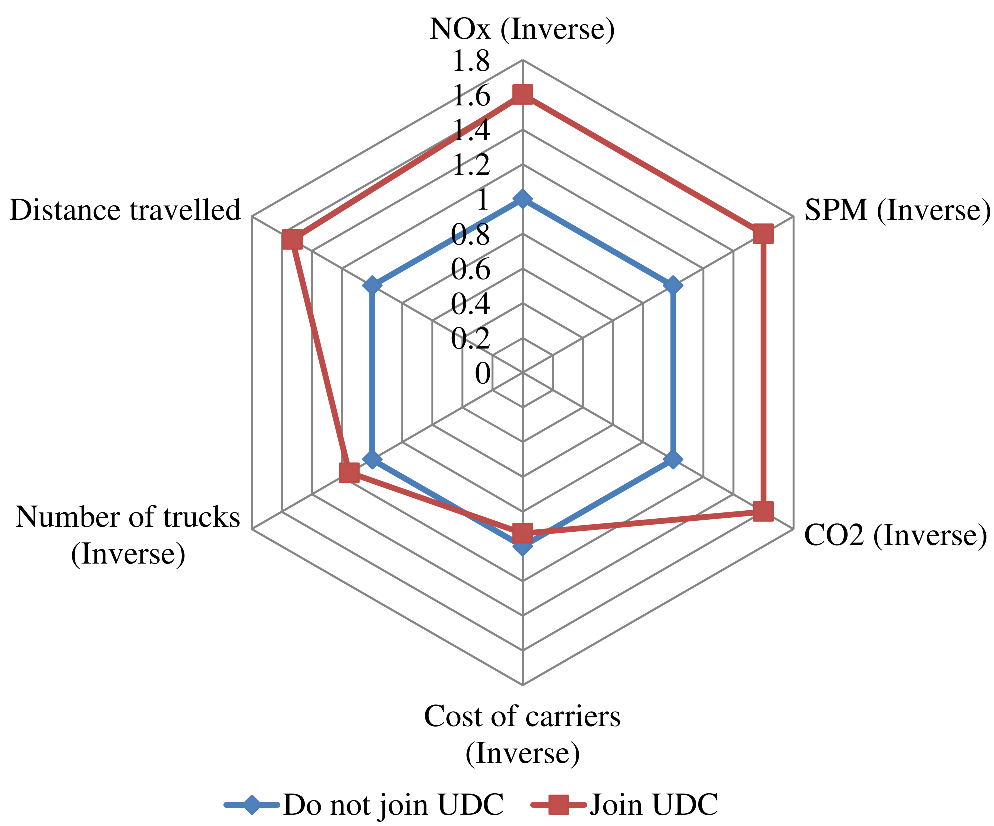


Figure 5.15 Radar plot of performance measures with UDC

A clearer visual observation of the benefit of UDC can be seen from the comparison of Figure 5.16 and Figure 5.17. From Figure 5.17, it is shown that the implementation of UDC has relieved several of the congested road links in Figure 5.16.

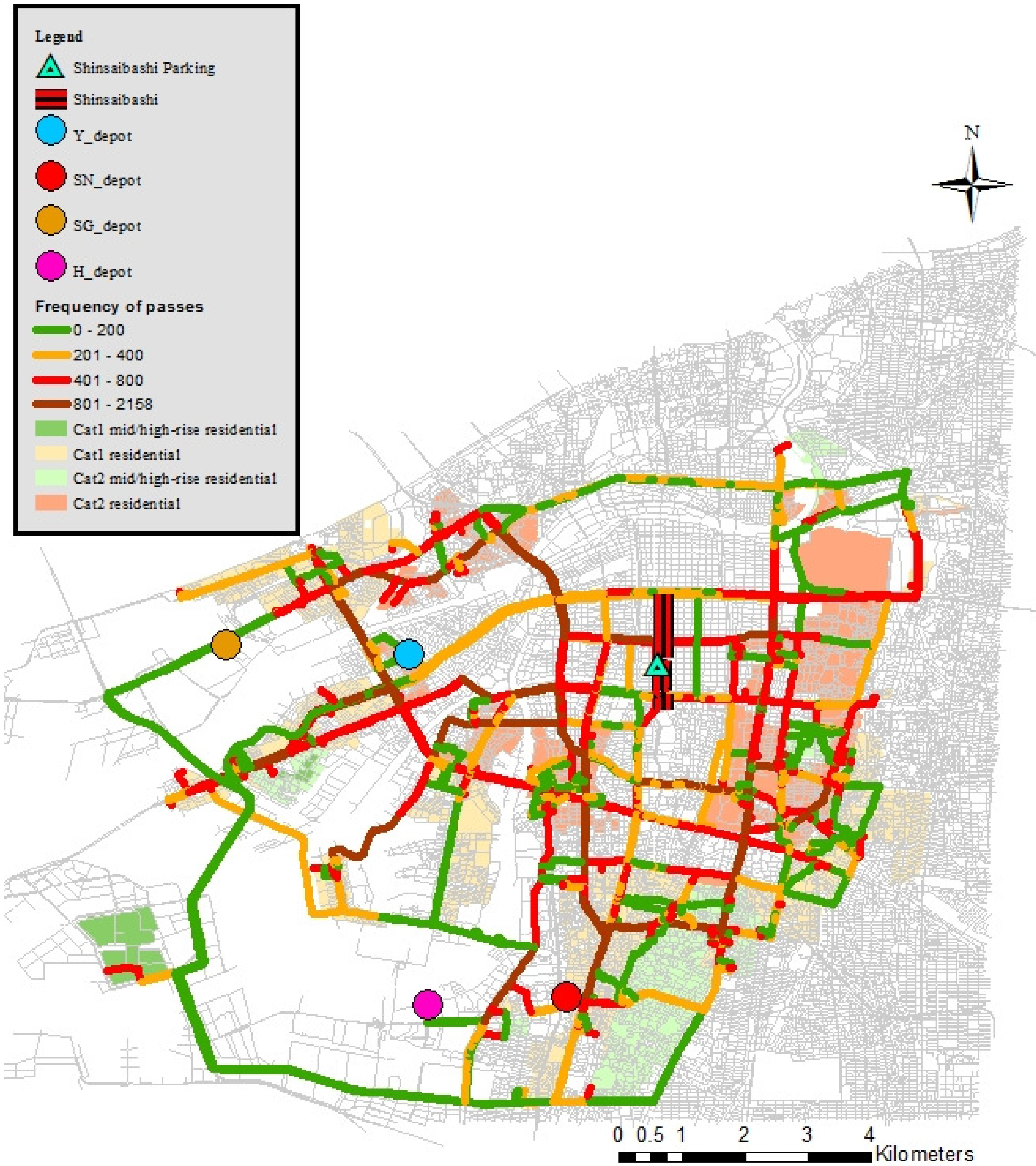


Figure 5.16 Link use frequency for base case

The following shows the results of the MAS model that is run for 360 days which is about a year of analysis Figure 5.18 to Figure 5.31. The charges for the UDC are adjusted to encourage more carriers to use the UDC. Therefore the range of charges is changed to 0yen, 3yen, 6yen and 10yen per unit. Figure 5.18 shows the Q-learning values that influenced the UDC operator's charging rate behavior with different carrier's learning values. Based on Figure 5.18(a), the carrier's learning rate of 0.1 meant that the carrier is more pessimistic towards the policy and considers the historical values more. This has led to the UDC operators' behavior of not changing the charging rate as much as what is shown in Figure 5.19(b) and Figure 5.19(c). Subsequent figures from Figure 5.20 to Figure 5.31 shows the effects of the presence of UDC and the cost that will affect the carriers.

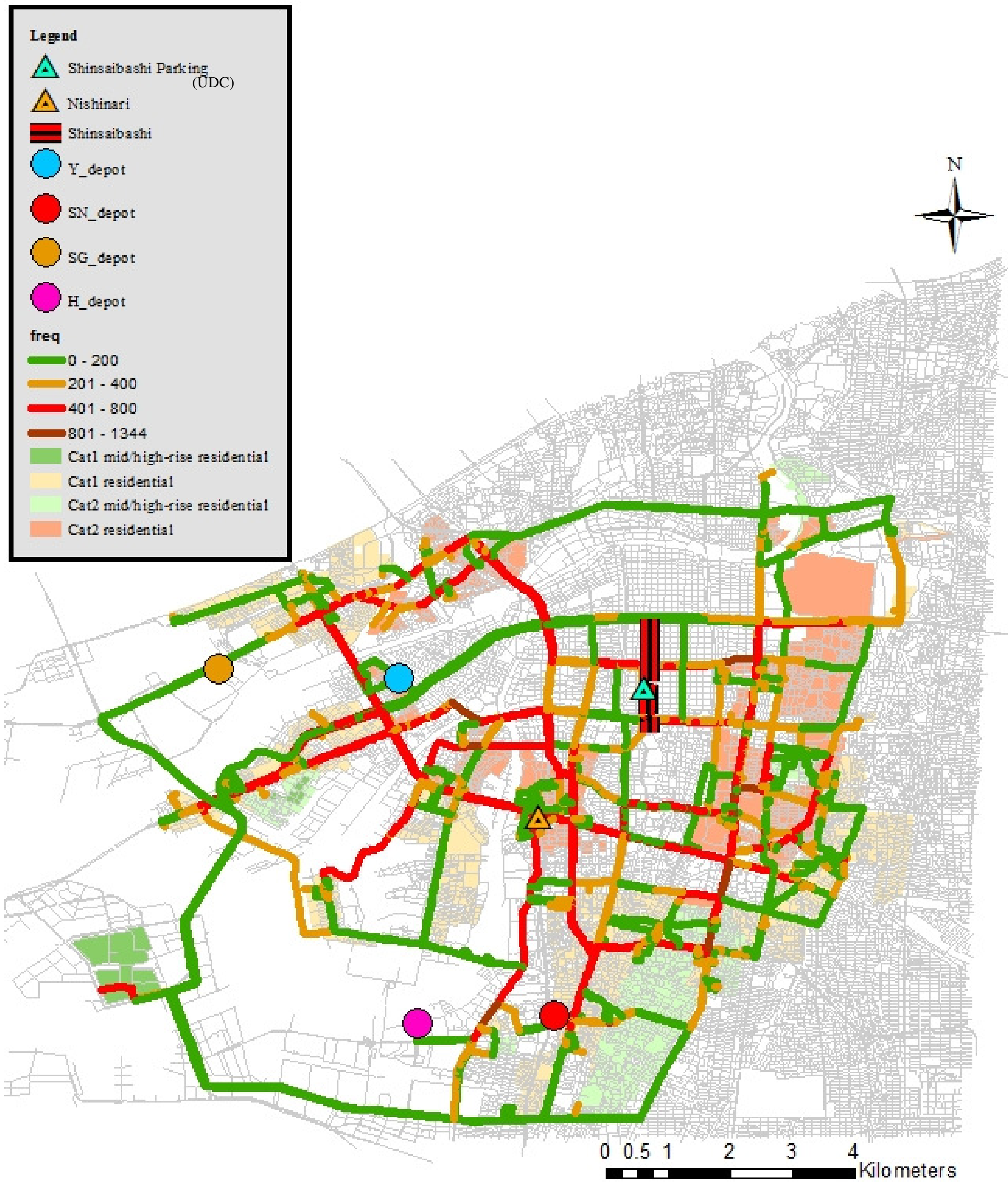


Figure 5.17 Link use frequency for UDC case

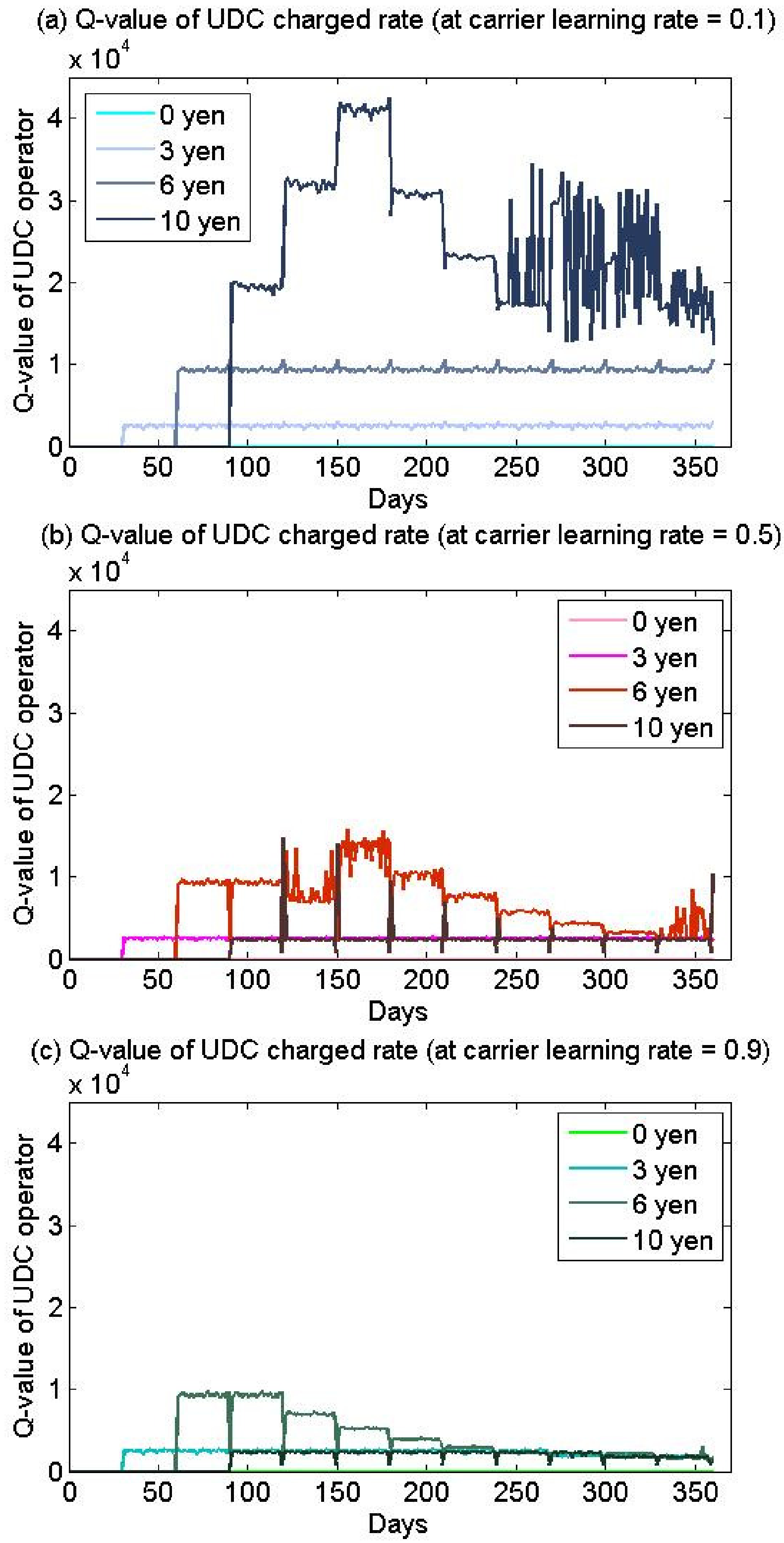


Figure 5.18 Q-values of UDC operator with different carrier learning rates over 360 days

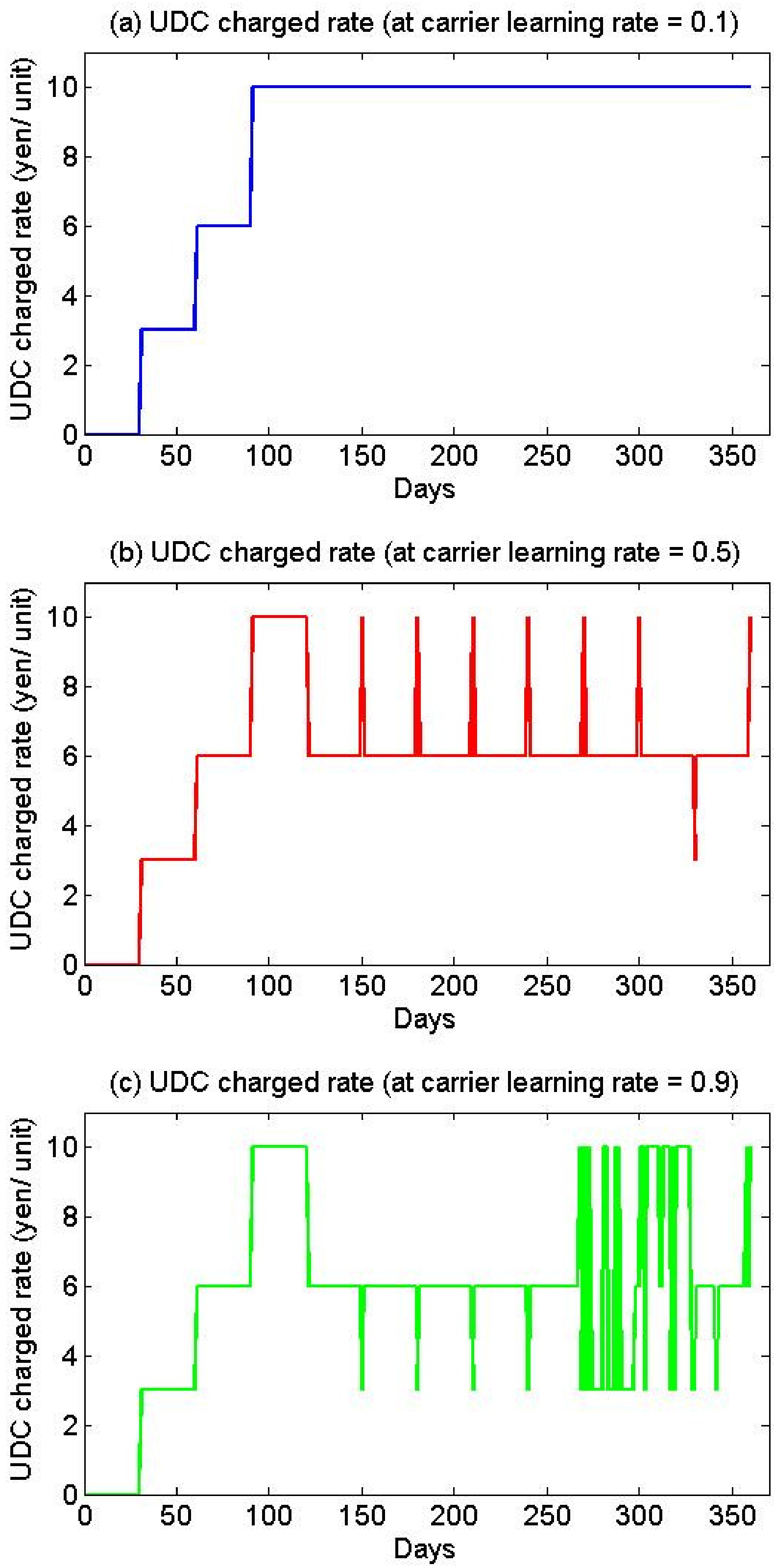


Figure 5.19 UDC charge rates with different carrier learning rates over 360 days

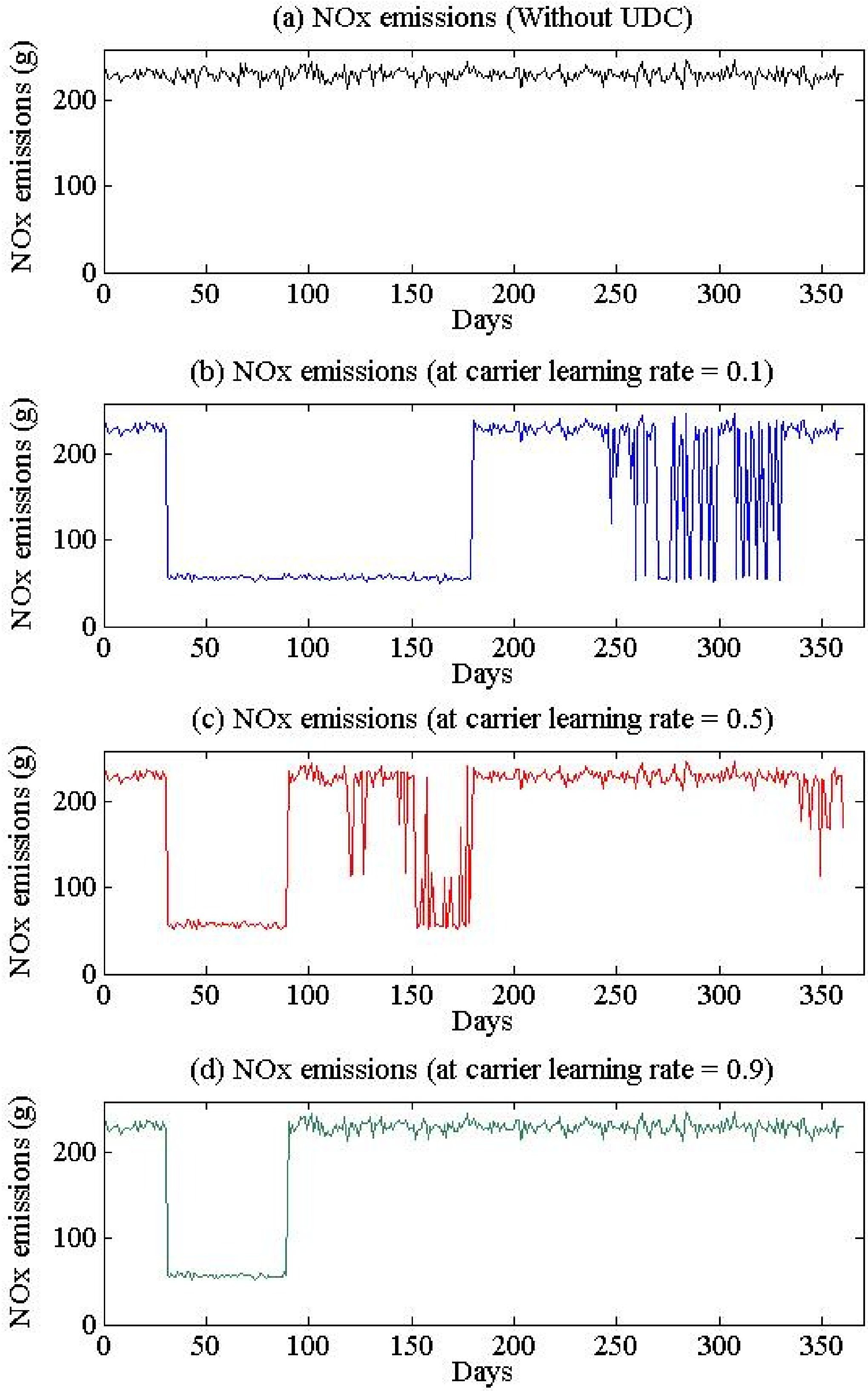


Figure 5.20 NO_x emissions with different carrier learning rates over 360 days

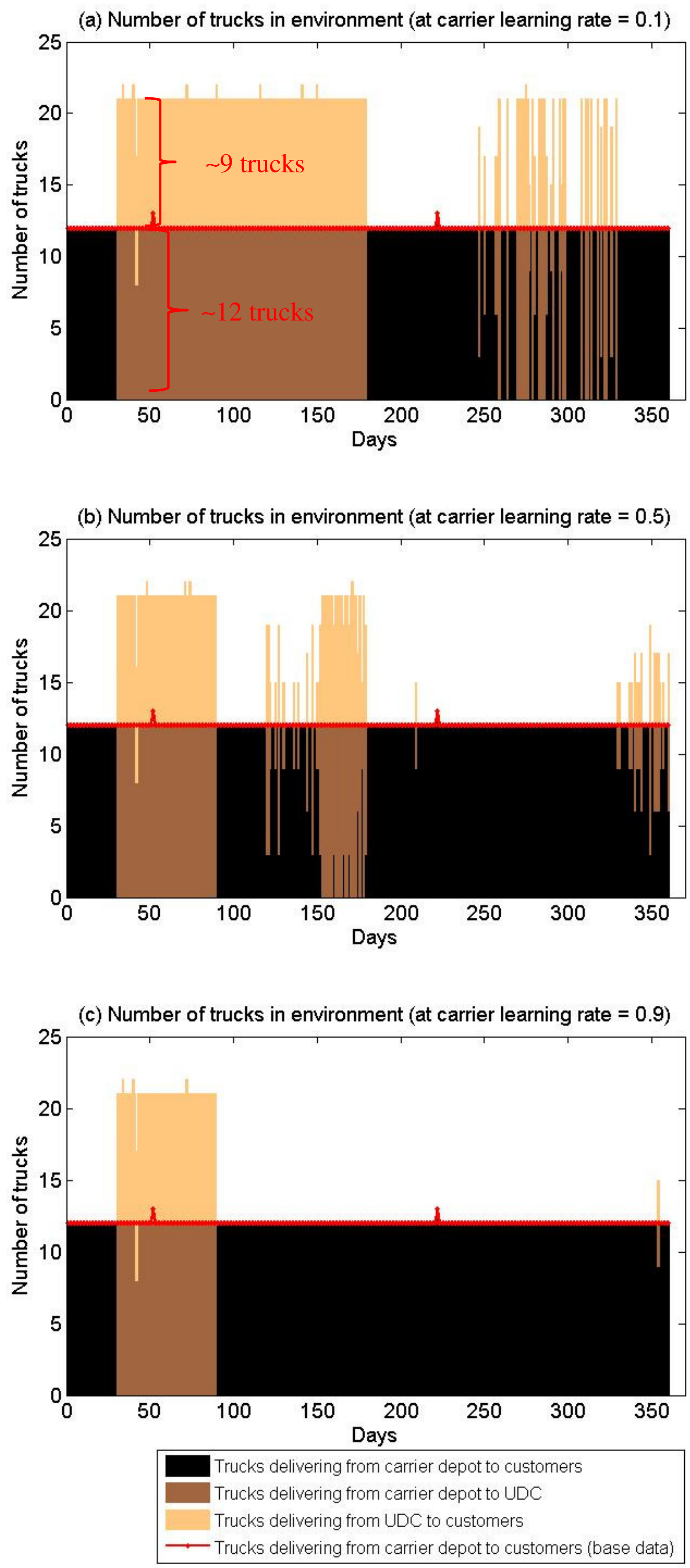


Figure 5.21 Number of trucks in environment with different carrier learning rates over 360 days

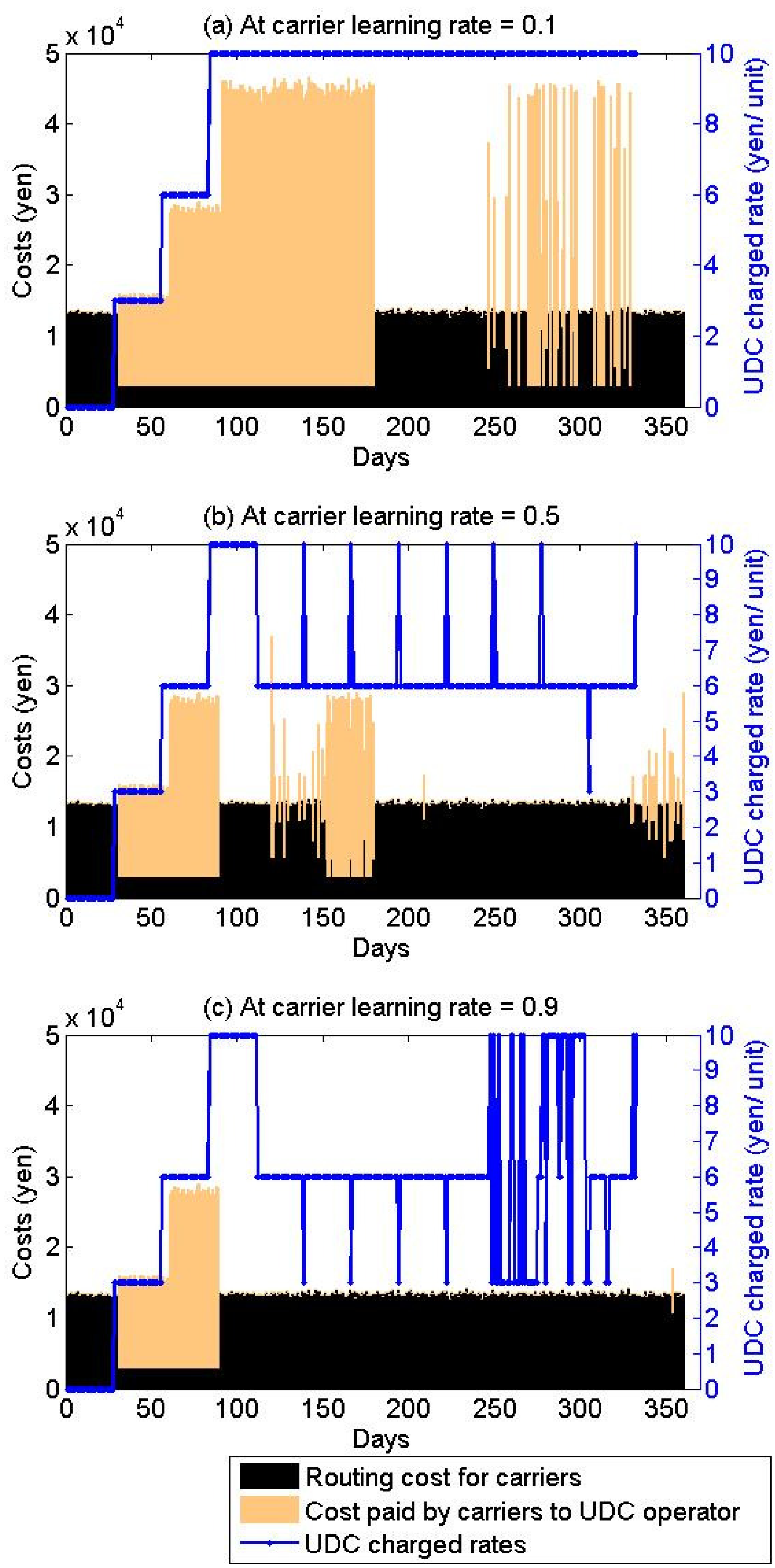


Figure 5.22 Costs for the freight carriers over 360 days

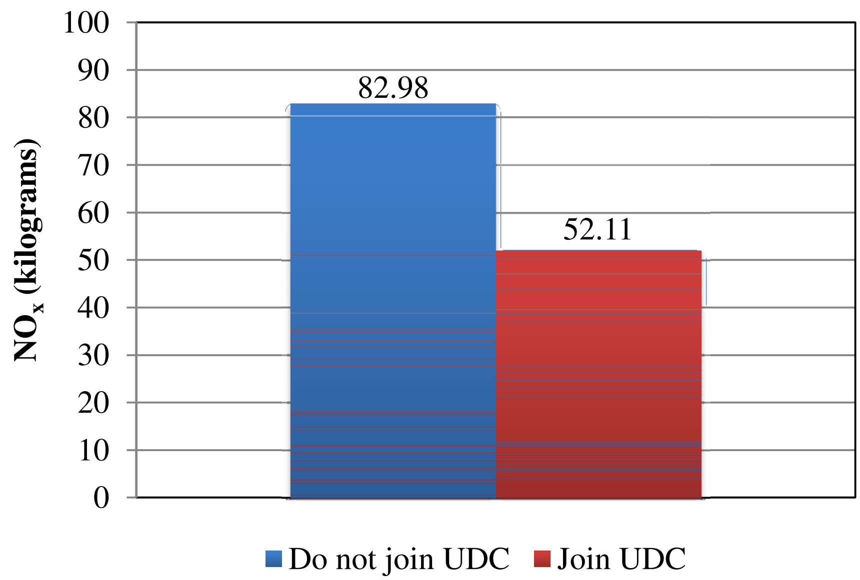


Figure 5.23 NO_x emissions comparisons for 360 days at carrier learning rate 0.1

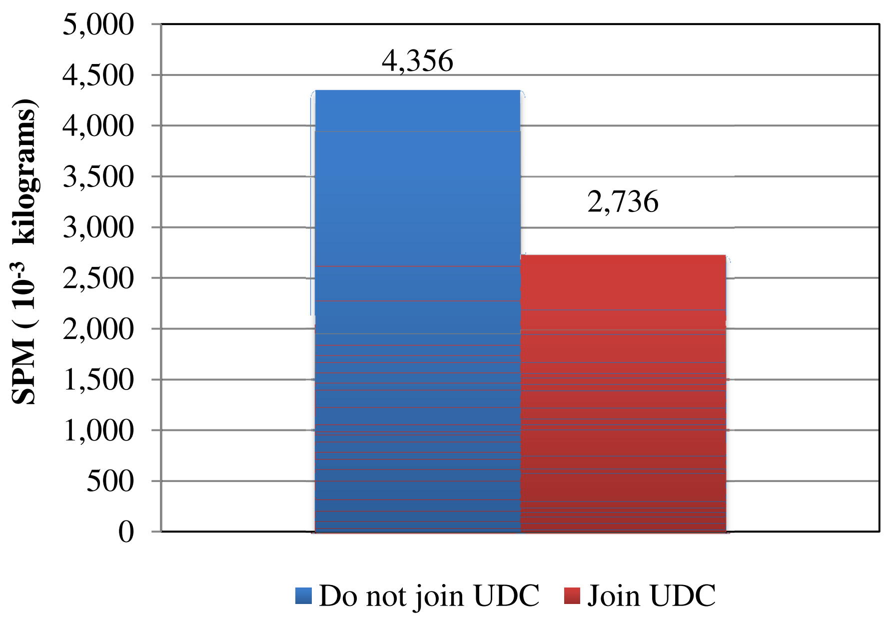


Figure 5.24 SPM emissions comparisons for 360 days at carrier learning rate 0.1

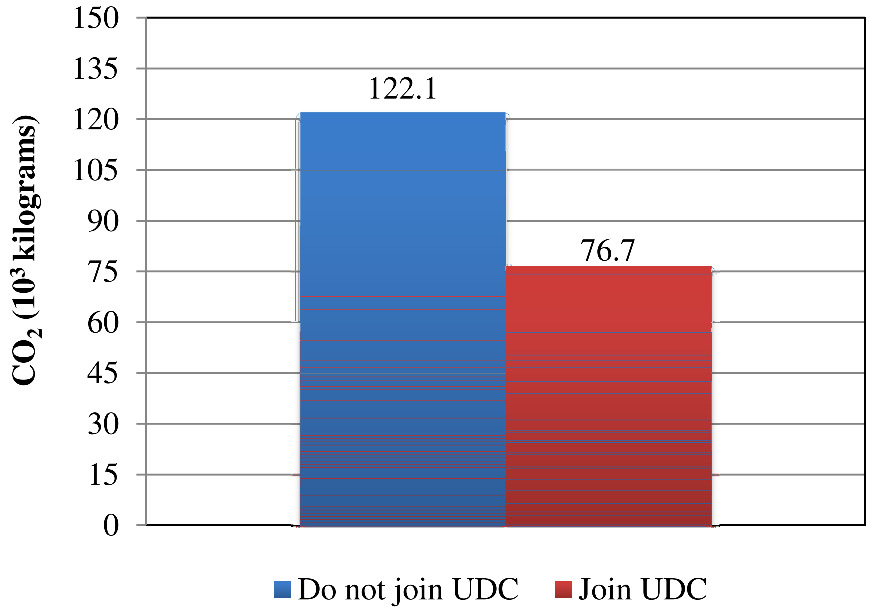


Figure 5.25 CO_2 emissions comparisons for 360 days at carrier learning rate 0.1

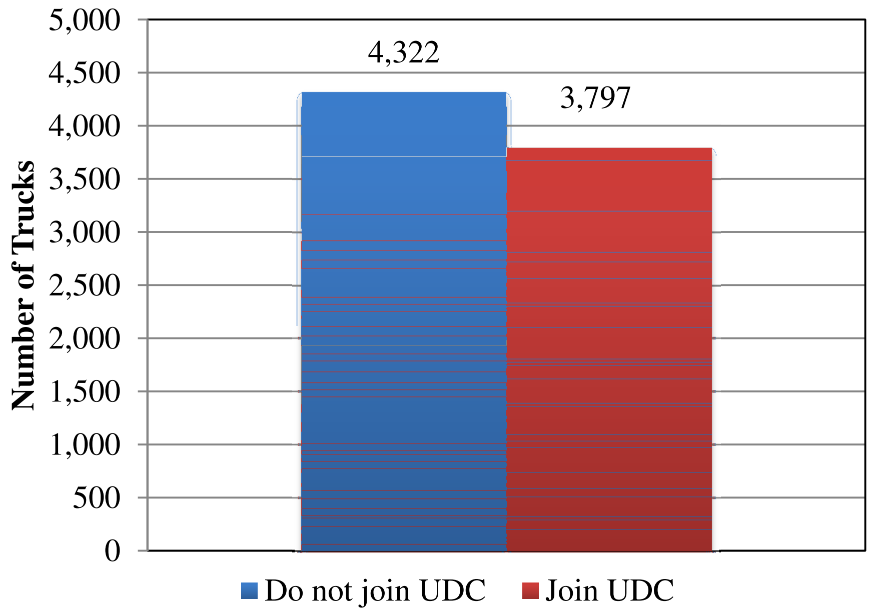


Figure 5.26 Number of trucks comparisons for 360 days at carrier learning rate 0.1

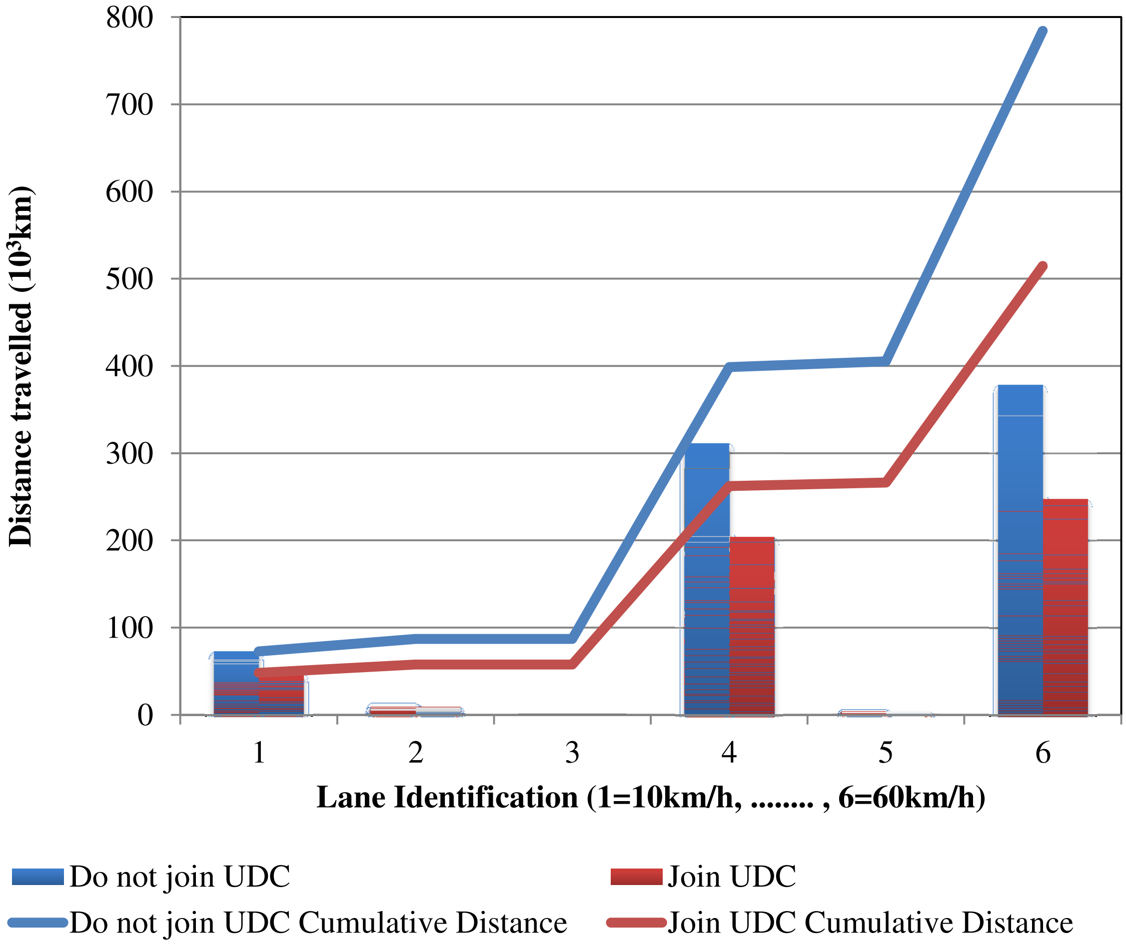


Figure 5.27 Distance travelled comparisons for 360 days at carrier learning rate 0.1

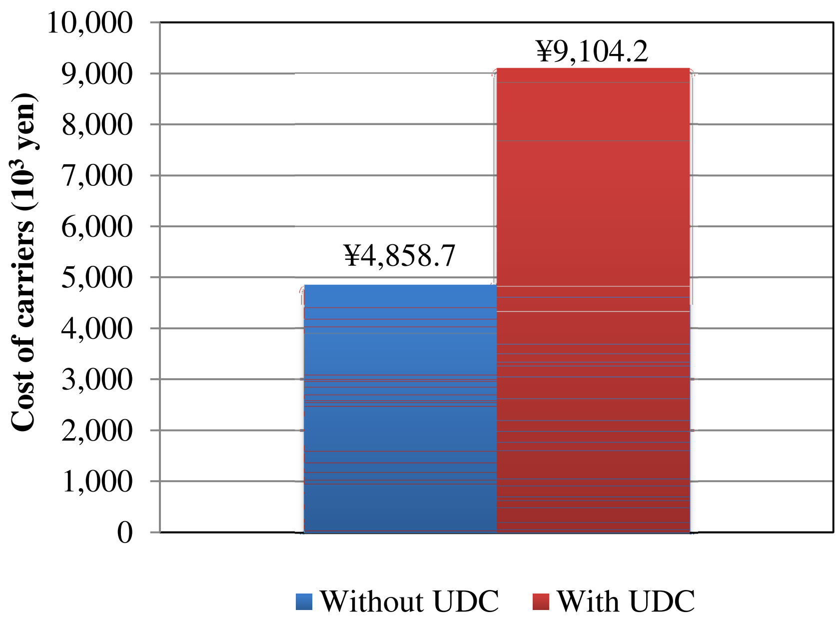


Figure 5.28 Cost of carriers for 360 days at carrier learning rate 0.1

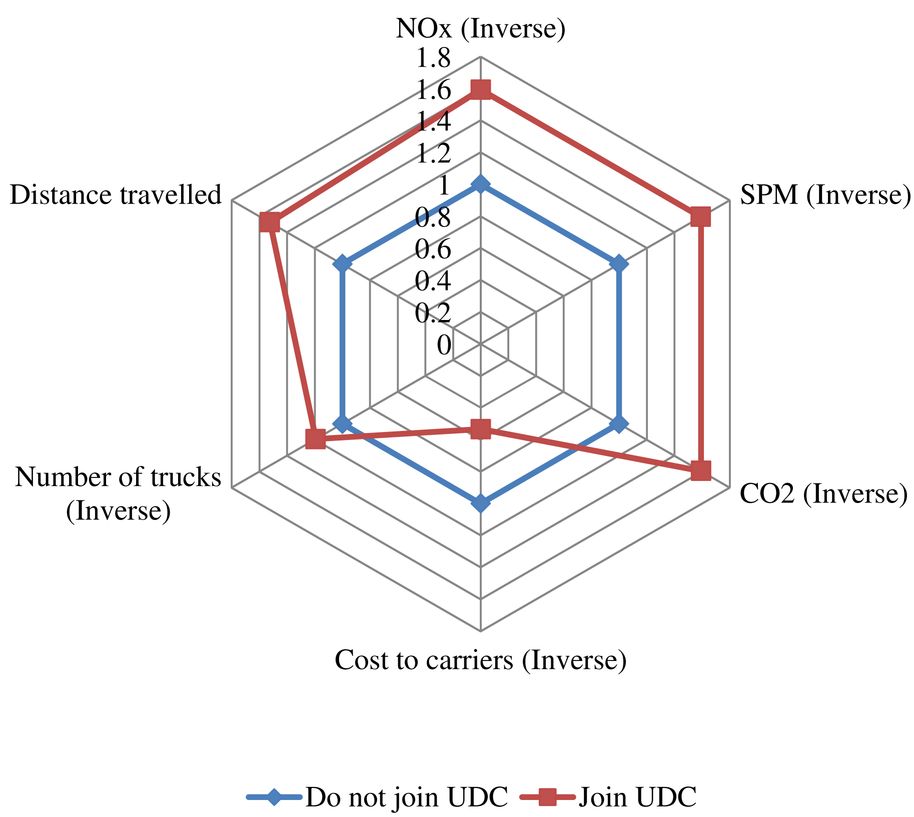


Figure 5.29 Radar plot of performance measures with UDC for 360 days at carrier learning rate 0.1

A comparison of the frequency of link passes is done between Figure 5.30 and Figure 5.31. It is shown in Figure 5.31 that some of the links have reduced the frequency of passes due to the presence of UDC which may lead to possible reduction in congestion in that area, especially for zones designated for or close to residential.

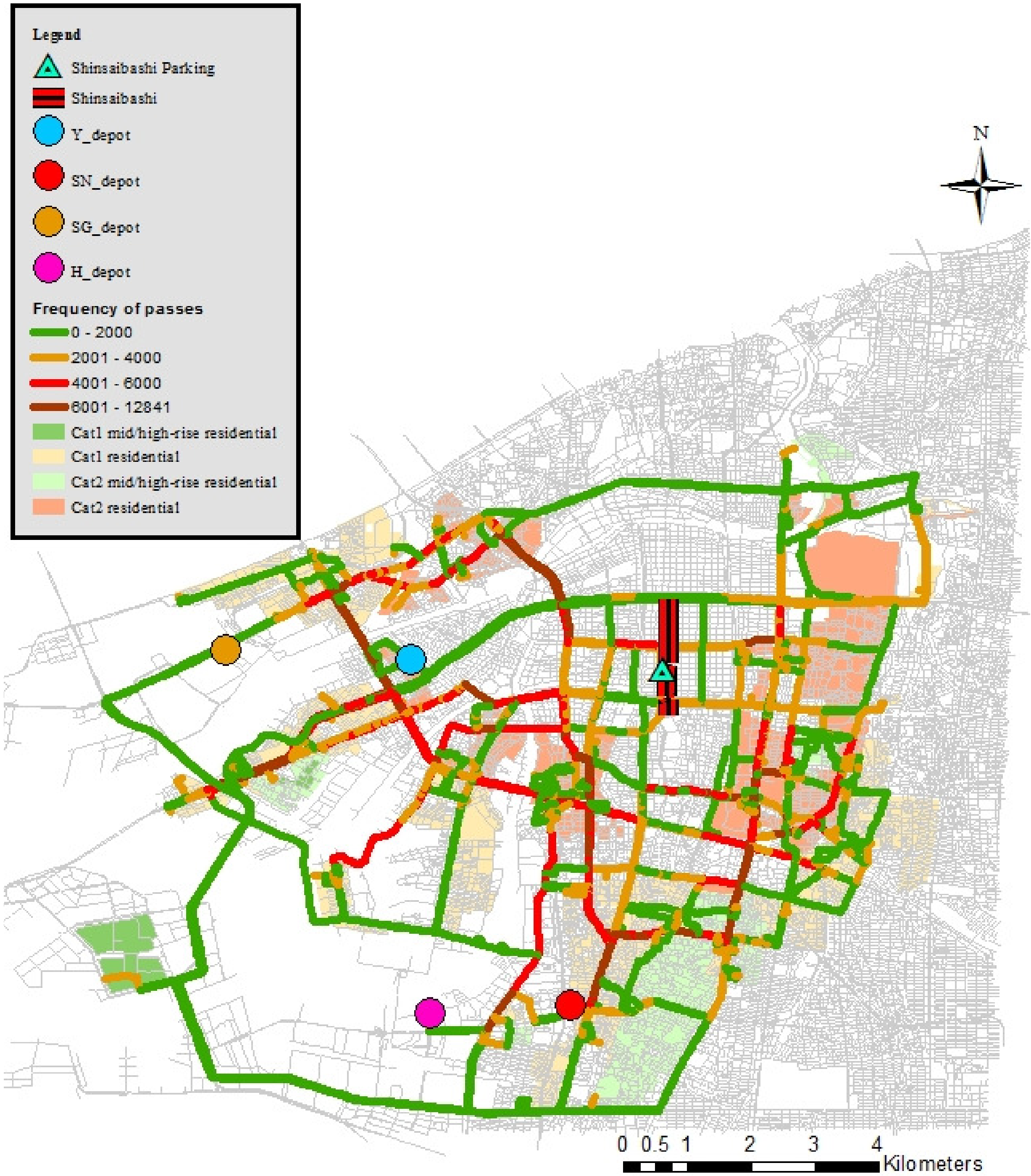


Figure 5.30 Link use frequency for base case for 360 days

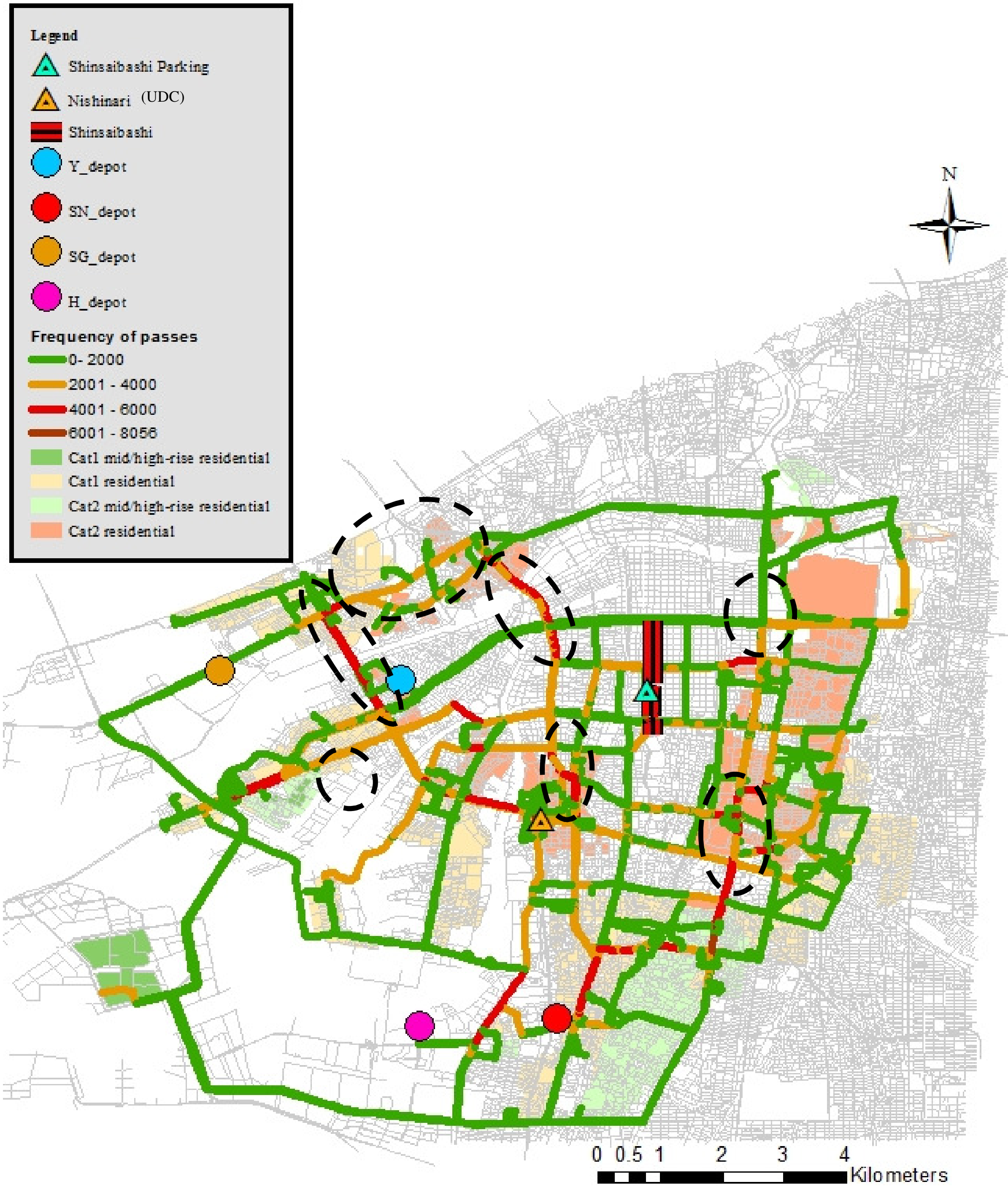


Figure 5.31 Link use frequency for with UDC case for 360 days (congestion relief locations)

5.5 Considerations for data collection in future

(1) General assumption for consideration

Since no real truck movement data is collected for this initial experiment, the following considerations are recommended for subsequent analysis when data like the probe data of truck movement becomes available.

Even with the probe data of truck delivery operations, there will be limitations in determining the locations and demand precisely and certain steps are required to obtain useful information for computation purposes and to compare the results.

a) Locations

The locations of each depot's customers can be based on the start and stop trip of the delivery truck. However, this starts and stop trip data may consists of signal stops or temporary stops for other purposes. To eliminate such data in the analysis, any trips with duration of less than 80 seconds between the stop trip and the next start trip should be removed.

b) Demand

The demand at each customer location during probe data collection may not be easily available due to privacy issues. A possible method to determine demand at customer locations can be based on the equation (5.1). The capacity of the truck in the vehicle routing problem with time window (VRPTW) computation can be the common capacity of the trucks used by all carriers during the data collection like a 3 ton truck and the truck load factor of 60% can be assumed. This load factor is set as a threshold measurement for a scheme named City Goods Ordinance in Copenhagen from February 2002 to 31 October 2003, which issued a green certificate if the trucks achieved a load factor of more than 60% over a 3 month period and an engine that met the criteria of not being older than 8 years (Kjaersgaard & Jensen, 2004).

$$d_i = q \times lf \times \frac{st_i}{\sum_i^N st_i} \qquad \forall i \in N \qquad (5.1)$$

where,

d_i = demand at customer *i*

q = capacity of truck

lf = load factor

st_i = stopping time at customer *i*

N = set of customers

c) Time window

The time window of customers may not be available during the data collection since it may also be classified by the private carriers. An assumption can be made for the time window requested by the customers for the VRP computation. Figure 5.32 shows the illustration of the soft time window with 10 minutes before the truck stopping time as early time window and 10 minutes after truck departure as the late time window.

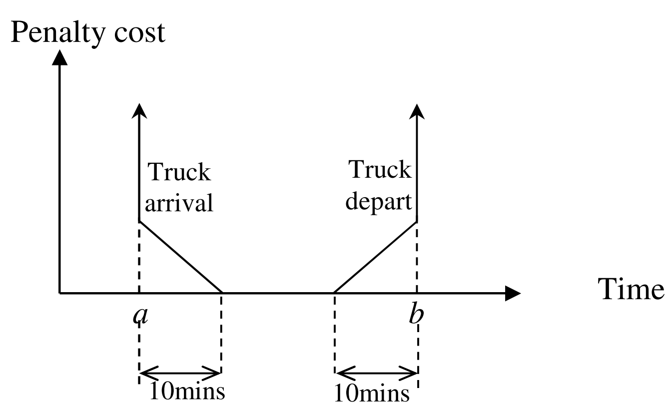


Figure 5.32 Time window assumption for carriers' customers

5.6 Summary

In this research, the MAS model was used to evaluate the delivery cost and environmental effect of present the UDC the real situation of the Osaka road network.

The experiment can be concluded that the freight carrier delivery cost was not reduced because of the implemented UDC usage charge. To deal with this purpose, the discount service charge and the subsidy from the administrator can be fulfilled. The environmental impact for implementing UDC in Osaka city, the urban freight emission reduction is achieved from the reduction in distance travelled resulting from the replacement of individual delivery to consolidated delivery with the presence of an UDC.

References

Crainic, T. G., Ricciardi, N. & Storchi, G., 2009. Models for evaluating and planning City Logistics systems. *Transportation Science,* Volume 43, p. 432–454.

Kjaersgaard, S. & Jensen, H. E., 2004. *Sustainable city logistics solutions..* Madeira, Portugal, pp. 441-448.

Taniguchi, E., Thompson, R. G., Yamada, T. & van Duin, J. H. R., 2001. In: *City Logisitics: Network Modelling and Intelligent Transport Systems,* The Netherlands: Elsevier Science Ltd.

Technical committee, 2012. *Technical committee B.4 freight transport and intermodality,* Public sector governance over urban freight transport.

Wangapisit, O., Taniguchi, E., Teo, J. S. E. & Qureshi, A. G., 2014. Multi-Agent Systems Modelling for Evaluating Joint Delivery Systems.. *Procedia-Social and Behaviour Sciences,* Volume 125C, pp. 472-483.

6

CONCLUSION AND FUTURE RESEARCH

6.1 General

According to the increasing of shoppers and changeable shopping life style, the shopping centers and shopping streets are attached the shoppers into the urban areas. The area around the shopping center and shopping street might be crowded with pedestrians, private vehicles and freight trucks. Theses cause the environmental problems such as nuisance, truck emissions and suspended particular matter (SPM). Besides, illegal parking frequently occurs in shopping streets especially for the loading/unloading activities which affect the health of inhabitants who live around the shopping areas. The problem highlighted contributes to our interest to identify the possible policies to resolve the effects due to an increase in freight traffic and truck emissions. The MAS approach of modeling city logistics is widely recognized as a way of modeling individual agent behavior and interaction while gradually expanding the model to cover all agents within a system. This approach wishes to discover the evolving behavioral phenomenon among agents, which possible for other modeling approaches to accomplish. The multi-disciplinary nature of MAS approach provided a form of flexibility in terms of modeling as different theoretical model can be experimented to give a close to reality evaluation of problems. A modified MAS learning model is developed in this research which combine by two main modules. Firstly, the vehicle routing problem with soft time window model (VRPSTW) can determine the optimize routing using genetic algorithm and reinforcement learning model. Secondly, the Q-learning for shopping and home delivery is added to incorporate a decision making and the interaction of major stakeholders, including freight carriers, neutral carrier, residents, shop owners, administrator and shopping street association. The selected city logistics policies were evaluated to consider the economic and social effect from freight delivery due to the appearance of the UDC.

6.2 Evaluated city logistics schemes for ascent the JDS participate

The presence of UDC and parking space restriction were identified as possible city logistics policy measures to decrease the environmental effect of the truck travelled from freight carrier depot to their customers. The MAS learning model was initially setup to include the JDS as representative of freight carriers and neutral carrier interaction to ensure that delivery cost was minimum. The reinforcement Q-learning model has been used in this research to test the developed MAS model and to perceive the freight carriers and neutral carrier interaction in the urban freight delivery. It is challenging to determine the agents learning objectives when each agent may be required to learn what other agents are learning or thinking. Learning by carriers influenced the performance of the UDC and its sustainability within the multi-agent model, compared to the model without learning. The low learning rate meant that a carrier is more pessimistic towards its perception of new information. In current study, it shows that a higher learning rate of carriers may lead to lower participation rate of the UDC and may take a longer time to attract them to use the UDC again. Therefore, the joint decision making and cooperate behavior can be attained.

The preliminary results from the freight carrier's learning showed the potential of reducing truck emissions level for example NO_x, CO_2 and SPM in the city when the freight carriers learnt and priced each link in the test road network based on the outcome of past actions and future rewards. Operating cost, number of trucks and distance travelled were reduced, which leads to a better environmental when UDC was implemented. In contrast of the practical road network economic viewpoint, the freight carrier delivery cost was not reduced because of the implemented UDC usage charge. To deal with this purpose, the discount service charge and the subsidy from the administrator can be fulfilled. A higher unit price of parcel for using UDC increase carriers' cost and reduce the carriers' participation in the joint delivery system. Therefore, subsidies can play importance in the sustainability due to its contribution for better environmental effect. The presence of joint schemes of UDC and parking space restriction were identified as potential city logistics policy measures to decrease the negative environmental effect and number of trucks used.

6.3 Limitations and challenges of MAS learning model for city logistics

The implementation of the UDC and parking space restriction in this study do not encompass the overall city logistic benefit. It can prove that the UDC is disadvantage in term of economic viewpoint either in hypothetical or real road networks. To increase the performance of city logistic measures, the further studies are considered to understand the diversity of freight policies such as UDC location and UDC subsidize.

Due to the MAS model of the UDC and parking space policy measures do not represent the overall city logistics. The real data is needed to verify and ensure that these policies are worthwhile for implementing. Nevertheless, the MAS learning model can be validated by the experts who has experiences, principle knowledge and assumptions. This method has done by other researchers where they interviewed the experts and practitioners in the field of transportation and freight logistics.

6.4 Future research

This research is limited due to the availability of customer' demand, time window, the real data from the freight carriers and actual UDC service charge, which may be useful to analyze more realistic behavior of UDC participation.

To ensure the logistics stakeholders behavior, the other machine learning technique could be apply to measure in future.

Delivery in vertical shopping area like a Matenro at Shinjuku, Japan is interested to be studied the behavior of logistics stakeholders.

APPENDIX A

LIST OF ABBREVIATIONS

Abbreviation	Full Expression
ABS	Agent-based simulation
CO_2	Carbon dioxide
CVRP	Capacitated vehicle routing problem
DP	Dynamic programming
EOQ	Economic order quantity
GA	Genetic algorithm
GIS	Geographic Information Systems
JDS	Joint Delivery Systems
LFC	Load factor control
MAS	Multi-Agent Systems
MDP	Makrov decision process
MC	Monte Carlo
NO_x	Nitrogen oxide
SPM	Suspended particulate matter
SSO	Shopping Street Association
TAPAS	Transportation and production agent-based simulator
TD	Temporal-difference
TSP	Travelling salesman problem
UDC	Urban Distribution Center
UTC	Urban Traffic Control
VICs	Vehicle Information and Communication Systems
VRP	Vehicle Routing Problem
VRPHTW	Vehicle Routing Problem with Hard Time Window
VRPSTW	Vehicle Routing Problem with Soft Time Window
VRPTW	Vehicle Routing Problem with Time Window
VRPTW-D	Vehicle Routing Problem with Time Window -Dynamic
VRPTW-F	Vehicle Routing Problem with Time Window -Forecasted