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Special Issue on “Urban Simulation and Modeling”
Guest Editor: Yan Liu and Anrong Dang

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Editorial introduction

Special Issue on "Urban Simulation and Modeling"

Guest Editors:

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Since the turn of this century, cities are homes to more than half of the world's population even though they cover only three per cent of the Earth's land surface. Cities are often the fast-growing innovation and socio-economic hub of a region; however, they also face the challenge of finding new space to accommodate the increasing number of urban habitants. While there has been a long tradition of urban modelling in geography and transportation research to understand urban growth dynamics and identify new growth directions, with its roots in both social physics and urban and regional economics, considerable globally efforts are being expended in developing models to understand how cities grow and evolve. However, urban modelling is still challenged by a diversity of methods, metrics, indicators and data (OECD 2011). After all, cities are places where people come together to interact with one another and therefore our understanding on the evolution of cities must be enriched by studies of networks, interactions, connections and transactions (Batty 2013). Thus, this special issue focuses on modelling the various aspects of urban dynamics ranging from urban evacuation modelling, agent-based simulation for on-line meetings to the modelling of truck driving and residents' outdoor recreation behaviours, all of which contributes to enhance our understanding on the interaction of urban individuals which shape the form and outcome of our cities.

The first paper by Li and Deng *et al.* (2015) presents a traffic model to simulate evacuation scenarios under various environment configurations. Developed and implemented using NetLogo on high performance computing platform, their model was used to evaluate drivers' evacuation performance and identify the best evacuation strategy in an emergency situation. By analysing a number of metrics including the evacuation time and average car speed for each strategy under different population distribution patterns, their results show that the model could reveal an effective evacuation strategy for realistic scenarios.

The second paper by Ma *et al.* (2015) introduces a conceptual design of an integrated agent based model (ABM) with an online decision making meetings (ODMM) model for sustainable management of water resources. This integrated modelling platform consists of a remote server, a number of clients representing several agents related to water resource management who will communicate with each other through online meetings, as well as an agent based simulation model for processing of data collected from the clients. On the one hand, the clients can set up global parameters based on their roles and policies for the simulation model to generate output scenarios. On the other hand, the ABM also supplies the clients with simulated policy outcomes in visual form which can facilitate online discussion, communication and decision-making. It is expected that this online simulation and decision making tool can help government department to share their views and visualise the policy outcomes, thereby making informed decisions and policy implementation.

Ando and Mimura's (2015) work tries to understand the driving behaviors of garbage truck drivers in Japan. Using survey data collected in Toyota City in Japan, their analyses show significant correlation between the drivers' personalities and consciousness, and the traffic accidents they experienced. In particular, truck drivers have a lower probability of looking aside and becoming irritated when driving the garbage trucks than private car drivers and drivers feel more difficult to drive on community roads in residential areas than on trunk roads. While further study is needed to confirm their findings in other city context, the results from this study alert important traffic safety measures on community roads.

Jiao *et al.* (2015) presents an integrated model to explore the spatial distribution of outdoor recreation trips of urban residents based on their case study in Salford, UK. Using annual household travel survey data collected between 2009 and 2013, their work modelled two types of recreation trips using logit discrete choice modelling approach; a) predominantly local trips; and b) predominantly non-local trips. Their results show that the choice of destinations for local trips is strongly influenced by travel time and socio-economic profiles of households, and relatively weakly influenced by the size of the greenspace. In contrast, the destination choice of non-local trips is strongly affected by greenspace size. While other factors such as the type and other attributes of the greenspaces need to be further investigated in to model, their work can be extended to offer policy intervention regarding the allocation and design of urban greenspaces.

The last paper by Li and Shen *et al.* (2015) presents a practical project which attempts to offer a solution to address the indoor space insufficiency of low-rent housing development based on China's Green Construction Standard for residential environments, using Tianjin city as a case study. Following interviews with the local residents and analyses of the characteristics of the residences towards housing space usages, their work shows that the low-rent housing space can be reorganised by shifting insufficient indoor functions to the outdoor space, a more cost-effective approach than rebuilding an area for residential improvement.

This special issue is one of the outputs of the biannual International Conference on Spatial Planning and Sustainable Development held on 30 August to 1 September in 2013 at Tsinghua University, Beijing, China. We would like to express our sincere gratitude to the researchers who joined the conference and submitted their works to our journal. Special thank you goes to Professor Qizhi Mao who organized the conference as the Chairman of SPSD2013. We would also like to express our sincere gratitude to the reviewers who gave us their most generous support on reading and commenting on the papers. We hope all our efforts would contribute to a more sustainable world.

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Evacuation Simulation and Evaluation of Different Scenarios based on Traffic Grid Model and High Performance Computing

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Key words: Evacuation Simulation; Traffic Model; Agent Based Model; High Performance Computing(HPC)

Abstract: This paper describes the design and implementation of an evacuation simulation model developed based on the Traffic Grid Model in NetLogo. In this model, different scenarios were tested in order to find out the best strategy within specific environments. The model is flexible and includes many parameters to adjust to environment conditions and agent rules. These parameters can be modified to study which driving factors contribute most to drivers' evacuation performance. This research also focuses on the method of results analysis and traffic performance evaluation for different combinations of two model parameters. In each experiment, we analysed metrics such as evacuation time and average car speed for each strategy under different population distribution patterns. The results showed that this model could reveal an effective evacuation strategy for realistic scenarios.

1. INTRODUCTION

Evacuation is an important issue in emergency situations; effective egress routes can decrease evacuation time, protect people's safety and minimize loss. There has been much research concentrated on evacuation planning. Evaluation of traffic operations during an evacuation is critical for assessing the effectiveness of a plan, including evacuation time and traffic congestion (Jha, Moore, et al., 2004). However, the evaluation requires an estimation of evacuation results for different plans, which can be simulated through traffic models. If the evacuation strategy for a specific environment can be simulated prior, or the congestion could be predicted, it will assist in getting better solutions for realistic problems.

Simulation is a very effective way of finding solutions for complex problems (Champion, et al., 1999). In the simulation models, egress routes and evacuation effectiveness can be implemented and evaluated rather than using empirical tests of their claims (Kuligowski and Erica, 2003). Nowadays, a large amount of literature focuses on models and methods for evacuation simulation, and there are many types of classification from different perspectives based on different research fields. According to different methods of representing reality, these models can be classed as continuous or discrete. Most of the continuous models use equilibrium equations to describe object change; while discrete simulations treat reality as discrete events or discrete time states, so states or events happen in each time interval (Champion, et al., 1999; Algers, et al., 1997; Schulze and Fliess, 1997). According to mainstream realization methods, the simulation models include flow based, cellular automata, agent-based, multi-agent based and activity-based models (Santos and Aguirre, 2004), with each model having its own merits and disadvantages. Depending on how detailed the information is in the model, models can be simulated on microscopic, mesoscopic or macroscopic levels (Sheffi, Mahmassani, et al., 1982) and the choice should always depend on the requirements for accuracy, calculation speed or study region scale. According to whether the experiment results need to be reproducible, there are stochastic or deterministic models corresponding to their different strategies for simulating randomness (Champion, et al., 1999).

The conventional models use static analysis on the macro simulation level and are quite limited for a real time simulation. With the development of computer technology, many complex models can be realized in a more vivid way using computers. Nowadays, individual based modeling and agent based modeling are widely used for micro modeling. Interaction rules and behavior patterns are studied in this kind of model, which enables us to simulate different types of agents which are driven by different behavior patterns. When every individual is given some simple interaction rules, the behavior patterns which were not programmed into the agents will emerge when many agents are simulated as a group; which is known as emergent phenomenon (Ferber, 1999). Therefore, agent based modeling is suitable for simulating complex systems and studying complexity. In this research, we chose agent based modeling to simulate an evacuation model because it provides flexibility to various parameters of the agents and environment easily, from which the user can gain results in real-time and test different parameter combinations.

We built this agent based model based on a software platform according to agent based modeling practice, which includes seven stages: brainstorming, theory, hypothesis, flowchart, code, analysis and publishing (The Institute for Modeling Complexity, 2004). This paper introduces a modeling process following the model design and development phase at the software level. After model realization, the method to evaluate the experiments' results is illustrated.

2. MODEL DESIGN

Model design is the first important stage for simulation, which includes listing critical components of the model, representing main objects using some parameters or properties, and describing processes and interactions abstracted from real world. The model is described according to the Overview, Design concepts, and Details (ODD) protocol, which is a standard used for the description of agent based models (Volker, Uta, et al., 2010).

2.1 Model components

This model contains three important components, the individuals, environment and process. Individuals correspond to the agents that are moving and reacting in the model, they have their specific behavior and movement rules. The environment provides the basic platform for individuals' activities; it also specifies the boundary and restrictions. Process is another important component in the model; the process needs to be kept simple and yet close to reality. Processes can be designed quite differently for different study objectives.

2.1.1Individuals

Two kinds of agents are included in this model. One is a super agent, an abstract agent, who takes charge of the work assignment and process; the other one is a normal agent, the car, which represents the evacuation entities. They will move forwards according to their speed, which is determined by the traffic situation and restricted by cars in front.

2.1.2Environment

Environment in this model includes blocks and roads. The basic spatial component unit for the environment is cells. Different blocks may have different population sizes, cars will park in blocks and run on roads. While the simulation is running, each road cell will be either empty or occupied by some vehicles.

2.1.3Process and scheduling

This model uses discrete time intervals to simulate events changing in the real world; the basic temporal unit is a tick. In the beginning, the whole model will begin scheduling. During the process, each agent will follow its rules to move and change. The states of all the objects will be checked and updated after each tick.

2.2 Unified Modeling Language(UML) diagrams

2.2.1Class diagram

An object oriented method is used to design the objects and procedures in this model. UML standards are implied in describing the model. The main classes in the model are shown as follows, the attributes for all the agents are quite straightforward. Cars are moving agents in the model, there are three different states for cars, one is parking in blocks and waiting for evacuation, one is waiting on the roads and blocked in a traffic jam, the other is moving on roads. Speed and wait-time can describe the features of cars during the evacuation process. Each car is able to turn at intersections, accelerate and decelerate, and when it arrives at its destination, it will disappear from the environment. Some other functions are designed to check the states of the cars, whether they are stopped or have reached destinations. Super agent is an abstract class, which will take charge of the arrangement of work to update the environment for agents. It can allocate cars on the road, and change the traffic lights. Cars belong to different blocks, which have block IDs and population information. Roads have limitations on car speed, intersections are the overlay cells of different roads, and the traffic lights are set near the intersections. Destinations are set on intersections, so some of the intersections are assigned as destinations. The relationships between different classes are also shown in Figure 1, below. Blocks and roads are composed of many cells; many cars can park in each block.

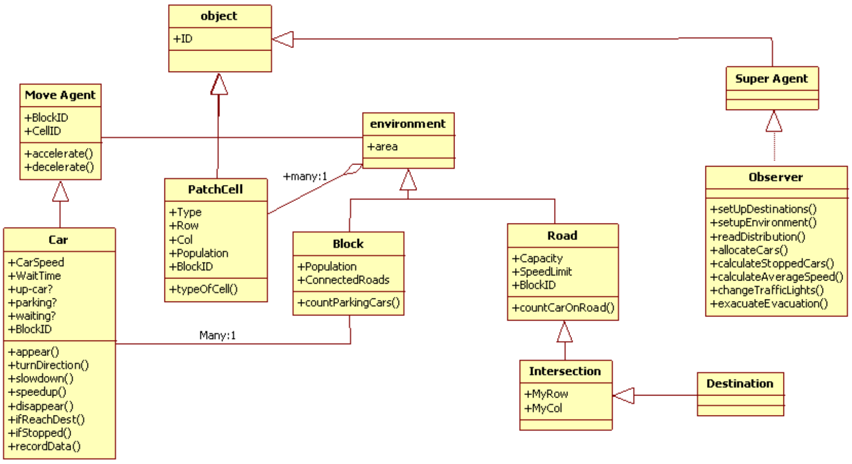


Figure 1. Class diagram of the model

2.2.2Sequence diagram

Sequence diagram is a kind of UML diagram that shows the flow of procedures which are executed in the model. It also shows how different agents interact with each other. The sequence will repeat during the simulation, until the model reaches its stop condition, for example, all the cars have already evacuated. In the "setup()" procedure, the environment will be set up, the cars will be allocated on blocks' roads according to which block they belong to and the road capacity. During the "go()" procedure, cars will move according to their action rules and their performance will be recorded. Then cars' states will be checked after their movement, if they reach the destinations they will disappear from the environment. See Figure 2, below.

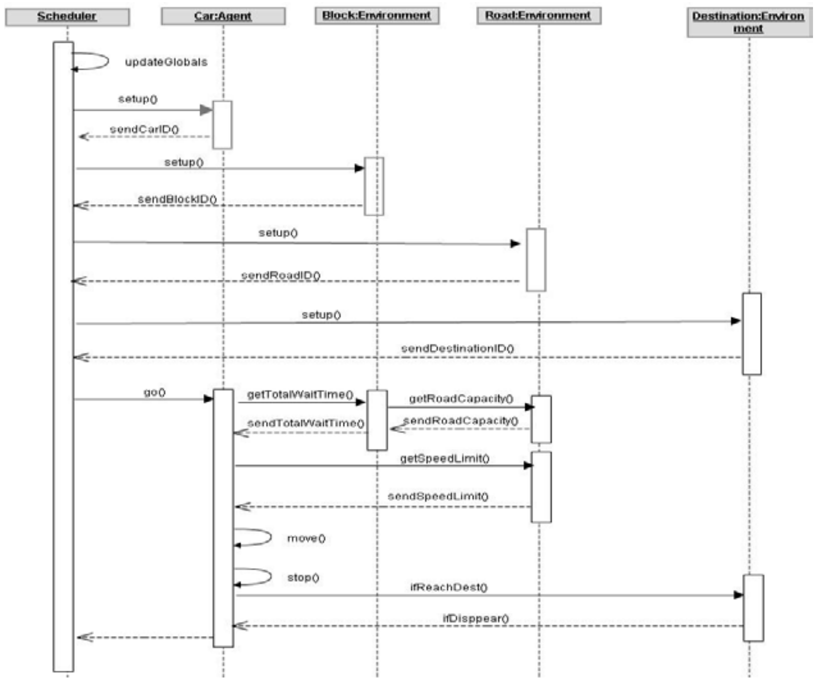


Figure 2. Sequence diagram of the model

2.3 Model platform

There are many types of platforms on which agent based simulations can be realized. There are integrated development environments (IDEs), toolkits and libraries. Models can be built, coded and run on these platforms, which usually utilize their own graphical interface and use abstract languages for model builders to interact with the model. Some popular toolkits and software such as Swarm, Repast, MASON and Cybele are widely used, they are all free open source and easy to use. It is important to compare and choose a platform after considering the time cost for learning and issues that may be run into during modeling. Existing research can be referred to for choosing models (RAILSBACK, et al., 2006).

We used NetLogo as the modeling platform. It is written in Java and free for use. It provides a friendly user interface to enable users to build any number of agents and change environmental setup of the world. This software is widely used by students and researchers to explore agent based modeling for its low programming requirements. It has a massive model library, which contains many model examples covering different disciplinary and research regions. Users can modify the models for their own research objectives. NetLogo includes some existing traffic models and the model of this current research is developed based on the traffic grid model in NetLogo.

The simulated world in NetLogo is composed of patches and turtles. Patches are arranged in grids, which have fixed locations. Turtles are individuals that can move on patches, they have their own properties to enable them to form their characteristics and behavior rules. The programming for this research was based on the two components of this platform, using turtles to simulate cars, patches to represent roads, blocks and destinations. The movement and action of each car is written in the car procedures. In NetLogo, scheduling works on every minimal time unit in the form of ordering agents to complete their procedures by turn.

3. MODELING REALIZATION

3.1 Environment preparation

The roads and blocks are set up as an evenly distributed grid pattern. The pattern is shown in Figure 3, below. Blocks are initialized with different populations, which show in the number of cars. Each block has two roads surrounding the block, one is below and the other one is to the right side of the block. Roads are set up as white cells; they are initialized with the same capacity and speed limit. Capacity is used to control how many cars can be put on the roads and is represented as the percentage of road cells occupied by cars. When the super agent allocates the cars, it randomly picks a number of cars from the blocks and sets them on the blocks’ roads. In Figure 3, we can see that cars have different colors according to their block ID, and they can only be arranged on the two roads of their blocks. Traffic lights are set near the roads’ intersections, in green or red; the destinations are set on the intersections on the right side of the simulated world, which are the blue cells.

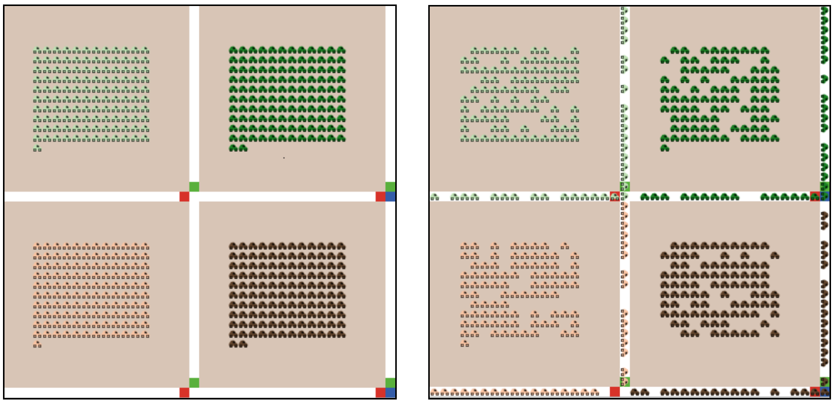


Figure 3. Environment initialization

3.2 Vehicle simulation

In this microscopic simulation, cars can respond individually to traffic situations. Roads in the model are one directional, so cars can only move to the right or move down. The speed of cars is set based on the basic rule of avoiding collision. For each car, it can speed up or slow down; meanwhile, we assume that a car can always stop immediately. The speed limit is the possible maximum speed for each car. The algorithm for car speed is, if there is a car in the patch ahead, slow down, or else speed up using acceleration, but all the cars are restricted by maximum speed. When the cars come to an intersection, they must stop if they encounter red traffic lights. Cars can also turn at intersections according to the traffic conditions, if they are blocked at an intersection they are more likely to turn in another direction.

3.3 Strategy simulation

Staged strategy is used in this paper; three kinds of strategies for this model are considered here. The first one is to evacuate simultaneously, the second one is for cars nearest to the destinations to go first, and the last one is for the cars furthest away from the destinations to go first. The strategies are realized by arranging blocks in a particular order and controlling the start time for each block using the time interval parameter. The evacuation order under different strategies is shown in Figure 4, below. The blue point is the destination, the number represents the order of evacuation.

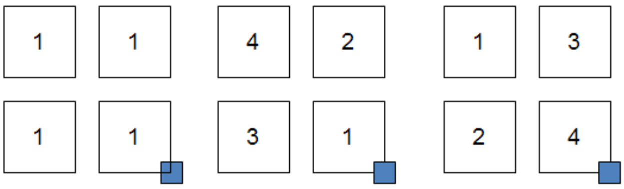


Figure 4. Evacuation order for different strategies

4. DESIGN OF EXPERIMENTS

4.1 Evacuation scenarios

In this research, the different combinations of road pattern, population distribution and evacuation strategy are considered as scenarios. In this experiment, the roads are set as a grid pattern; six columns multiplied by six rows of blocks in total. We designed three kinds of population distribution, including an even, distance and inverse distance distribution. Based on these distributions, the three kinds of evacuation strategies were tested.

4.2 Model parameters

We design some parameters to increase the flexibility of the model. All of the parameters can be changed through the graphic user interface of the model. So that users may adjust the values and study on the effects of different parameters. In the experiment, we only change two parameters, and set other parameters unchanged, shown in Table 1.

Table 1. List of Parameters

Name	Definition	Value
grid-size-x	Number of blocks in horizontal direction.	6
grid-size-y	Number of blocks in vertical direction.	6
capacity	The limitation for cars on the road.	0.7
time-interval	Time interval for different blocks to evacuate.	20
num-dest	Number of destinations.	4
distribution-pattern	Population distribution pattern (three types).	Adjust
evacuation-strategy	Different evacuation order for blocks (three types).	Adjust
speed-limit	Speed limit for cars.	1.0
ticks-per-cycle	To control the traffic lights' cycle.	15
show-distribution	Whether to show distribution graph as background.	no

4.3 Recording of metrics

During the running of the model, some metrics are monitored in order to evaluate the performance of each experiment. Some of the metrics were recorded from the monitor windows of NetLogo; some were only observed.

Table 2. Metric List

Name	Definition	Record
Total Cars	Number of cars in the model.	No
Waiting Cars in Block	Number of cars which are parked around the blocks, waiting for evacuation.	No
Waiting Cars	Number of cars which are blocked on the roads.	No
Cars on Evacuation	Number of cars which are on the roads.	No
Roads	The total area of roads, which are composed of patches.	No
Evacuated Cars	Number of cars which have arrived at destinations.	No
Stopped Cars(SC)	Total number of cars which are stopped on the roads.	**Yes**
Average Speed of Cars(ASC)	Average speed for all the cars which are evacuating.	**Yes**
Average Wait Time of Cars(AWT)	Average waiting time for cars.	**Yes**
Evacuation Time	The total time for all the cars to evacuate.	**Yes**

4.4 Experiment running

In this research, the experiments were run in NetLogo based on high performance cluster, using VIPER Queue, from the University of North Carolina, Charlotte (UNCC). The programs are encapsulated in different jobs and are automatically sent to queue. Once the experiments are set up and parameters are modified, the whole process will run multiple times on different nodes. After that, results can be achieved on the queue; instead of waiting by the computer for the duration of the experiment, results were achieved from the queue after about 30 minutes. It is much faster than running all the experiments in the windows' operation environment manually.

5. RESULTS AND ANALYSIS

5.1 Evaluation method

Different metrics have different units and ranges of values. In order to get an overall evaluation result, the values need to be standardized, and then the metrics aggregated. In this model, the extreme value standardization method is used and then the weighted summation method is employed to achieve an overall evaluation result. Two types of metrics are summarized using the different formulas shown below. The weighted summation formula is:

Evaluation Score = w1×Evacuation Time + w2×Average Speed + w3×Average Wait Time + w4×Stopped Cars.

In this research, the weights are set as 40, 30, 20 and 10 according to the importance of the metrics; Evacuation Time (ET) is assumed as the most important metric. After this standardization process, all the data for metrics will be in the range of 0 to 1. The overall evaluation score for one experiment will be in the range of 0 to 100.

Table 3 Standardization

Type	Metrics	Formula
Positive	Average Speed of Cars	x = (x-Min)/(Max-Min)
Negative	Evacuation Time Stopped Cars Average Wait Time of Cars	x = (Max-x)/(Max-Min)

5.2 Results from experiment

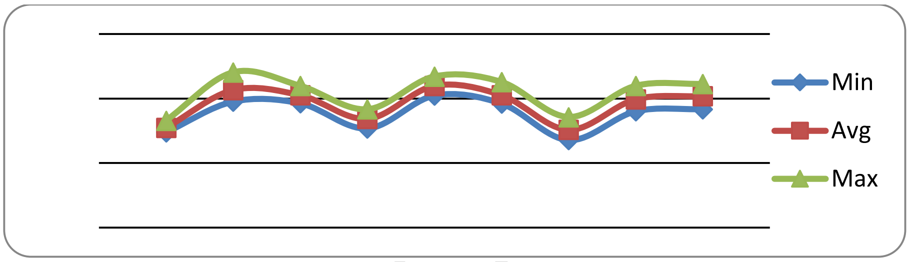
Each experiment was run 20 times, which is acceptable for the conditions of the Monte Carlo test (Marriott, 1979). The results are concluded as maximum, minimum and average values of the 20 repetitions, and the average values are used to compare the performances of the different experiments. The results achieved for different scenarios are shown below in Table 4.

Table 4 Results for simulation scenarios

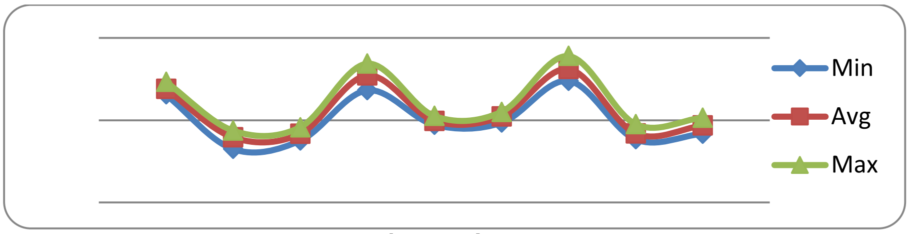
	Type	Evacuation Time	Stopped Cars(SC)(Avg)	Average Speed of Cars(ASC)	Average Wait Time of Cars(AWT)
	Min	1476.00	656.54	1.53	0.73
exp1	Avg	1545.95	689.74	1.62	0.74
	Max	1656.00	734.51	1.68	0.75
	Min	1952.00	325.56	1.29	0.60
exp2	Avg	2129.95	396.37	1.38	0.62
	Max	2406.00	437.64	1.45	0.64
exp3	Min	1926.00	376.40	1.31	0.60

	Avg	2050.38	418.03	1.37	0.61
	Max	2196.00	457.64	1.44	0.63
	Min	1536.00	682.40	1.60	0.73
exp4	Avg	1685.19	772.12	1.67	0.74
	Max	1832.00	844.66	1.77	0.76
	Min	2046.00	472.68	1.24	0.56
exp5	Avg	2196.43	496.49	1.28	0.58
	Max	2342.00	526.49	1.34	0.59
	Min	1922.00	484.98	1.39	0.63
exp6	Avg	2051.24	523.27	1.44	0.64
	Max	2256.00	550.98	1.51	0.65
	Min	1356.00	739.69	1.47	0.66
exp7	Avg	1515.81	810.80	1.53	0.68
	Max	1712.00	890.75	1.62	0.70
	Min	1802.00	384.10	1.30	0.60
exp8	Avg	1987.90	420.64	1.38	0.62
	Max	2196.00	476.70	1.49	0.64
	Min	1836.00	418.45	1.12	0.51
exp9	Avg	2037.52	468.01	1.19	0.54
	Max	2226.00	516.10	1.26	0.56

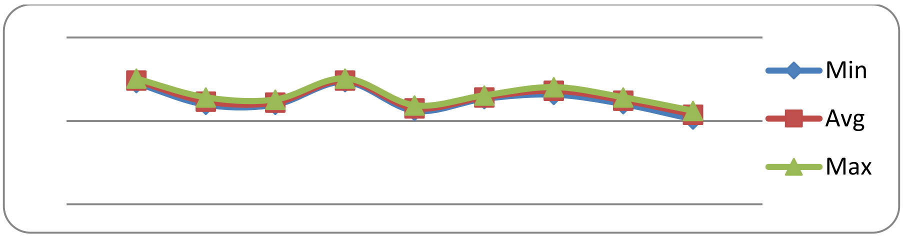
The results for different metrics are shown in Figure 5. According to the type of metrics, the three negative metrics should be similar, and they should be almost inverse to the Evacuation Time. However, we can see that the result trends for SC and AWT are quite similar with ASC. Through observing the running of the model, it was found that when the speed of cars is very high, which will happen near the end of the evacuation process, then the cars become blocked because of the traffic lights and spend time waiting for green lights. This explains the reason why the higher the ASC, the higher the value of the SC and AWT.



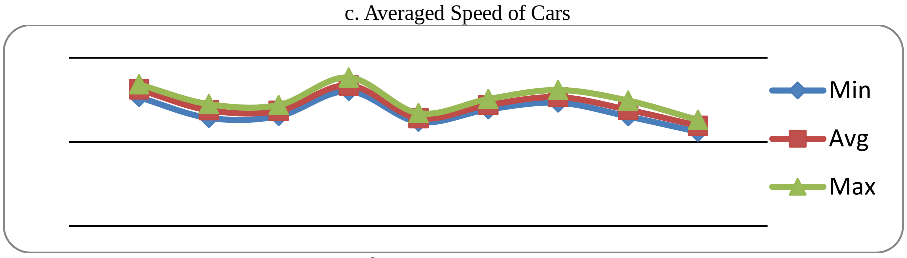
a. Evacuation Time



b. Stopped Cars



c. Averaged Speed of Cars



d. Average Wait Time

Figure 5. Results of metrics

5.3 Evaluation results

The evaluation results for all the experiments are shown in Table 5. The results are compared in Figure 6. The data of the weighted evaluation, evacuation time, the number of stopped cars, the average speed of cars and observed average wait time of cars in different scenarios are clarified.

Table 5. Evaluation Scores

	Weighted Evaluation	Evacuation Time	Stopped Cars (SC)(Avg)	Average Speed of Cars(ASC)	Average Wait Time of Cars (AWT)
exp1	68.159	95.571	29.211	89.899	0.198
exp2	37.733	9.767	100.000	38.353	61.602
exp3	42.074	21.458	94.772	36.747	64.945
exp4	60.979	75.114	9.333	100.000	0.000
exp5	29.484	0.000	75.842	18.507	81.739
exp6	40.764	21.332	69.378	51.396	49.372
exp7	67.291	100.000	0.000	70.774	30.294
exp8	45.220	30.637	94.142	39.456	58.568
exp9	37.610	23.347	82.713	0.000	100.000

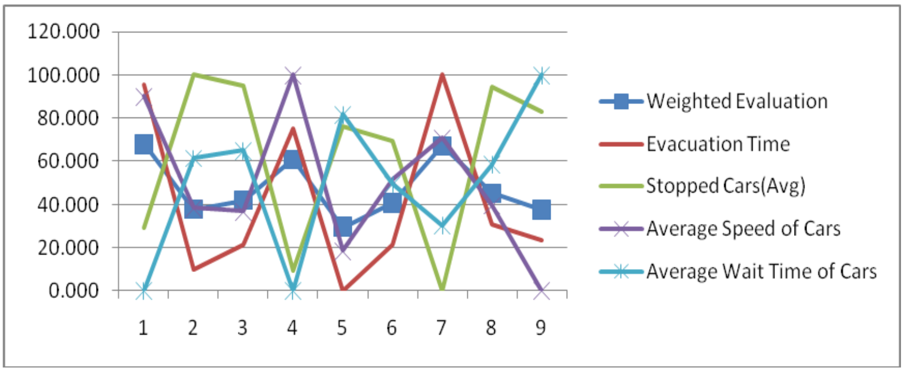


Figure 6. Evaluation results for different scenarios

6. CONCLUSION

Conclusions have been arrived at according to the evaluation results. For each population distribution, the first strategy always results in the best outcome, so the population distribution pattern in these experiments is not significant.

The best performance of all the experiments is Experiment 1, the simultaneous evacuation under even distribution, because under this scenario roads are fully utilized, while in other cases, drivers waste a lot of time waiting for cars from other blocks to evacuate first.

When the average car speed is high or there are few cars on the roads, the traffic control becomes a significant factor for evacuation efficiency. Therefore, the evacuation speed can be improved by reducing the switch interval time for traffic lights under this situation, or by trying to use people for directing traffic.

This research built a traffic model to simulate different evacuation scenarios and evaluated the simulation results. The whole process proves to be an effective and convenient way to collect feedback simulation data, which can assist in analyzing evacuation strategies and bottleneck issues.

There is a lot of research that can be referred to regarding this model. Many parameters were set as fixed values; some of them may be critical factors under specific conditions. Those parameters can be adjusted and then the results analysed. What's more, the model can be improved and developed in many ways. For example, two lanes and directions for roads can be considered, which would be closer to a realistic situation. Also, empirical data could be imported into the model. For example, true road networks and real population distributions. In this way more meaningful suggestions for evacuation plans in specific regions can be attained.

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Conceptual Research on Decision Making Meetings for Urban Water Management

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Key words: Urban Water Management, Multi-Agent System (MAS), Cellular Automata (CA)

Abstract: We will introduce an integrated model of Online Decision Making Meetings (ODMM) for sustainable management of water resources, which combines online meetings with an agent-based simulation function. This model is able to supply the decision makers with visualized simulation results of different policy scenarios and then support them to have online discussions, communication and make final decisions. The model consists of a remote server, a simulation model for background processing and clients. We assume that several departments related to water resource management will join this meeting and make proposals based on their data and policy. These departments are clients in our model and they are granted with special authority according to their departments. During an online meeting, the clients can choose global parameters for a simulation model that relates to their department based on their roles. Afterwards, simulations for different scenarios can be conducted by the model and the simulation results will be displayed for and visualized by the clients through the server on time. Thus, the government planners can easily view the simulation results regarding different policy scenarios using this tool, thereby making informed decisions and policy implementations.

1. INTRODUCTION

Based on the development trend of information technology, we introduce a new planning support model in our present research. An integrated model of Online Decision Making Meetings (ODMM) for sustainable management of water resources was developed, which combined online meeting functions with agent-based simulation. This model was developed via online meeting technology and an Agent-Based Modeling (ABM) method. It aims at supporting water related policy making meetings for urban areas. We assume several water resource management related departments would participate in such a meeting, making proposals based on their data and policies. A web conferencing software named “TeamViewer” and decision-making support software developed upon “NetLogo” are integrated to develop a visible and easy-to-communicate environment.

Water is one of the key resources for urban development. Since water is such an important resource for human life, different levels of government, from the United Nations and down to local government, must hold meetings to decide water related policies. With urbanization, people tend to gather in cities, leading to the prediction that the world's urban population will reach 5 billion by 2030, nearly double the amount in 2010 (United Nation, 2007; UN Water, 2010). These concentrated human activities in urban areas result in intensive demand on all types of natural resources, with water amongst the most vital. For cities which lack water resources, the development of a city is closely related to the ability to manage existing water resources (Vairavamoorthy et al., 2008; Zhang et al., 2010). For example, the Chinese government has established the most restrictive water management policies in Guidelines of the Twelfth Five-Year Plan for National Economic and Social Development. These policies include not only the total amount of water resources controlled, but also water quality requirement, waste water reuse, and optimization of industrial structures.

Conventionally, people from relevant departments participate in meetings at pre-determined places for several days' discussions, negotiations and communications till they reach agreements on targeted policies. This kind of conventional decision meeting has its own advantages, such as face-to-face communication. However, it needs people gathering at a physical meeting place according to a pre-determined time schedule which may not be convenient to all that are involved. Along with the development of information technology, online meetings are widely employed, especially by companies, so that managers can communicate with their employees in a timely manner, no matter where they are. This new meeting mode enables us to think of new ways of communicating through virtual online space.

To develop the ODMM model, ABM and Cellular Automata (CA) are applied to provide simulation functions. ABM is employed to simulate the water consumption of an urban area and CA is used for simulating the spatial processes where the agents are living. ABM is an emerging approach to modelling complex processes and phenomena in the social sciences in recent years (Torrens and Benenson, 2005; Torrens, 2007; Batty et al., 1997). Being the basis of ABM, the definition of an agent is as summarized by Wooldridge and Jennings in 1995, "An agent is a computer system, situated in some environment, which is capable of flexible autonomous action in order to meet its design objectives." ABM offers a way to model social systems that are composed of agents who interact with and influence each other, learn from their experiences, and adapt their behaviours so they are better suited to their environment. For these advantages, ABM is widely used in urban studies (Ettema, 2011; Dawn and Filatova, 2008; Parker et al., 2003; Noth et al., 2003; Fontaine and Rounsevell, 2009), economic applications (Diappi and Bolchi, 2006; Moeckel et al., 2003), etc.

The detail of the ODMM will be introduced and illustrated in the following sections.

2. MODEL DEVELOPMENT

2.1 Framework of ODMM

In our present research, a web-based conferencing software namely "TeamViewer" is combined with a decision-making support model developed on "NetLogo" platform to achieve a visible and convenient online meeting environment. Thus, the ODMM model can be separated into two parts: the NetLogo platform for urban modelling and the TeamViewer platform for collaborative online meetings (as shown in Figure 1). On the

NetLogo platform, the interface of ODMM and the simulation model for background processing is developed. The simulation model is developed using Cellular Automata (CA) and multi-agent system (MAS) methods. The CA method is used for simulating urban growth and land use change, the spatial process of urban development, which is the basis of further agent-based simulation.

The framework of the ODMM is shown in Figure 1, the whole model is developed on NetLogo platform and TeamViewer platform, respectively. On the NetLogo platform, the background simulations are organized, which includes urban modelling and impacts of urban development on water resources. Just as shown in Figure 1, the interface of the ODMM is also designed on the NetLogo platform, by which the constraints for urban development can be determined by the clients of the ODMM. As introduced in Section 1, these clients are the participants of the online meeting and they come from different planning departments. In the interface of the ODMM, there are different parameters for the background simulation. The clients can adjust the parameters according to their determined role.

Then, determined parameters and a simulation database will support the background of the urban modelling, which is also realized on the NetLogo platform. In this part, different simulation models will be developed to support the simulations. The models can be divided into two kinds, the CA model for urban growth and agent-based models for agent simulations. The details of these two kinds of models will be introduced through Subsections 2.2 and 2.3.

The simulation results can be displayed on the interface of ODMM. In order to support the clients' communication with each other, the online meeting function is developed on the TeamViewer platform. This function is finally combined in ODMM and makes the participants able to adjust the simulation parameters for the background urban modelling.

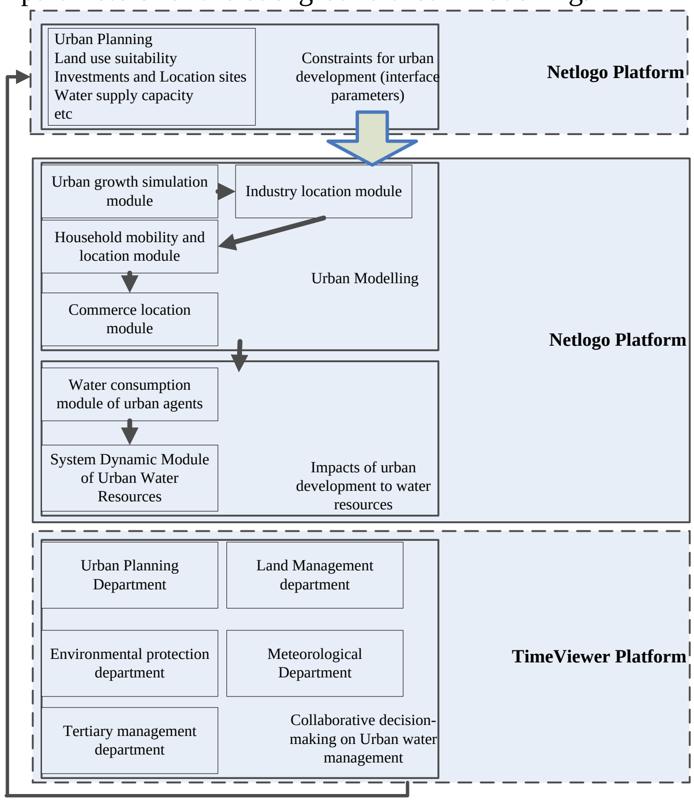


Figure 1. The framework of ODMM

2.2 Urban Simulation on NetLogo Platform

2.2.1 Urban Growth Simulation

As shown in Figure1, an urban modelling process is needed in the ODMM model. Within the urban modelling, we are concerned with two points, urban growth and urban agent behaviours. Basically, we see the urban growth process as the basis of agents' behaviours. Based on the simulation of urban growth, each cell's development can be known and the urban agents can determine locations of the developed cells in the next step, then, as a result, they will live and working on those cells. Because this is conceptual research, the urban modelling is conducted in a virtual space. In the virtual urban space, we first simulate the spatial process of urban development. This virtual city represents a typical job oriented newly developed town. In this virtual city, we assume the driving power of urban development is employment. In the initial stage, this city has one downtown area, and with simulation progress, the development potential of each cell (representing an urban area) is calculated according to the attributes of the cell, such as slope, urban planning, land use suitability, transport accessibility (such as distance from river, road, railway station, airport etc.), distance from downtown and neighbourhood effects. Moor Neighbourhood is utilized for this simulation and each cell is defined as having four neighbours.

The details about the transition rule of cell status are showed in (1) (Ma at al., 2010):

$$
\begin{aligned}
& s_{ij}{}^{t} = x_0 + \sum_{k=1}^{n-1} x_k \times a_k + x_n \times a_n{}^{t} = s_0 + x_n \times a_n{}^{t} \\
& p_g{}^{t} = \frac{1}{1 + e^{-s_{ij}{}^{t}}} \\
& p_{ij}{}^{t} = \exp\left[\alpha\left(\frac{p_g{}^{t}}{p_g{}^{t}{}_{\max}} - 1\right)\right] \qquad (1) \\
& \text{if } p_{ij}{}^{t} \geq p_{threshold}(p_{ij}{}^{t}, Development\text{stage}^{t+1})\ S^{t+1}(ij) = \text{Developed} \\
& \qquad \text{otherwise } S^{t+i}(ij) = \text{UnDeveloped}
\end{aligned}
$$

$s_{ij}{}^{t}$ is the land use suitability of cell (i, j) at time t. x_0 is a constant and s_0 is the static part of land use suitability during each simulation step. $S^{t+i}(ij)$ is the status of a cell (i, j) at time t+1. x_k is a parameter set reflecting institutional policies besides neighborhood rules, such as land use suitability. x_n is a parameter reflecting impact from the neighborhood, a_n are spatial features of a neighborhood, a_k are spatial features besides neighborhood, and p_g^t is global probability for transition. $p_{g\max}^t$ is the max global probability during each step. α is diffusion coefficient which is in the range of (1-10), $p_{ij}{}^{t}$ is the final probability, $p_{threshold}(p_{ij}^t, \text{Development}\text{stage}^{t+1})$ is the neighborhood cell number and developing speed control, which can change according to $p_{ij}{}^{t}$ and $Dvelopment\text{stage}^{t+1}$ in order to make the developing speed in $Dvelopment\text{stage}^{t+1}$ the same as in the settings.

The final probability of each cell is employed to decide whether the cell can be developed by comparing it with the threshold expressed as $p_{threshold}(p_{ij}{}^{t}, Development\text{stage}^{t+1})$ in Equation (1). If one cell is decided to be developed, then the developing potential of that cell for different land uses will be further calculated and the cell will be developed into the land use type with the biggest potential.

2.2.2 Simulation of Agents' Behaviours

Based on the simulation of spatial changes in the urban area, different types of urban agents will tend to be centralized in the city due to employment opportunities. The types of agents we considered in the ODMM model are household agents, shop agents and industry agents.

- Industry agents will enter the virtual city and select locations for their factories. There are two kinds of factory scales, large and small ones. The large one has a bigger employment capacity than the small one. We assume that the total amount of industry will be controlled by local government so that the number of industry agents is limited to a peak value. The industry agents will determine locations on the industrial land cells to maximize their utility. The key factor that industry agents use to evaluate utility is transport accessibility. When they make decisions on locations, they will build factories on the cell and hire workers.
- Shop agents will enter the virtual city and select locations for their shops. There are big shops and small shops. The big shops have a larger employment capacity than the small ones. Shop agents determine locations for their shops based on the household density of that region. We assume that different shop scales have different service radiuses.
- Household agents will enter the city and look for jobs. We assume that this type of agent will start their job hunting for high salary positions. When this kind of position is fully occupied, the agents will turn to other opportunities. When they finally find jobs, they will settle down in the city; otherwise, they will leave the city. During the residential location process, agents will assess the utility of different residential location alternatives based on the accessibility, commuting time and land prices of the locations.

These agents will all live in the virtual urban space and interact with the space and other agents by following the state diagram shown in Figure 2.

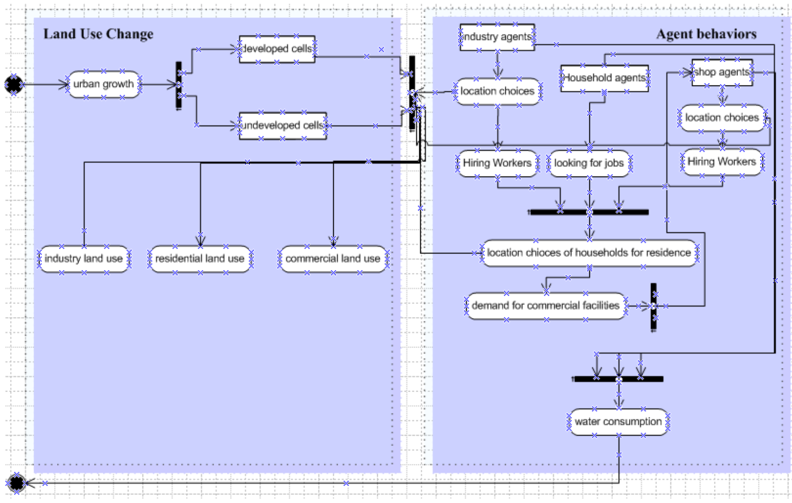


Figure 2. UML State diagram of ODMM

2.2.3 Simulation of Urban Water System

The urban water system can be divided into three parts: supply, consumption, and waste water treatment. Figure 3 shows the dynamic process of urban water supply and waste water treatment in ODMM. This module is developed using the "System Dynamics Model Builder" function in NetLogo.

For water supply, the water resource in a real situation can be from surface flow, lake, ground water, etc. However, to simplify the simulation process, we assume the water resource is taken from a reservoir. The impact factors for domestic water supply are precipitation, temperature, upstream flow and downstream flow.

Water consumption in the virtual urban space is composed of by industrial water consumption, commercial water consumption, residential water consumption and municipal water consumption. The amount of urban water consumption is related to the agents' behaviour explained in subsection 2.2.2. Industrial water consumers should have their own water supply and wastewater treatment facilities, and other types of water consumption are supported by municipal water supply and wastewater treatment facilities.

The amount of wastewater from commercial, residential, and municipal water consumption are supposed to be treated by municipal waste water treatment facilities, and the treated water will be released to surface flow, such as rivers or lakes.

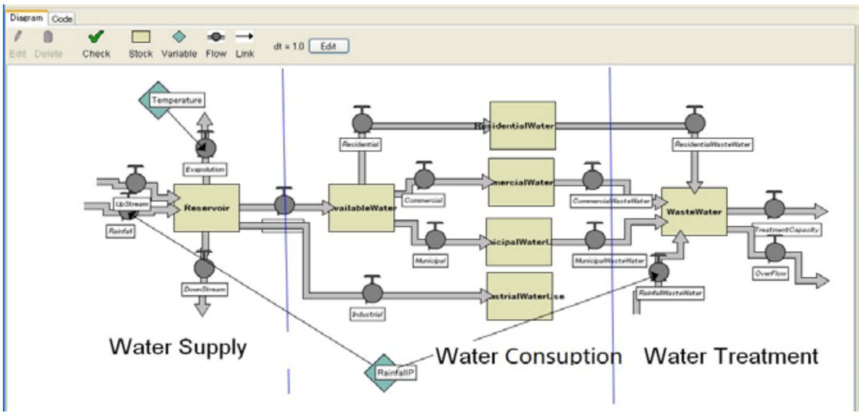


Figure 3. Dynamic process of urban water supply and waste water treatment.

2.3 Participatory Decision-Making on Teamview Platform

In ODMM, the object of water management related policies is affected by many factors and these factors usually relate to different departments. For example, the Meteorological Department is in charge of the factors of rainfall potential and temperature, while the Environmental Protection Department is responsible for ecological water requirements, etc. However, the work locations of these departments are different. In order to make collaborative decision-making possible, ODMM provide a Server-Client decision support environment to let decision-makers from different government departments adjust the related parameters for updating scenario simulations based on their professional knowledge backgrounds. Figure 4 shows an example of the departments involved in a decision making process of water management. The client is only authorized to adjust parameters of his responsible department by selection of identity when he logs into the system. During the online meeting process, all the legal adjustments to parameters of the ODMM from clients will be broadcast to others.

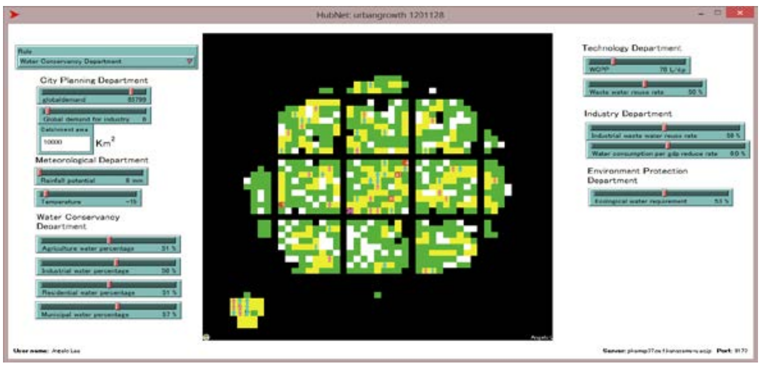
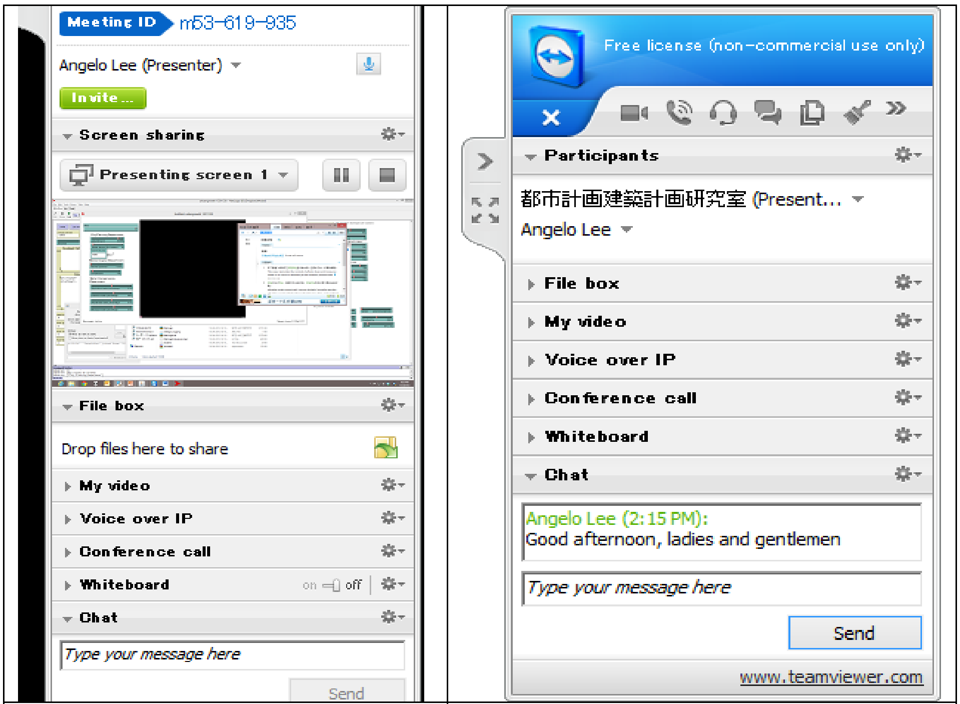


Figure 4. Example of server- client parameter setting

ODMM also provides an online meeting environment, which includes the functions of Screen sharing, Remote control, Video chatting, Voice chatting, Type chatting, File transfer and White board. Through these functions, planners can easily propose their arguments and communicate with others. The adjusted parameters will be sent to servers for background urban simulation. The simulation results for urban development can be observed and refereed by all participants participating in the decision meeting. The example of functions for a web-meeting are as shown in Figure 5.



(a) Toolbox of server (b) Toolbox of clients

Figure 5. Online meeting environment

3. CONCLUSIONS AND DISCUSSIONS

In this research we introduced a conceptual framework of a planning support system for integrated urban water management, termed ODMM. By integrating a cellular and agent-based simulation system with an online meeting function, a virtual communication meeting environment was achieved. By using the ODMM, online communication and policy simulation can be conducted between participants of the meeting. Its friendly interface for operation and participation makes it an innovative planning support model for government decision making and it is helpful for improving public understanding and awareness of the decision process.

For future work, a validation of ODMM by importing real data is needed. We also need to apply the ODMM to a real decision making process in order to assess the effectiveness of the model and how it can be used to improve stakeholders' participation in their decision making process.

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On relations of the consciousness of garbage truck drivers and their experiences of unsafe driving behaviors

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Key words: Traffic Safety, Garbage Collection, Community Roads, Drivers' Personalities

Abstract: In 2011, the authors published an analytical paper in order to understand the driving behaviors of garbage trucks on the basis of the data collected by drive recorders. As further study, this paper focuses on finding significant correlations between driver consciousness and their unsafe driving experiences. The methodology includes many statistical tools such as statistical tests, analyses of variance, factor analysis, the principle component analysis, and so on. The results show that truck drivers have a lower probability of looking aside and of becoming irritated when driving the garbage trucks than private car drivers. They feel it is more difficult to drive on community roads in residential areas than on trunk roads. The statistical analyses show there were significant correlations between the drivers' personalities, their consciousness, and the experienced traffic accidents. In particular, the event "near accident with oncoming cars when passing each other" is statistically significant with respect to the negation overtaking of the other cars, the awareness of driving on community roads and the convenience of driving the garbage trucks.

1. INTRODUCTION

Recently, in order to reduce the number of traffic accidents in residential areas, limitations for vehicle thoroughfares and access into certain areas have been considered as effective measures. To approach these goals, tools such as raised bollards and speed restrictive zoning such as Zone 30 or Zone 20 have been introduced in many countries around the world. However, some special vehicles such as ambulances, garbage trucks and the other emergency and utility vehicles cannot be limited because of their special purposes.

In Toyota City, Japan, the study site of this research, the population is about 420,000. The total area is about 918 km^2, 4% of which is roads and 6% residential area. The total household garbage amounted to 84,566 tons in the 2008 fiscal year, that being from April 2008 through March 2009 (Waste Reduction Promotion Division, 2009). 72 garbage trucks were used for the collections of the household garbage in April 2009. Usually, two workers are paired for the collection of the garbage. Each garbage truck may have five or six round trips every day between the garbage treatment facility and the residential areas.

To review the existing studies, Matsuto et al. (1987) tried to model 'station-type' collection in order to search for the best collection routes. Two groups of researchers (Aoshima et al., 1987 and Matsunaka et al., 2006) discussed how to locate the waste treatment facilities by considering the collection routes and transportation plans. Recently, the authors published a paper (Ando and Mimura, 2011) on such an analysis having tried to understand the driving behaviors of the garbage trucks on the basis of the data collected by the drive recorders. However, there is little study regarding the issue of garbage collection transportation safety.

On the basis of the above background, this study aims to identify the relationship between driver consciousness and unsafe driving experiences. For this study, the viewpoint regarding driver consciousness is hinted at by studies conducted by the Japan Safe Driving Center (1995, 1996, and 1997). They have made it known that driver safety is normally related todriver' consciousness. However, the correlations with drivers' unsafe driving experiences have not been studied. Considering the limited number of unsafe driving experiences had by a limited number of drivers, additional factors are combined and considered. By referring to the psychological studies on environment issues (Kanno et al., 1998, and Oishi et al., 2003) the Semantic Differential (SD) method is used in this study.

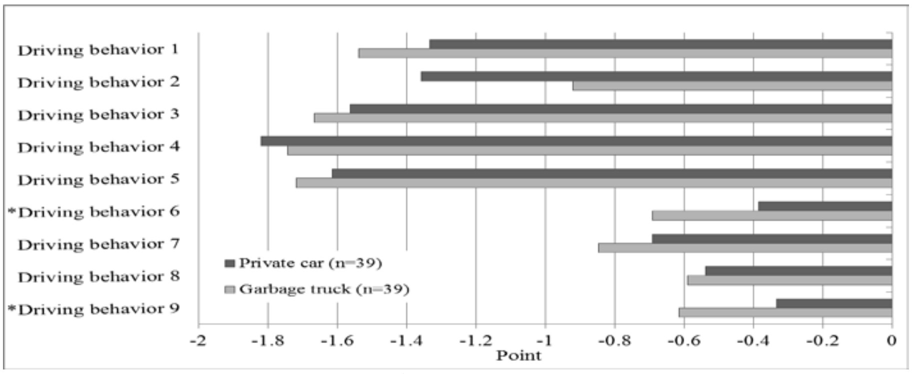
A questionnaire survey was conducted in February 2011 in Toyota City, Japan. 96 drivers and assistants for the collection of household garbage, whose trucks can be specified, have been chosen as the target people. The survey sheets were distributed at seminars organized by the administration office and collected several days later. As a result, 64 effective responses have been collected. Therefore the response rate is 67%. Among the respondents, 39 individuals were truck drivers. In the survey, the drivers' personalities, consciousness of their driving, the road and work environment, and the vehicle and safety are all considered. The analysis considers discernible reasons for traffic accidents and the approach considers the following three viewpoints: vehicle, environment and driver.

2. OUTLINE OF THE SURVEY RESULTS

The items and the indicators include everyday driving behavior, with respect to both truck driving and private car driving, the amount of house garbage to be collected, consciousness in the road traffic environment, the work environment, evaluation of the truck, the individuals and so forth.

Figure 1, on the following page, summarizes the results of the driving behaviors. A Wilcoxon signed-rank test shows that driving behaviors 6 and 9 are significantly different at the 5% level between driving the private car and the garbage truck. The drivers have higher probabilities of looking aside and becoming irritated when driving their private cars.

Figure 2, below, shows the considerations of the drivers when they are driving their private cars and the garbage trucks. A Wilcoxon signed-rank test shows that considerations 1, 7 and 10 are significantly different at the 5% level between the driving of private cars and the garbage trucks. Due to the occurrence of considerations 7 and 10, the drivers noted that they feel calmer when driving the garbage trucks. At the same time however, they do not feel calmer if driving the garbage truck, even when employing the same considerations.

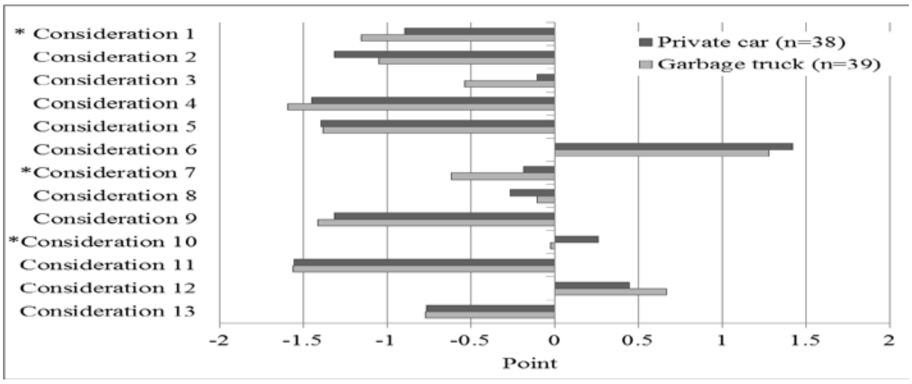


Note: **Driving behavior** 1=Not keeping enough safe distance between the car just ahead in order to prevent the interruption of another car, 2=Parking at a no-parking area, 3=Not stopping even where there is a stop sign, 4=Assuming it is safe to turn left or right just by following the car ahead, 5=Not feeling nervous when changing lane because of the assumption other cars will give way, 6=Looking aside sometimes during driving, 7=Being careless sometimes even during driving, 8=Being calm always when driving, 9=Being irritated always during driving.

Point 2=Exactly, 1=Yes, -1=No, -2=Never.

※significant at the 5% level with Wilcoxon signed-rank test.

Figure 1. Normal driving behavior.



Note: **Consideration** 1=Enjoying driving even with no intended destination, 2=All drivers are in the same boat in the sense that driving may be bothersome, 3=A car is only a transport tool, 4=A traffic accident is a result of luck, 5=Driving is purposeful in life, 6=Danger cannot be avoided if driving, 7=Feeling unhappy when overtaken by someone, 8=Considering pedestrians/bicycles is a nuisance, 9=Tending to go fast when driving parallel with someone, 10=Getting angry with the car just ahead if it is slowing down, 11=There is a correlation between the violation of traffic regulations and traffic accidents, 12=Near misses always happen to all drivers, 13=Not dangerous when driving at a speed that is about 10km/h over the limitation.

Point 2= Agree, 1=Somewhat agree, -1=Somewhat disagree, -2=Disagree.

※significant at the 5% level with Wilcoxon signed-rank test.

Figure 2. Considerations on driving.

Figure 3 tells us what the drivers think about the quantities of the combustible garbage from the houses. The quantities on Mondays and Tuesdays have been felt to be more than on the other days. This is almost consistent with what was summarized in Table 1. An important result to note is what is shown in Figure 4. That is, the drivers feel more tired and hurried when transporting the larger quantities of garbage, which may be a cause of drivers being restless, dangerous and stressed.

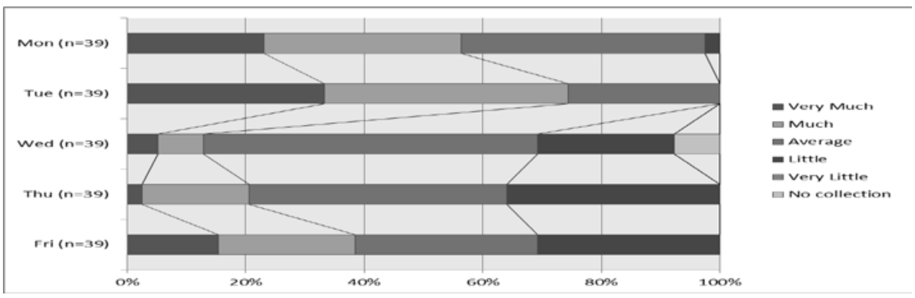


Figure 3. Feelings on amounts of household garbage by day.

Table 1. Amounts of the combustible household garbage by day (2009)

Day	No. of days	Daily average (ton)	Average derivation (ton)
Mon	52	448.6	63.3
Tue	52	383.5	52.8
Wed	39	0.6	0.7
Thu	51	305.7	29.0
Fri	51	275.2	21.7

※significant at the 1% level with one-way analysis of variance
※significant at the 1% level among all days when applying Bonferroni Method

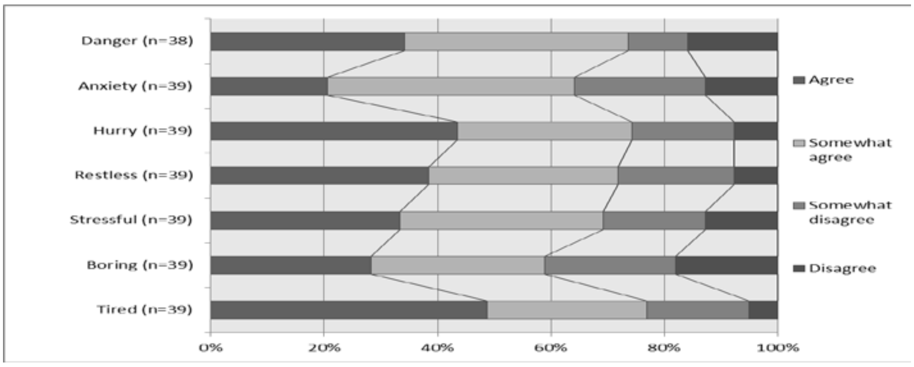


Figure 4. Consciousness in the relative to garbage quantity.

Figure 5, where the points are defined the same as in Figure 2, compares the consciousness of the drivers on both trunk and community roads. A Wilcoxon signed-rank test shows that all items are significantly different at the 1% level between the trunk roads and the community roads. That is, the drivers feel driving difficultly and anxiety on the community roads is higher than on the trunk roads.

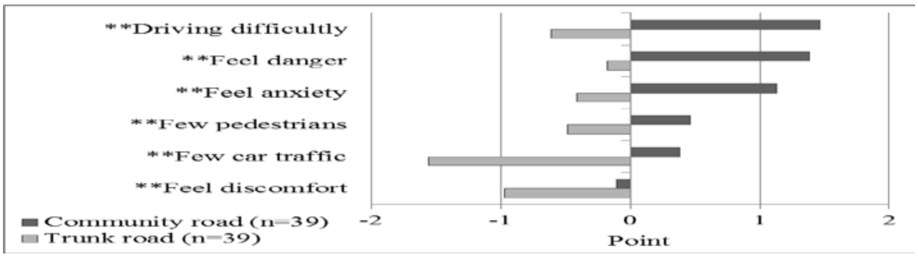


Figure 5. Consciousness on both trunk road and community road.

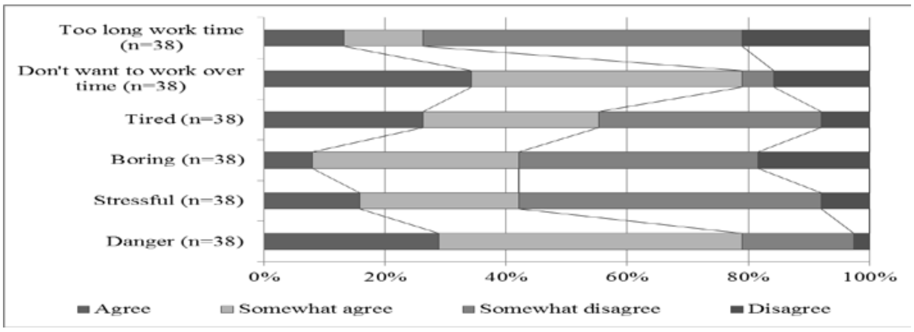


Figure 6. Consciousness regarding garbage collection work.

Regarding the consciousness during their work, Figure 6 tells us that the drivers do not expect to work overtime, and feel tired or dangerous, however, most of them do not feel they have to work long hours, nor do they become bored or stressed. As for the garbage trucks, the vehicles have been evaluated as being useful, powerful and easily driven, as shown in Figure 7. On the other hand, the trucks have not been thought to be quiet, fast or new.

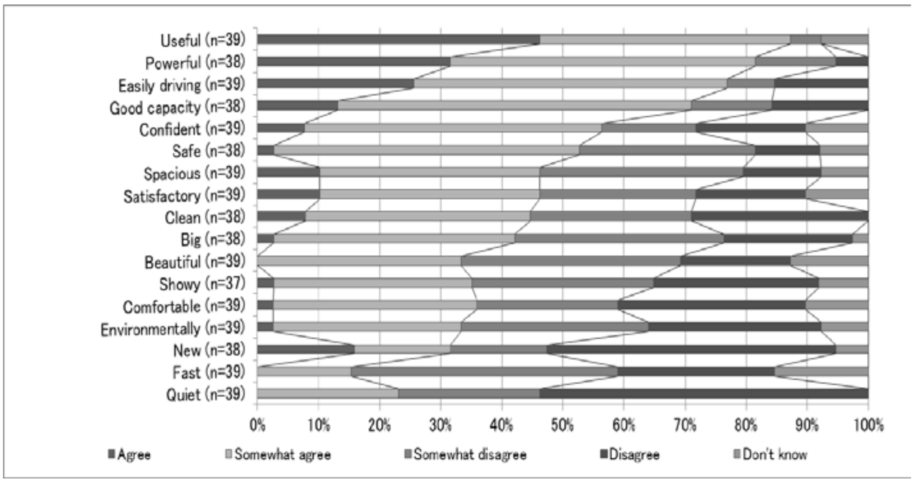


Figure 7. Consciousness of garbage trucks.

3. ANALYSIS OF FACTORS RELATED TO UNSAFE EXPERIENCES

In this section, the analysis is carried out among factors such as the personality of the drivers and their consciousness on the road environment and the vehicle, along with their unsafe experiences in the past. The methodology includes many statistical tools such as factor analysis, principle component analysis and so on.

Table 2. Factor (F) loading in case of driving private cars

Variable	F 1	F 2	F 3	F 4	F 5	F 6	F 7
B 1	0.15	0.11	0.07	0.30	0.07	0.62	0.15
B 2	0.05	0.36	0.26	0.67	0.24	0.20	0.17
B 3	0.08	-0.02	0.13	0.67	-0.03	0.20	0.27
B 4	0.02	0.50	0.22	0.18	0.11	0.20	-0.06
B 5	0.07	0.21	0.01	0.57	0.04	0.13	0.39
B 6	0.25	0.20	0.18	-0.02	0.94	0.19	0.09
B 7	0.37	0.13	0.22	-0.02	0.80	0.35	0.40
B 8	-0.69	-0.15	-0.28	-0.07	-0.18	-0.06	0.07
B 9	0.68	0.20	0.27	0.08	0.36	0.34	0.13
C 1	-0.05	0.72	0.04	0.04	0.37	0.12	0.19
C 2	0.28	0.28	0.92	0.25	0.24	0.20	0.37
C 3	-0.07	-0.68	0.45	-0.04	0.14	-0.02	0.18
C 4	0.04	0.09	0.34	0.25	0.22	0.33	0.92
C 5	0.16	0.69	0.01	0.28	0.13	0.17	0.20
C 6	-0.01	-0.16	0.53	-0.64	0.32	-0.11	0.08
C 7	0.24	0.20	0.10	0.21	0.18	0.29	0.44
C 8	0.69	-0.06	0.26	-0.17	0.24	0.12	0.39
C 9	-0.07	0.40	0.15	0.02	0.58	0.79	0.35
C 10	0.81	0.01	0.05	0.14	0.17	-0.01	0.11
C 11	0.03	0.10	0.25	0.34	0.09	0.37	0.54
C 12	0.19	-0.22	0.69	-0.03	0.07	0.15	0.19
C 13	0.11	0.09	0.27	0.08	0.28	0.86	0.49
Eigenvalue	4.99	2.86	2.37	1.96	1.59	1.30	1.20
Contribution (%)	22.68	13.02	10.78	8.90	7.23	5.89	5.44

※Definition of Behavior (B) 1~9 and Consideration (C) 1~13 are the same as used in Figures 1 and 2.
※Figures in the greyed cells mean the absolute value of the factor loading is 0.5 or greater.

At first, regarding the personalities of the drivers, an analysis has been made (Ando and Mimura, 2011) by referring to the research reports published by the Japan Safe Driving Center (1995, 1996 and 1997). In order to express the distances across the answer categories, the ordinal scale has been converted to an interval scale by applying the Sigma Level. The factor analysis using the interval scale is then implemented. The factors showing an eigenvalue of 1.0 or greater are estimated in terms of Iterative Principal Axis Factoring.

The results when driving private cars are summarized in Table 2, above. Seven factors have been selected. The accumulated contribution is 73.94%. To easily define the factors, an oblique rotation (Promax Rotation) was applied. Thus the seven factors can be defined by referring to the output of the Japan Safe Driving Center's research as follows:

Factor 1: aggressive
Factor 2: value appreciation for driving
Factor 3: accept danger
Factor 4: accept violation
Factor 5: random rambling, look aside
Factor 6: go ahead of the other cars
Factor 7: deprecate the accidents

In addition, the results when driving garbage trucks are summarized in Table 3. Eight factors have been selected and their accumulated contribution is 77.99%. As with the private cars, the oblique rotation was applied, thus the eight factors can be defined as the following:

Factor 1: random rambling, look aside
Factor 2: aggressive
Factor 3: deprecate the accidents
Factor 4: value appreciation for driving
Factor 5: accept danger
Factor 6: calm driving
Factor 7: go ahead of the other cars
Factor 8: negation being led by the other cars

Table 3. Factor (F) loading in case of driving garbage trucks

Variable	F 1	F 2	F 3	F 4	F 5	F 6	F 7	F 8
B 1	0.01	0.15	0.46	0.23	-0.30	-0.27	0.21	0.18
B 2	0.70	0.18	0.21	0.13	0.12	-0.20	0.03	0.00
B 3	0.05	0.05	0.61	0.35	-0.30	0.08	0.20	0.11
B 4	0.25	0.20	0.25	0.73	-0.06	0.06	0.24	0.34
B 5	0.02	0.06	0.17	0.29	-0.21	0.06	0.10	0.40
B 6	0.83	0.29	-0.05	0.25	0.11	0.09	0.29	0.19
B 7	0.83	0.56	0.26	0.18	0.25	-0.03	0.26	0.38
B 8	-0.17	-0.09	0.09	-0.06	-0.01	0.98	0.19	0.06
B 9	0.34	0.88	0.22	0.15	0.17	-0.09	0.13	0.24
C 1	0.36	-0.33	0.12	0.74	-0.25	-0.15	0.36	-0.23
C 2	0.70	0.42	0.45	0.08	0.45	-0.37	0.04	0.28
C 3	-0.18	0.06	0.45	-0.32	0.13	0.10	0.14	0.24
C 4	0.26	0.19	0.76	0.23	0.11	0.03	0.24	0.39
C 5	0.06	0.05	0.22	0.84	-0.34	-0.09	0.18	0.09
C 6	0.16	0.07	-0.04	-0.27	0.86	-0.01	-0.04	-0.17
C 7	0.21	0.33	0.49	0.15	0.03	-0.03	0.33	0.80
C 8	0.37	0.70	0.10	-0.10	0.29	-0.17	0.12	0.21
C 9	0.19	0.04	0.29	0.22	-0.14	0.06	0.78	0.19
C 10	0.25	0.72	0.27	0.04	0.14	-0.12	0.04	0.54
C 11	0.20	0.32	0.61	0.12	0.22	0.08	0.28	0.29
C 12	0.00	0.35	0.11	-0.20	0.49	-0.39	-0.18	0.31
C 13	0.01	0.47	0.36	0.22	0.40	0.34	0.73	0.22
Eigenvalue	5.12	3.18	2.28	1.75	1.48	1.20	1.11	1.03
Contribution (%)	23.27	14.44	10.36	7.97	6.73	5.48	5.06	4.68

※Definition of Behavior (B) 1~9 and Consideration (C) 1~13 are the same as t used in Figures 1 and 2.
※Figures in the greyed cells mean the absolute value of the factor loading is 0.5 or greater.

Regarding the garbage quantity, the roads and the work environments, a principal factor analysis has been similarly conducted.

The result for the community roads, as shown in Table 4, considers the consciousness variables. The factors with eigenvalues 1.0 or greater are the first and the second. The accumulated contribution of these two factors is 72.24%. The first factor mainly expresses the feeling when driving. The second factor represents the understanding of the pedestrian and vehicle traffic.

Table 4. Principal component analysis of consciousness on community roads

Variable	Principal Component 1	Principal Component 2
Driving difficultly	0.82	0.19
Feel danger	0.81	0.27
Feel anxiety	0.69	0.56
Few pedestrians	-0.56	0.78
Few car traffic	-0.50	0.80
Feel discomfort	0.53	0.12
Eigenvalue	2.66	1.68
Contribution percentage (%)	44.28	27.97

For the vehicles, in order to express the distances across the answer categories, the ordinal scale has been converted to an interval scale by applying the Sigma Level. The factor analysis using the interval scale is then implemented. The factors with an eigenvalue 1.0 or greater are obtained. Table 5 shows the resulting five factors. The accumulated contribution is 74.49%. The oblique rotation allows the naming of the five factors as follows:

Factor 1: safety and anxiety
Factor 2: clean
Factor 3: functional
Factor 4: appearance
Factor 5: convenient

Table 5. Principal component analysis of consciousness of the garbage trucks

Variable	Component 1	Component 2	Component 3	Component 4	Component 5
Easily driving	0.56	0.16	0.42	0.46	0.61
Useful	0.22	0.21	0.09	0.20	0.61
Beautiful	0.51	0.45	0.40	0.75	0.52
Powerful	0.35	0.26	0.61	0.07	0.14
Fast	0.72	0.39	0.53	0.41	0.09
Safe	0.84	0.37	0.13	0.36	0.28
Good capacity	0.23	-0.18	0.86	0.13	0.07
Confident	0.76	0.63	0.51	0.36	0.17
Spacious	0.59	0.20	0.56	0.53	0.32
New	0.16	0.27	-0.05	0.66	0.09
Clean	0.31	0.89	0.26	0.57	0.12
Showy	0.39	0.45	0.36	0.32	-0.28
Big	0.58	-0.13	0.51	-0.01	0.30
Quiet	0.29	0.61	-0.01	0.21	0.17
Environmentally	0.05	0.64	-0.42	0.15	-0.01
Eigenvalue	5.02	2.58	1.43	1.14	1.01
Contribution percentage (%)	33.47	17.18	9.50	7.57	6.76

※Figures in the greyed cells mean the absolute value of the factor loading is 0.6 or greater.

The experiences of the previous three years have been scored as 0 or 1. Regarding the near miss experiences, the 15 types (refer to Table 9), listed by referring to existing research outputs (Ando and Mimura, 2011), have been shown and the results in the most recent year were scored as 0, 1, 2 (having occurred 2 or 3 times), or 3 (having occurred 4 or more times), respective with each type. The total scores of each respondent have then been summed up. Finally, the correlations among the summed scores, the drivers' personalities, the consciousness of the environment and vehicles are discussed in terms of the factor analysis.

Table 6 shows the results of the correlation analysis between the personalities and the unsafe experiences. The Mann-Whitney U Test shows that the negation overtaking of other cars is significant with the experience of near miss at the 1% level of significance.

Table 6. Correlations among drivers' personalities and their unsafe driving experiences

	Experiences of traffic accidents			Experiences of near misses		
	More	Less	P Value	More	Less	P Value
Aimless・looking aside when driving	0.06 (18)	0.26 (19)	0.091	5.22 (18)	3.28 (18)	0.565
Aggressive	0.05 (19)	0.28 (18)	0.067	5.72 (18)	2.78 (18)	0.100
Ignoring of experienced accidents	0.17 (18)	0.16 (19)	0.943	3.94 (17)	4.53 (19)	0.576
Emphasizing the enjoyment of driving a car	0.06 (18)	0.26 (19)	0.091	3.78 (18)	4.72 (18)	0.886
Approval for dangerous behavior	0.16 (19)	0.11 (18)	0.682	3.28 (18)	5.22 (18)	0.643
Calm driving	0.17 (18)	0.11 (19)	0.590	2.88 (17)	5.47 (19)	0.096
Tendency to overtake	0.11 (18)	0.16 (19)	0.682	3.39 (18)	5.11 (18)	0.565
Negation overtaking of other cars	0.11 (19)	0.17 (18)	0.590	6.26 (19)	2.00 (17)	0.002**
Approval for violation of traffic regulations	0.11 (18)	0.16 (19)	0.682	4.00 (18)	4.50 (18)	0.380

※（）＝Sample number
※** :1% significance when doing the Mann-Whitney U Test

Table 7 show the results of the correlation tests with respect to the consciousness on community roads and unsafe experiences. The awareness of driving on the community roads shows a 5% significant difference between the 'more' and the 'less' experiences of near misses when the Mann-Whitney U Test is applied. The drivers who perceived more safety problems when driving on the community roads had had more experiences of near misses.

Table 7. Correlations among the consciousness on community roads and the drivers' unsafe experiences

	Experiences of traffic accidents			Experiences of near miss		
	More	Less	P Value	More	Less	P Value
Awareness of driving on community roads	0.16 (19)	0.17 (18)	0.943	6.42 (19)	2.88 (17)	0.024*
Consciousness of less traffic flows on community roads	0.17 (18)	0.16 (19)	0.943	4.65 (17)	4.84 (19)	0.555

※（）＝Sample number
※* :5% significance when applying the Mann-Whitney U Test

Furthermore, regarding the correlations among the consciousness of the garbage trucks and the unsafe experiences, the results are summarized in Table 8. Of the five viewpoints on the trucks, 'convenient' results in 5% significance with the near miss experiences when applying the Mann-Whitney U Test. The drivers who consider the trucks to not be convenient tend to have more near miss experiences.

Table 8. Correlations among the consciousness on garbage trucks and the drivers' unsafe experiences

	Experiences of traffic accidents			Experiences of near miss		
	More	Less	P Value	More	Less	P Value
Safe and confident	0.12 (17)	0.25 (16)	0.332	3.76 (17)	4.50 (16)	0.283
Clean	0.13 (16)	0.24 (17)	0.419	4.38 (16)	3.88 (17)	0.813
Functional	0.18 (17)	0.19 (16)	0.936	3.94 (17)	4.31 (16)	0.536
Good looking	0.13 (16)	0.24 (17)	0.419	4.13 (16)	4.12 (17)	0.623
Convenient	0.25 (16)	0.12 (17)	0.332	3.19 (16)	5.00 (17)	0.037*

※（）＝Sample number
※* :5% significance when applying the Mann-Whitney U Test

As a summary of the above analysis, the traffic accidents experienced cannot be concluded as having statistically significant correlations with the drivers' personalities, the consciousness on the community roads and the garbage trucks. However, the near miss experiences have statistically significant relations with some of the drivers' personalities, the consciousness on the community roads and the garbage trucks.

On the basis of these results, further discussion is conducted on the correlations of the near miss experiences in more detail and the items selected that are statistically significant are presented in Table 6 through Table 8.

Table 9, below, is the summary of the results when applying the Mann-Whitney U Test. The item "near accident with oncoming cars when passing each other" is statistically significant with respective to the negation overtaking of the other cars at the 1% level of significance and the awareness of driving on the community roads and the convenience of the garbage trucks at the 5% level. This item is the most representative near miss event, having correlations with specific behaviors. Another statistically significant near miss event is the item "near accident because the car just ahead jammed on its brakes". This is correlated with the negation overtaking of the other cars at the 5% level.

4. CONCLUSIONS

In the process of promoting the measure of Zone 30 in Japan, one serious issue is how to deal with the garbage trucks, because it is impossible to limit these trucks from accessing the community roads. To discuss this issue concretely, this study was undertaken to understand the driving behaviors of truck drivers. On the basis of a questionnaire conducted in Toyota City, a statistical analysis has been carried out. The results show that truck drivers have a lower probability of look aside and being irritated when driving the garbage trucks than the private car drivers. They feel it is more difficult to drive on the community roads in the residential areas than on the trunk roads. Furthermore, the statistical analyses showed there are many correlations among the drivers' behaviors, their consciousness of the environments and the vehicles, and the experienced traffic accidents and near misses, and so forth. In particular, the event "near accident with oncoming cars when passing each other" is statistically significant with respect to the negation overtaking of other cars, the awareness of driving on the community roads and the convenience of the garbage trucks.

Although further studies should be extended to more cities, the results in this study have given many hints for discussing the traffic safety measures on community roads.

Table 9. Concrete description of experienced near-misses in terms of personal behaviors

Specialized items	Negation overtaking of other cars			Awareness of driving on community roads			Convenience of garbage trucks		
Contents of near miss	More	Less	P Value	More	Less	P Value	More	Less	P Value
Near fatal encounter with pedestrians crossing road	0.26 (19)	0.12 (17)	0.278	0.32 (19)	0.18 (17)	0.342	0.25 (16)	0.18 (17)	0.611
Near accident with oncoming cars when overtaking	0.16 (19)	0.00 (17)	0.175	0.21 (19)	0.00 (17)	0.092	0.13 (16)	0.00 (17)	0.139
Near accident on opposite lanes when driving on curved line	0.21 (19)	0.00 (17)	0.092	0.21 (19)	0.06 (17)	0.338	0.06 (16)	0.12 (17)	0.588
Near accident when approaching the preceding cars	0.32 (19)	0.06 (17)	0.101	0.32 (19)	0.12 (17)	0.259	0.25 (16)	0.12 (17)	0.332
Near accident with the stopped cars because of signal or parking	0.37 (19)	0.12 (17)	0.379	0.47 (19)	0.18 (17)	0.163	0.25 (16)	0.35 (17)	0.705
Near crossing collision with cars/bicycles at intersections	0.47 (19)	0.18 (17)	0.106	0.53 (19)	0.18 (17)	0.056	0.31 (16)	0.24 (17)	0.624
Near accident with the preceding cars when overtaking	0.11 (19)	0.00 (17)	0.344	0.16 (19)	0.00 (17)	0.175	0.06 (16)	0.00 (17)	0.303
Near accident with other cars when changing lanes	0.32 (19)	0.06 (17)	0.101	0.37 (19)	0.06 (17)	0.053	0.06 (16)	0.29 (17)	0.090
Near accident with oncoming cars when passing each other	0.95 (19)	0.29 (17)	0.009 **	1.05 (19)	0.29 (17)	0.015 *	0.31 (16)	1.06 (17)	0.022 *
Near fatal encounter with cars /pedestrians when turning left	0.32 (19)	0.06 (17)	0.101	0.26 (19)	0.24 (17)	0.930	0.13 (16)	0.24 (17)	0.419
Near fatal encounter with cars/pedestrians when turning right	0.37 (19)	0.18 (17)	0.313	0.42 (19)	0.24 (17)	0.353	0.19 (16)	0.35 (17)	0.294
Near accident when driving backward	0.84 (19)	0.41 (17)	0.143	0.84 (19)	0.53 (17)	0.347	0.31 (16)	0.88 (17)	0.088
Near accident because of skidding	0.21 (19)	0.00 (17)	0.092	0.21 (19)	0.06 (17)	0.338	0.06 (16)	0.12 (17)	0.588
Near accident because of pedestrians/bicycles appearing suddenly	0.89 (19)	0.47 (17)	0.100	0.74 (19)	0.59 (17)	0.539	0.69 (16)	0.71 (17)	0.854
Near accident because the car just ahead jammed on its brakes	0.47 (19)	0.06 (17)	0.026 *	0.32 (19)	0.18 (17)	0.497	0.13 (16)	0.35 (17)	0.224

※（）＝Sample number
※** :1％ significance when applying the Mann-Whitney U Test; * :5％ significance when applying the Mann-Whitney U Test.

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Modelling Spatial Distribution of Outdoor Recreation Trips of Urban Residents

An in-depth study in Salford, UK

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Key words: Spatial distribution, outdoor recreation travel, travel demand modelling, urban greenspaces, GIS.

Abstract: Outdoor recreation is one of the most important leisure activities of urban residents, with urban greenspace accruing the highest value of benefits among all greenspaces in the UK. However, access and trip-making to outdoor greenspaces by urban residents remain poorly understood. Existing trip-making prediction models that have been established for assessing the recreation benefits of outdoor greenspaces have dealt separately with visits to urban and rural greenspaces. This makes it difficult to assess greenspace strategies when considering them as a whole infrastructure. Meanwhile there is a risk of misjudging the value (e.g. double counting) when they are summed mechanically. This research aims to investigate the strengths and weaknesses of predictive models of outdoor recreation travel. An output of the research is a new model with two components: (a) predominantly local trips and (b) predominantly non-local trips. The resultant model is able to make an assessment that seamlessly combines urban and rural greenspaces. It also links the spatial distribution of visits to key spatial factors, such as distribution of population, location of recreational sites, transport accessibility and travel time. The resulting quantification of the impacts of policy interventions provide a robust basis for decision making

1. INTRODUCTION

Greenspace generates a wide range of valuable ecosystem services in urban areas. Outdoor recreation is one of the most important leisure activities of the urban residents, with urban greenspace accruing the highest value of benefits among all greenspaces in the UK (Natural England, 2013). In a recent survey from Nature England (2013) it is estimated that 2,858 million outdoor recreational visits were made in England during 2012, entailing direct expenditure of over £20 billion. The main benefits include recreation, aesthetics, and improved physical and mental health (Davis et al., 2011), yet land-use decisions often ignore the value of these services (Bateman, 2013). However, access and trip-making to outdoor greenspaces by urban residents remain poorly understood. In particular, travel prediction models used for transport planning purposes tend not to focus on access and travel to outdoor spaces; there is a resultant lack of precision in trip-making predictions; on the other hand, trip-making prediction models (for example, the UK National Ecosystem Assessment/NEA) that have been established for assessing the recreation benefits of outdoor greenspaces distinguish between visits to urban greenspaces and those to outside cities or towns. The separation of destinations makes the assessment of greenspace strategies difficult because there is no evidence to prove that either people's choice of outdoor recreational destinations nor greenspace planning/design strategies' intent indicate that urban and rural areas should be treated separately. It would be useful to have a method that is able to assess consistently the benefits regarding the spatial distribution of the greenspaces. Meanwhile, the existing valuation methods have very limited spatial granularity, particularly in urban areas; this limits their use in local studies.

In this research a logit discrete choice model was used, which has been widely recognised in the transport planning area, and new predictive model was developed with two components: (a) predominantly local trips, and (b) predominantly non-local trips. This method allowed the prediction of the number of trips continually in the sense of spatial distributions. Meanwhile, site location, size and some other social-demographic characteristics were linked with a prediction of the number of trips. The resultant model had significantly improved capabilities in assessing policy interventions regarding allocation and design of urban greenspaces.

The main research questions we aim to answer in this paper are:

1) Existing models in UK NEA (Sen, et al., 2013; Perino et al., 2011) deal separately with (a) visits to urban greenspaces and (b) those to rural areas, while people's choices are continuous in space – can the two models be integrated into one to reflect destination choice behaviour?

2) Existing models have very limited spatial granularity which limits their use in local studies – can the model incorporate more local details through applying travel demand modelling techniques?

The remainder of this paper is organised as follows. Section 2 is reviewing the exiting research related to outdoor recreational value and the discrete choice modelling. Section 3 contains a description of the data and the empirical methodology for building the trip prediction model. In Section 4 the model results are set out and in section 5 the manuscript concludes with an evaluation of the future works for this research. We aim to develop a new predictive model, which can estimate the outdoor recreational behaviour consistently. It will improve significantly the capabilities of choice modelling in assessing policy interventions regarding allocation and design of urban greenspaces.

2. LITERATURE REVIEW

2.1 Existing outdoor recreational value models

The Millennium Ecosystem Assessment (2005) not only demonstrated the importance of ecosystem services to human well-being, but also showed that at the global scale many key services are being degraded and lost. As a result, in 2007 the House of Commons Environmental Audit recommended that the Government should conduct a full Millennium Ecosystem Assessment type assessment for the UK to enable the identification and development of effective policy responses to ecosystem service degradation. The resultant UK National Ecosystem Assessment (UK NEA) was the first analysis of the UK's natural environment in terms of the benefits it provides to society and continuing economic prosperity.

Many previous studies for recreational sites focus on either single habitat recreational sites (Public Opinion of Forestry, 2013; Inland Waterways Visits Survey, 2013; National Park Visitor Survey, etc.) or on a particular type of activity (Great Britain Tourism Survey, since 1989; International Passenger Survey; NI Sports and Physical Activity Survey, 2009 etc.). Sen et al. (2014) developed a flexible, interdisciplinary and readily transferable methodological framework relying on off-site household survey data which can be applied to estimate recreational demand and values for any area, spatial unit and habitat mix. They implement a two-step statistically driven model of open-access recreational visits and their associated values in Great Britain. First, they develop a trip generation function (TGF) which models the expected number of visits from a given outset area to a given site. This is modelled as a multi-level Poission regression of several independent variables including the characteristics of the outset location (including socioeconomic and demographic characteristics of the population and the availability of potential substitute sites), the characteristics of the destination site (habitat type) and the travel time (and hence cost) of the journey. This model is based on a large sample, annual in-house survey carried out by Natural England since 2009. In the second step, they developed a trip valuation meta-analysis model, which combined data from approximately 300 previous assessments of the value of outdoor recreational visits, to determine the recreational use value of predicted visits.

The strength of this model is its ability to provide estimates of the annual number of visits and the value of visits across Great Britain for both the current situation and any future time. However, this model works best at the regional and national levels (Personal communicate with Sen). Local level models can only be successful if the local variations adequately reflect the real reasons behind trip variability. In fact the variations normally happen at a much smaller scale, such as the individual site. Therefore, it is clear that more work will have to be done at the local level to make this tool more implementable for local authorities. The research reported here takes a step in that direction.

Key ecosystem services provided by urban greenspace are valued using the benefit transfer method, including three different valuation methods: hedonic pricing, contingent valuation, and expert interview (Barnaby 2009, Carolyn et al, 2006, 2007, CabeSpace, 2005). Perino et al. (2011) carried out a meta-analysis based valuation of urban greenspace in the UK. They estimated marginal value functions of proximity to formal recreation sites (parks, gardens, accessible recreation grounds and accessible woodlands of at least 1ha), city-edge greenspace and general greenspace and found that the marginal value functions are monotonically decreasing in distance, income and population and monotonically increasing in relation to the size of a Formal Recreation Site. A limitation of this research is that the key benefits derived from urban greenspaces are measured as a bundle and, therefore, it is not possible to disentangle individual value categories.

2.2 The discrete choice modelling

Aggregate demand models, as discussed above, are either based on observed relations for groups of travellers, or on average relations at the zone level. On the other hand, disaggregate demand models are based on observed choices made by individual travellers or households. In general, discrete choice models postulate that “the probability of individuals choosing a given option is a function of their socioeconomic characteristics and the relative attractiveness of the option” (Ortúzar & Willumsen, 2011, p227).

The discrete choice model is based on random utility theory (Domencich and McFadden, 1975; Williams, 1977). Individuals have been categorised into a given homogeneous population Q. Each option has an associated net utility for an individual. The utility can be represented by two components, first is a measurable part (e.g. travel time, travel cost) and the second part is a random part which reflects the idiosyncrasies and particular tastes of each individual. Error terms are assumed to be independently and identically distributed (IID) following the double exponential (Gumbel Type II extreme value) distribution. Together the function calculates the probability of an individual’s choice of a destination for an outdoor recreational purpose.

The multinomial logit model is the simplest and most popular practical discrete choice model (Domencich and McFadden, 1975). The choice probabilities are:

$$P_{iq} = \frac{\exp(\beta V_{iq})}{\sum_{A_j \varepsilon A(q)} \exp(\beta V_{iq})}$$

Where the utility functions usually have the linear in the parameters：

$$V_{iq} = \sum_{k} \theta_{ki} x_{ikq}$$

There is a certain set A = {A_1, …, A_j} of available alternatives and a set X of vectors of measured attributes of the individuals and their alternatives. A given individual q is endowed with a particular set of attributes x ∈ X and in general will face a choice set A(q) ∈ A. The parameters θ are assumed to be constant for all individuals in the homogeneous set, but may vary across alternatives, and the parameter β cannot be estimated separately from the parameters θ in V_{iq} is known as theoretical identification. Some useful properties summarised by Spear (1977) are:

a). Disaggregated demand models are based on theories of individual behaviour and do not constitute physical analogies of any kind. Therefore, it is more likely that disaggregate demand models are stable or transferable in time and space.

b). Disaggregated demand models may be more efficient than aggregated models in terms of information usage; fewer data points are required as each individual choice is used as an observation, and in principle, disaggregated demand models may be applied at any aggregation level.

c). Disaggregated demand models are less likely to suffer from biases due to correlation between aggregate units.

d). The explanatory variables included in the model can have explicitly estimated coefficients. In principle, the utility function allows any number and specification of the explanatory variables.

The Discrete choice model has been used as a serious modelling option in transport modelling since the 1980s (Ortúzar & Willumsen, 2011). However, travel prediction models used for transport planning purposes tend not to focus specifically on access and travel to outdoor spaces, thus lacking precision in trip-making predictions.

3. METHODOLOGY

3.1 The trip generation function

The trip generation function models a dependent variable defined as the expected number of visits from a given outset area to a given site. Individuals have been categorised into a given homogeneous population Q, we use socioeconomic groups (UK Census, 2011). Each option has an associated net utility for an individual. The utility can be represented by two components, 1) travel time, and 2) a random part. In the logit discrete choice model, the random part is assumed to be independently and identically distributed (IID) following the double exponential (Gumbel Type II extreme value) distribution (see Section 2.2). This random utility has then been weighted by the area of available greenspace within each destination. Together the function calculates the probability of an individual’s choice of a destination for an outdoor recreational purpose. To generate an estimate of the number of visits, it is then multiplied by the mean total of trips per person per year (data from Natural England, 2009-2013) and the total population in each socioeconomic group (UK Census, 2011).

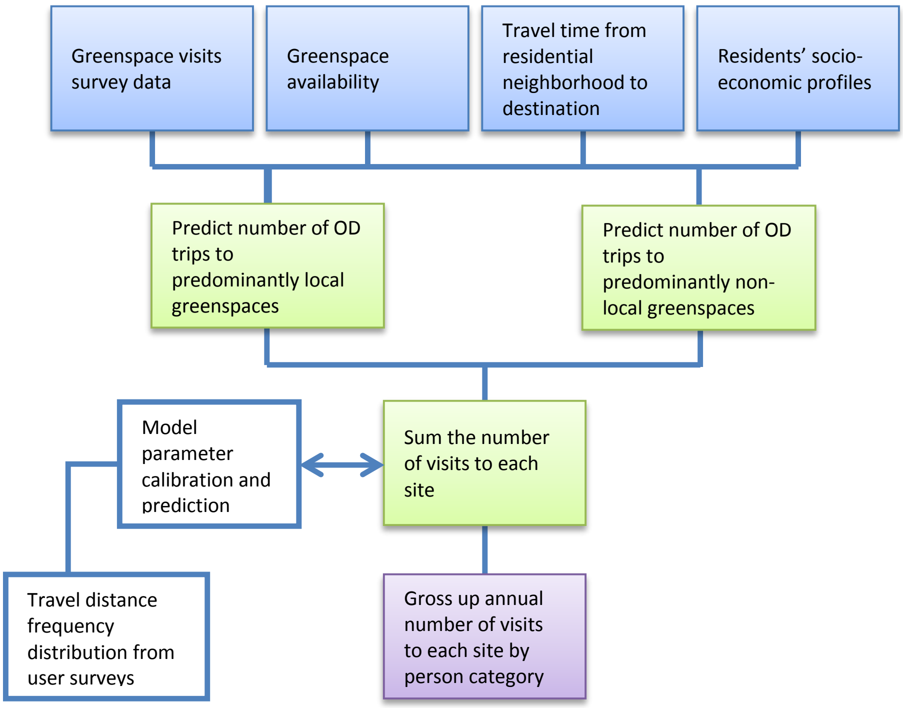


Figure 1. Schematic representation of the model methodology

Through initial analysis of observation data (Natural England, 2013), we categorised recreational trips into two major types (See Figure 2). The first group of trips are predominantly local trips which are generated for short visits at the destination. Those are mainly daily visits to green spaces nearby as day-to-day routine trips. The second group of trips are predominantly non-local trips. Those trips are for long visits to destinations such as the countryside, coastal areas or other cities or towns away from home. They usually happen during weekends or holidays, where attributes of the destination are more important than distance. This assumption is based on the travel time budget theory (Makhtarian and Chen, 2004), which states "*At the aggregate level, travel expenditures initially appear to have some stability. Similar travel time and money budgets may be found within a sub-population and in certain areas*". The method to define the local and non-local trips is based on a review of previous studies on how long people will spend on traveling in average. Eg. 1.1–1.3hrs per traveller per day (Zahavi and Ryan, 1980; Zahavi and Talvitie, 1980), about 430hrs per person per year (Hupkes, 1982), 50mins to 1.1hrs per person per day (Bieber et al., 1994), 1.1hrs per person per day (Schafer and Victor, 2000) or 1.3hrs per person per day (Vilhelmson, 1999). In conclusion, Travel Time for Local Trips (day trips) is likely to be less than 1.3hrs (78mins) per person. Considering an 8min penalty for people to get into their cars, a trip's travel time that is less than 35mins (about 40km driving) is defined as a "Local Trip". In this paper, we have used 40km as a benchmark distance to separate local trips (distance equal or less than 40km) from non-local trips.

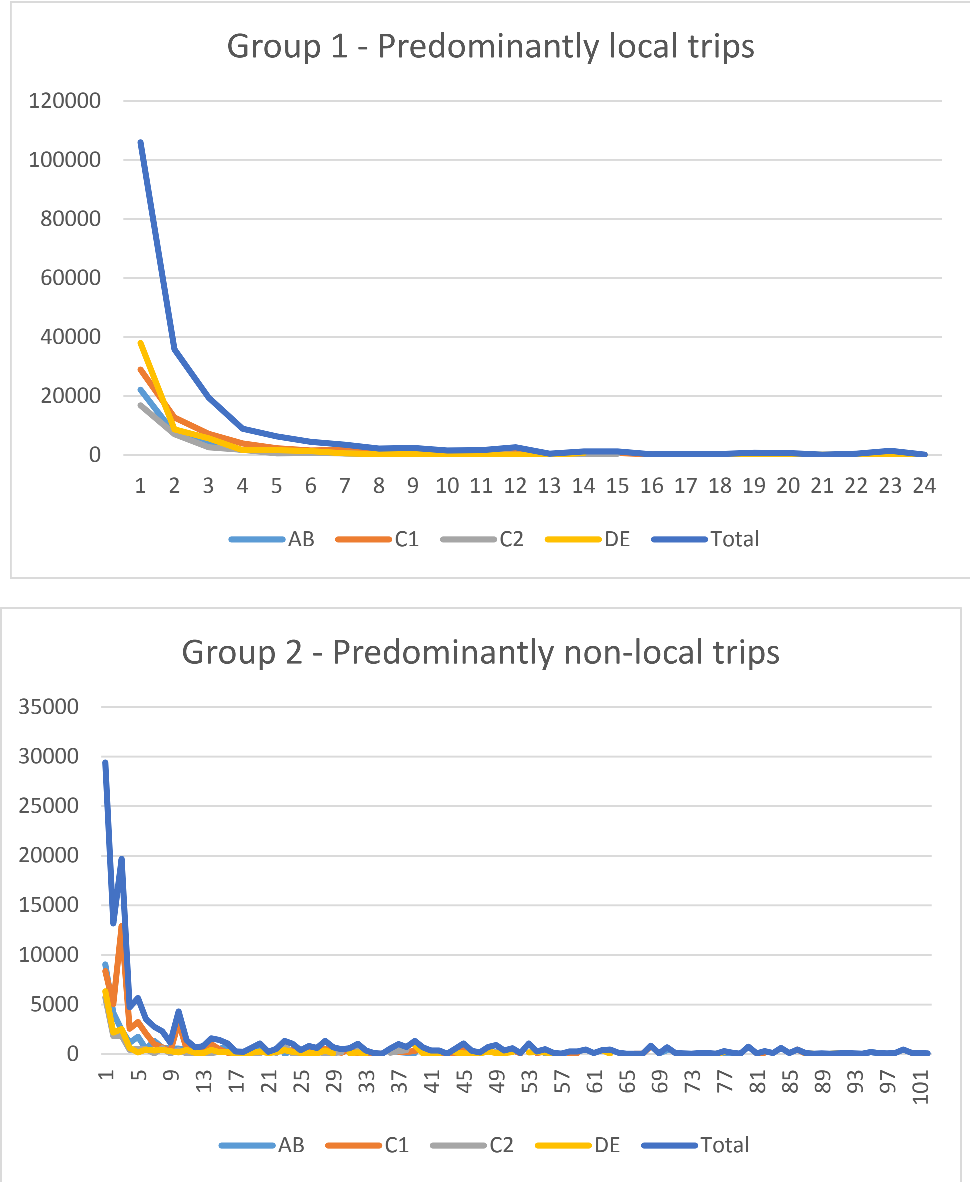
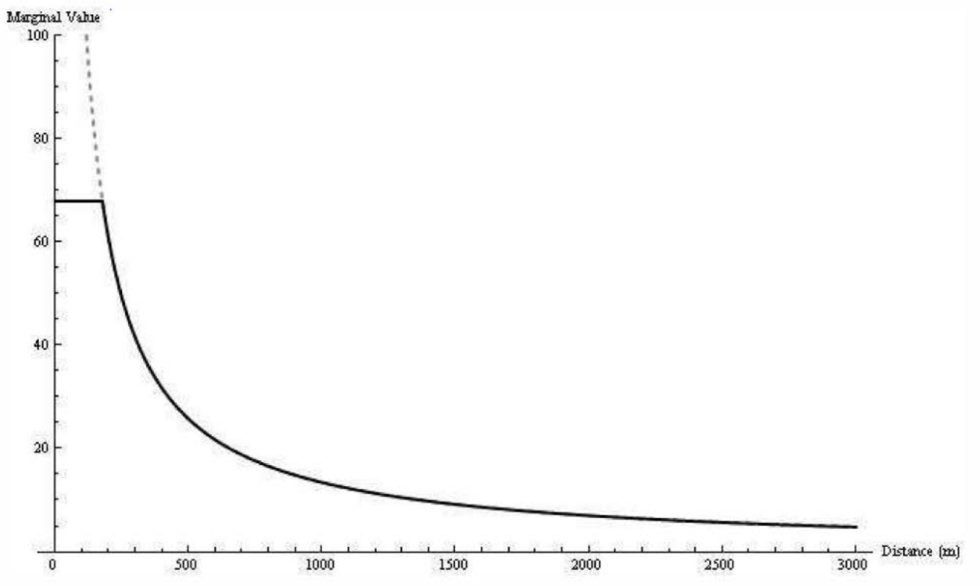


Figure 2. Greater Manchester outdoor recreational trips' distance choice. X axis represents distance (m) and Y axis represents number of trips per year. Observation data from the MENE (2013) survey, charts are drawn by the author.

The pattern of predominantly local trips gives similar results to Perino et al. (2011) in terms of a steep distance decay profile in destination choices (See Figure 3). On the other hand, the analyses of predominantly non-local trips



prove the assumption from Sen et al. (2013), that the longer distance visits are strongly affected by other variables such as the attributes of the greenspaces rather than distance.

Figure 3. Distance decay function of marginal value for a 10ha park. Source: Perino et al, 2011

Building on the above assumptions, we estimate the TGF using a discrete choice logit model through two parts:

$$VL_{ijx} = \frac{S_j^b * \exp(-\lambda_x t_{ij})}{\sum_{j=0}^{m} S_j^b * \exp(-\lambda_x t_{ij})} * Al_{ix}$$

$$VN_{ijx} = \frac{S_j^{b'} * \exp(-\lambda_{x'} t_{ij})}{\sum_{j=0}^{m} S_j^{b'} * \exp(-\lambda_{x'} t_{ij})} * An_{ix}$$

VL_{ijx} denotes average number of local recreation trips per person per year from residential neighbourhood i to destination j, in socio-economic group x. VN_{ijx} denotes the number of non-local recreation trips from the same origin to the same destination and for the same group of people. S_j is the size of greenspace within destination j and m is the total number of destinations. b and λ are parameters for local trips, b' and λ_x ' for non-local trips. x indicates socioeconomic group x. t_{ij} denotes the travel time from residential neighbourhood i to destination j. Al_{ix} and An_{ix} denotes the average total of predominantly local or non-local trips per person per year from neighbourhood i in socioeconomic group x.

$$\mathrm{N(j)} = \sum_{x=0}^{r} [\sum_{i=0}^{k} (VL_{ijx} + \mathrm{VN}_{ijx}) * Pl_{ix}]$$

N(j) is the total annual number of visits at destination j. r represents the total number of socioeconomic groups. k is the total number of residential neighbourhoods i. Pl_{ix} means the population of socioeconomic group x in residential neighbourhood i.

3.2 Data

Observations of outdoor recreational visits were taken from the MENE 2009-2013 survey (Natural England, 2013). It is a questionnaire based annual survey of how and why people engage with the natural environment. Individuals from selected households are interviewed for diary records of their recreational trips in the week running up to the interview date. One of these trips is then selected at random and the geographic location of the destination is recorded. The latest survey was carried out from March 2012 to February 2013. The observation data we used for calibration and validation purposes amounted to 2,900 interviews in the Great Manchester area, and more than 650 places have been identified.

Figure 4. Destinations from MENE survey data 2009-2013.

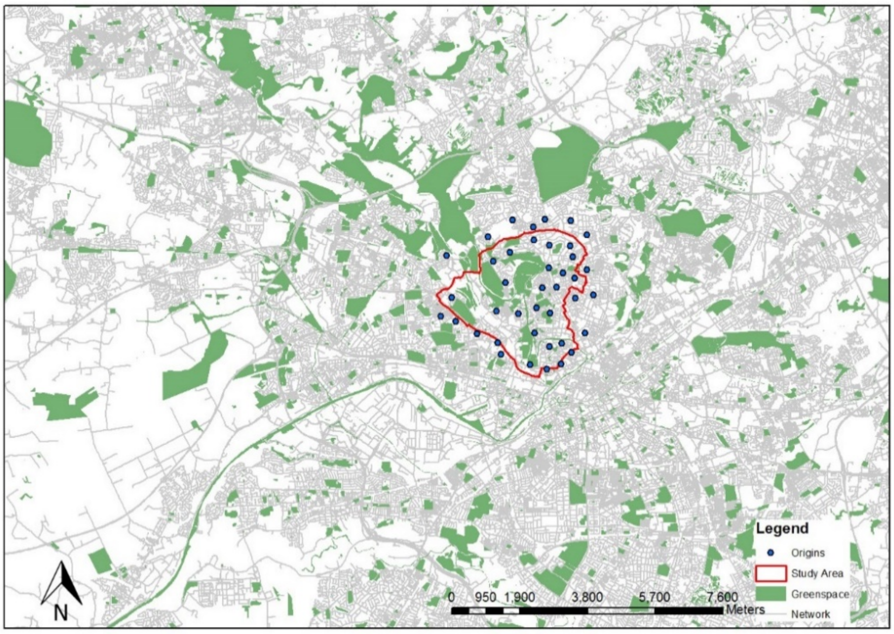


Figure 5. Population weighted LSOA centres.
Source: The UK Census, 2011.

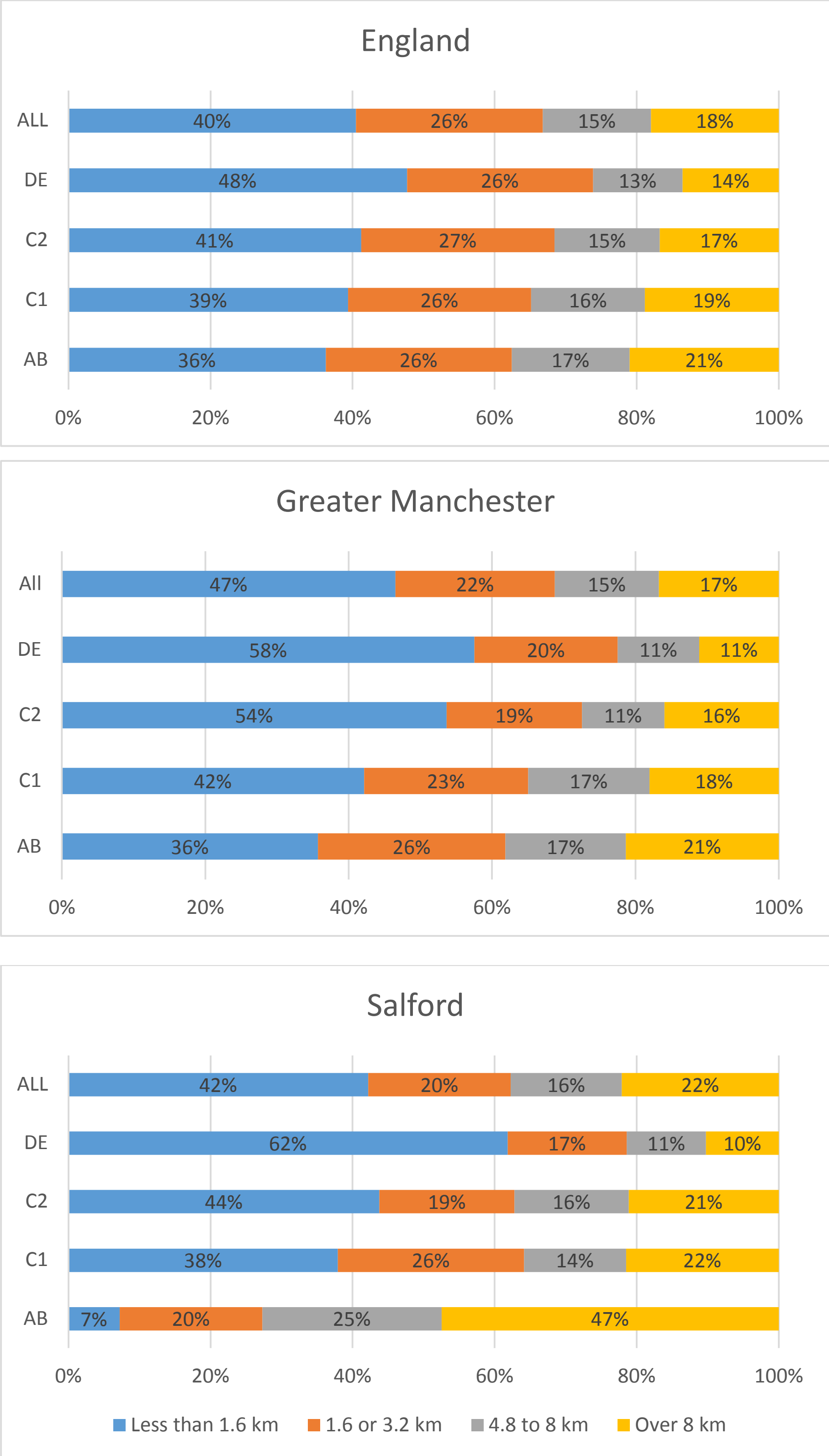


Figure 6. Observed outdoor recreational trips distances for England, Greater Manchester and Salford.
Source: The MENE Annual Report, 2013.

Our case study area is in the City of Salford, in North West England. It covers approximately 16 km^{2}and includes 40 Census Lower Super Output Areas. We have used the population weighted centres as the origins for trips. The MENE annual report (Natural England, 2013) indicates that more than 80% of people are willing to travel less than 8 km for outdoor recreational purposes. These patterns are consistent from the whole England scale to the Greater Manchester area. The pattern for the Salford area does not look very stable due to the very small sample size (162).

We expanded our research area by applying an 8 km radius buffer around each single origin, and defined the destination using 1km squares; the data in Figure 6 show more than 80% of adults travelled less than 5 miles (equal to 8 km) for outdoor recreational trips. There are two main criteria for identifying destinations: first is the location of the destination from the MENE survey and second is the availability of greenspace from the Open Street Map. Eighty-one destinations have been located within an 8 km radius buffer and their geometrical centres are later used for calculating travel time. We also create a 10km^2 grid acting as a proxy for the other 20% of destinations more than 10km away.

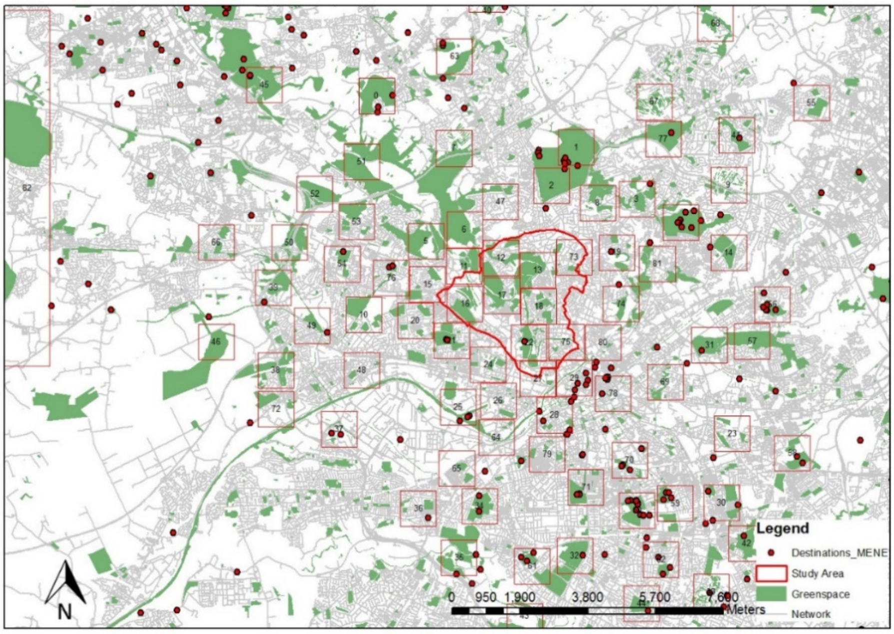


Figure 7. 8km (5 mile) buffer, as the MENE survey suggests, 80% of the destinations for adults who live in the studying area should be drawn from within this buffer area.

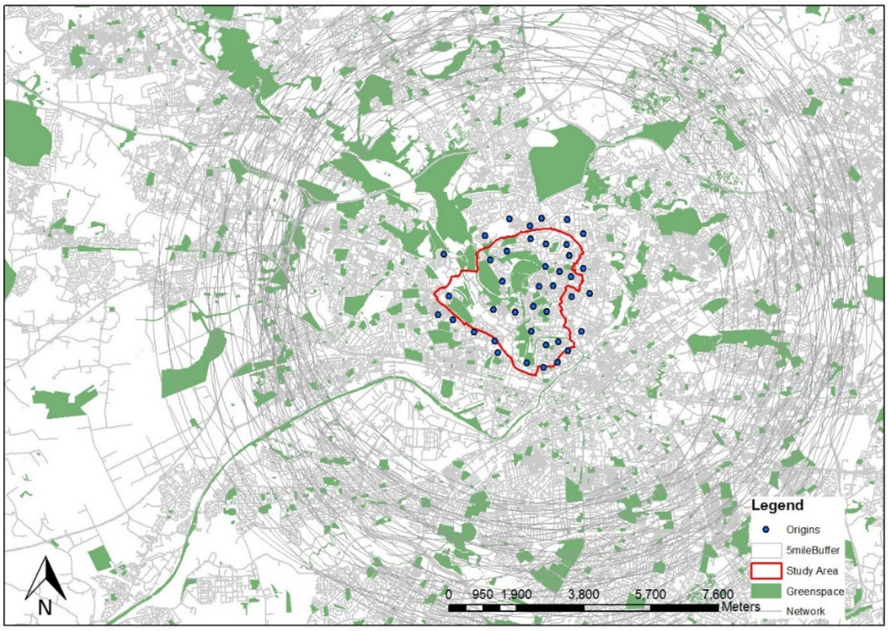


Figure 8. Destinations defined by 1 km^2 grids, drawn by the author.

Travel time from population weighted centroids of all LSOAs to destination sites were calculated using the OS Integrated Transport Network. This is a GIS dataset consisting of motorways, A-roads, B-roads, minor roads, pedestrian footpaths and cycle ways. Data from Jones et al. (2010) were employed to make allowances for varying average road speeds. The travel time calculated through the OD Matrix tool in ArcMap was validated by traveling times from Google Map.

Socioeconomic status has also made a significant difference on peoples' behaviours regarding outdoor recreation trips (Sen et al., 2013, Natural England, 2013). We took account of variations by dividing the whole population into four different socioeconomic groups according to national census data.

Table 1. Socioeconomic status classification. Source: The UK Census, 2011.

Socioeconomic Group	
AB	Higher and intermediate managerial/administrative/professional occupations
C1	Supervisory, clerical and junior managerial/administrative/professional occupations
C2	Skilled manual occupations
DE	Semi-skilled and unskilled manual occupations; unemployed and lowest grade occupations

4. RESULTS

The estimations of models have been presented in Table 2, below. As expected, travel time plays a less important role for non-local destinations than for the local destinations. In contrast, as the area of a greenspace increases, so does the ratio of the number of trips from local and non-local destinations move to favour the non-local trips. Meanwhile, for both local and non-local destinations, travel time is more important to the people who are in the lower socioeconomic groups when making their travel decisions.

Table 2. Calibrated Trip Generation Models for each socioeconomic group.

Socioeconomic Group	**Calibrated Model**
Component a). Predominantly Local Trips	
AB	$VL_{ij}\{\text{AB}\} = \frac{S_j^{0.2} * \exp(-0.56t_{ij})}{\sum_{j=0}^{\text{m}} S_j^{0.2} * \exp(-0.56t_{ij})} * 47.73$
C1	$VL_{ij}\{\text{C1}\} = \frac{S_j^{0.2} * \exp(-0.6t_{ij})}{\sum_{j=0}^{\text{m}} S_j^{0.2} * \exp(-0.6t_{ij})} * 34.84$
C2	$VL_{ij}\{\text{C2}\} = \frac{S_j^{0.2} * \exp(-0.72t_{ij})}{\sum_{j=0}^{\text{m}} S_j^{0.2} * \exp(-0.72t_{ij})} * 34.31$
DE	$VL_{ij}\{\text{DE}\} = \frac{S_j^{0.2} * \exp(-73t_{ij})}{\sum_{j=0}^{\text{m}} S_j^{0.2} * \exp(-0.73t_{ij})} * 35.48$
Component b). Predominantly Non-local Trips	
AB	$VN_{ij}\{\text{AB}\} = \frac{\text{S}_j * \exp(-0.001t_{ij})}{\sum_{\text{j}=0}^{\text{m}} \text{S}_j * \exp(-0.001t_{ij})} * 37.5$
C1	$VN_{ij}\{\text{C1}\} = \frac{\text{S}_j * \exp(-0.002t_{ij})}{\sum_{\text{j}=0}^{\text{m}} \text{S}_j * \exp(-0.002t_{ij})} * 21.35$
C2	$VN_{ij}\{\text{C2}\} = \frac{\text{S}_j * \exp(-0.006t_{ij})}{\sum_{\text{j}=0}^{\text{m}} \text{S}_j * \exp(-0.006t_{ij})} * 16.9$
DE	$VN_{ij}\{\text{DE}\} = \frac{\text{S}_j * \exp(-0.008t_{ij})}{\sum_{\text{j}=0}^{\text{m}} \text{S}_j * \exp(-0.008t_{ij})} * 11.83$

The combined result was well validated with the observed MENE data, in a way that satisfies the standard requirements of travel demand prediction models.

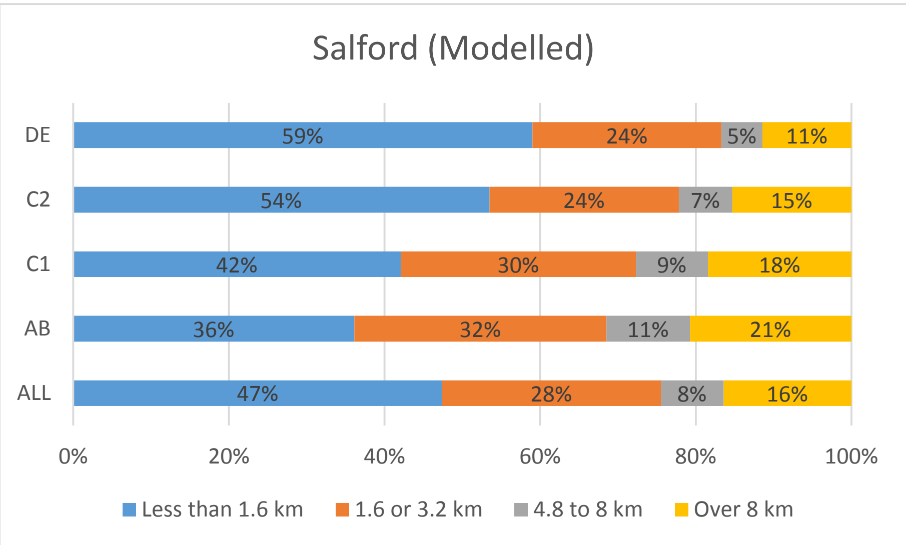


Figure 9. Modelled outdoor recreational trips in the study area.

5. CONCLUSIONS AND FUTURE WORK

Our integrated model has two components for (a) predominantly local trips and (b) predominantly non-local trips. Unlike existing methods, both components of our model are based on the discrete choice model, which gives a transparent representation of the choices of greenspace sites visited. This is also more consistent with residents' destination choice. When the model is used to test scenarios, it combines greenspace in urban and rural areas as a whole infrastructure instead of treating them separately. Component (a) gives similar results to Perino et al. (2011) in terms of a steep distance decay profile in destination choices, which is strongly influenced by travel time and socio-economic profiles, and relatively weakly by greenspace size. Component (b) gives similar results to Sen et al. (2013), with a gentle distance decay – the longer distance visits are strongly affected by greenspace size.

We have realized that greenspace size alone would not be able to describe all the attraction for visits. More detailing of attributes, such as the percentage of different types of land cover within each destination will be explored in the next stage of work. This may provide us with the answer to "what kind of greenspace will attract more visits?" This is a very hard question for urban green space modelling which has not been satisfactorily answered in the existing literature. We hope we will be able to make significant progress in the next steps. Meanwhile, the value of a single trip per person will also be reviewed based on existing literature. The ultimate objective of this study is to provide a toolkit which is able to quantify a greenspace's recreational value.

One main challenge is to obtain detailed observations for validation; it is rare to find origin-destination surveys or even systematic arrivals for greenspace sites. New social media data may have some potential in filling this gap. It would seem necessary to develop a new research agenda to collect such information in order to strengthen the empirical basis of the model.

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Planning review on residential environment of low-rent housing: a method to solve low-rent housing space insufficiency in Tianjin, China

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Key words: Low-rent Housing, Environment Design, Barrier-free Design, Design Guideline

Abstract: Globally, there has been a substantial increase in the number of people who are not able to buy their own dwellings due to the phenomenal appreciation of real estate prices in China. With the growing worldwide demand for low-rent housing and the importance of supporting and stimulating sustainable development, the need for sustainable solutions in the low-rent housing sector is at a peak. For achieving new design methods for low-rent housing, we attempted to employ a practical project to explore the residential environment from the viewpoint of the Chinese national green building standards and municipal low-rent housing policy. Firstly we investigate the low-rent housing residential area in Tianjin, China. After a questionnaire and interview of local residents has been conducted, the characteristics of the residential environment are analysed. We consider that the outdoor space of low-rent housing could be diversified to partly fulfil interior functions, by which way the cost of the low-rent housing could be reduced to a certain extent.

1. INTRODUCTION

In this work we attempt to find out how the planning regulations can provide a solution by using public space for solving housing space insufficiency to improve residential environments in China. For this, we reviewed the planning system regarding the Chinese Green Construction Standard for exploring the environmental design guidelines of low-rent housing, residential areas. As a result, the design guidelines of low-rent housing environments balances public space and housing space for community communication in residential environments from the viewpoint of indoor and outdoor spaces.

Regarding policy measures for low-rent housing, the definition of housing affordability was used to overcome the difficulties for accessing acquisition of new housing buildings (Hulchanski, 1995). The rising need of housing is also a reflection of the difficult situation that individual households confront with affordable housing issues because of the rising cost (Edward et al., 2005). Chinese cities with high density development undergoing rapid urbanization processes often lack green space (Jim, 2002a), particularly in low-rent housing areas. Most Chinese low-rent residential areas are developed under an intensive urban policy and planners have tried to create high density and low-rent housing to confront the fast population growth since the 1980s, while during the 1990s a good amount of cities augmented greening space programs, which need considerable financial support to maintain the green spaces in low-rent housing areas.

Recently, the compact city has become a term for a sustainable urban form that has control of urbanization and at the same time controls natural land use areas (Beatley, 2000). In cooperation with human activity, natural land use areas, especially along the edge of the countryside, need to be enlarged (Swenson and Franklin, 2000). Some research reports in the fields of environment and ecology provide suggestions on an optimization of environmental space utilization within conservation, consumption and improvement (Forman and Godron, 1986; Dramstad et al., 1996). Some design concepts of spatial arrangement have been conducted effectively in environment landscape projects and urban planning designs (Goldstein et al., 1982/1983). For example, many studies have proposed landscape design concepts which are composed of linear mosaic elements to enlarge the possibilities of connection of the land, including green plants for urban inhabitants, including small living creatures, in order to create a harmonious natural living environment (Ahern, 1991; Walmsley, 1995; Mazzotti and Morgenstern, 1997; Quayle and Lieck, 1997; Flores et al., 1998; Schrijnen, 2000). However, few research reports focus on the functions of green space for improving housing space insufficiency with a viewpoint of indoor and outdoor community communication in low-rent residential areas.

So far, housing space insufficiency research has been conducted on comprehensive low-rent housing design and planning in the environment of high density developments (Jim, 2002b). In the European and American developed countries, there has been little research on housing space insufficiency and it is difficult to find typical references to the practice in China. Regarding housing morphology related to low density or scattered layouts, the studies on residential area landscapes mostly focus on residential garden type, which is not directly applicable for low-rent housing in uptown areas with high density. Although the landscape design is not specifically for low-rent housing environments, its application to residential environment improvement is possible in order to find some solutions for housing space insufficiency in low-rent housing areas.

In recent years in China, there has not been any official national regulation of low-rent housing development. Although the establishment of the system of low-rent housing in China has been around more than ten years, there is no literature discussing housing space insufficiency as one of the planning issues of low-rent housing. Only 18 papers in the Chinese National Knowledge Infrastructure (CNKI) database can be retrieved when searching for "low-rent housing" and "design", thus little literature can be found about low-rent housing planning and design guidelines on residential environments. Moreover, low-rent housing has been discussed in recent years in developing countries (Bajunid and Ghazalib, 2009), addressing the problem through a sociological viewpoint for reviewing the crisis of poor families. For finding a possible solution to residential environments in low-rent housing areas, the objective of this paper is to review how landscape design can be a new method for balancing housing space insufficiency due to the limited cost for low-rent housing, to improve the living quality of the residents.

2. APPROACH

For achieving a new design solution for residential environments in low-rent housing areas for housing space insufficiency, we investigate the low-rent housing residential area in Tianjin, China. We consider that the outdoor space of the low-rent housing could be diversified to partly fulfil the interior functions.

In this paper, we attempt to find a solution for housing space insufficiency in low-rent housing areas based on the Green Construction Standard for residential environments. With interviews of the local residents, the characteristics of the residences towards housing space usages are analysed. A couple of design solutions are given respectively for each problem in the existing low-rent housing environment and an evaluation of the design solutions is discussed based on the case study.

The remainder of this paper is organized as follows: Section 3 describes the research area and investigation information details; Section 4 discusses the liveability requirements of the residential environment in low-rent housing area based on the interview investigation with residents; in Section 5 and 6, design solutions are reviewed according to the national Green Construction Standard; and finally, in Section 7, a brief conclusion is given and future work is discussed.

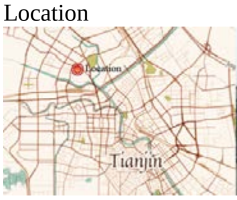
3. INVESTIGATION AND STUDY AREA

For understanding what kinds of design guidelines on landscape design and public space are possible for solving the problem of housing space insufficiency, a field survey and interview have been conducted in Tianjin.

Tianjin is ranked as the fourth largest city in China. Tianjin's GDP reached 1.12 trillion Yuan in 2011, an increase of 16.4 percent from 2010. The city of Tianjin recorded China's highest per-capita GDP with $13,393, followed by Shanghai with $12,784 and Beijing with $12,447.

For this investigation, the current conditions of the study area related to location, traffic, landscape, space intensity, facilities for the disabled and sense of belong have been summarized in *Table 1*. As summarized in *Table 1*, RuiXian Yuan and RuiXiu Yuan are typical projects of low-rent housing built in 2005 and 2006 in Tianjin, China, which are located in the suburb of HongQiao District. The buildings are six-storeys with each apartment 40-50 square meters. Most of the apartments are low rent housing, managed by the department of housing management of the local government. The residents who meet the conditions for low-income groups can be selected to live in the apartments. Since most of the apartments were built by the local government for low-income groups, the budget for the maintenance of the building management is limited.

Table 1. Current conditions of the study area

Field Investigation	Photograph	Current Conditions	Analysis
Location 		Most of the apartments are built by the local government, there are not enough funds to maintain the building.	The design should consider the sustainability of the construction budget and the sustainability of low-cost maintenance.

Traffic 	The residential location is on the edge of the city, however, the convenience of reachin g the city centre has been considered, so it's next to a station.	Maintain the current s tatus
Landscape 	Not enough green plants in the environment.	Consider vertical and group greening plans to form effective damage resistance.
Space Features 	Outdoor space is crowded, while interior space is narrow.	Maximize the efficiency of the space, interlace the activity space, resting space and walking paths.
Facilities for the Disabled 	Most facilities in the park facilitate are for the disabled and the eld erly.	According to the budget, at least achieve the basic standards for the disabled.
Sense of Belonging 	The public stigma of poor people concentrated in one location is still to be solved.	Beside the design, also consider housing residents psychological factors

4. LIVING NEEDS ANALYSIS OF LOW-RENT HOUSING ENVIRONMENT

4.1 Indoor and Outdoor Factors

We conducted a field survey in October 2009 in the study area, which mainly focused on the different aspects of the living needs of low-rent housing environment residents. The interview survey follows Maslow's hierarchy of needs (Maslow, 1943) to examine the different needs of residents, which are the physiological needs, social communication needs, aesthetic needs and needs regarding a sense of self-worth. The majority of the residents are elderly or disabled (See *Figures 1* and *2*, below). Thus, the interview was chosen as a method to investigate residents' opinions in the study area. Limitations to the interview included their education level and the health condition of the elderly (bad hearing, weak eyesight), meaning they could not understand the questions properly during the questionnaire. In this interview survey, 26 residents were chosen; however, the effective answers received were from only 11 healthy residents, consisting of seven elderly and four youth under 18. We tried to figure out the living needs in both the indoor and outdoor housing environments.

Figure 1. The elderly or disabled residents in the study area

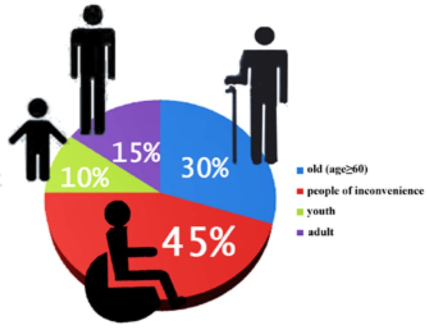


Figure 2. Ruixiu Yuan age structure percentage (from the community service center)

Based on the interview, most problems of the housing environment point to the insufficient indoor space and lack of outdoor space. Problems of environmental scene and management are mentioned during the interview, which are not as strong as the issue of insufficient indoor space. All the responders suggested strengthening the communication function in public spaces instead of indoor spaces. Thus, the communication function that is difficult in indoor space is actually fulfilled by the outdoor space in this study area.

Other responders argued for aesthetic demand and sense of self-worth, which are not related to our purpose in the paper and will not be discussed further in the remaining parts of this paper. *Figure 3* is a psychological structural model that summarizes the field survey, which we will discuss in detail in the following sub sections.

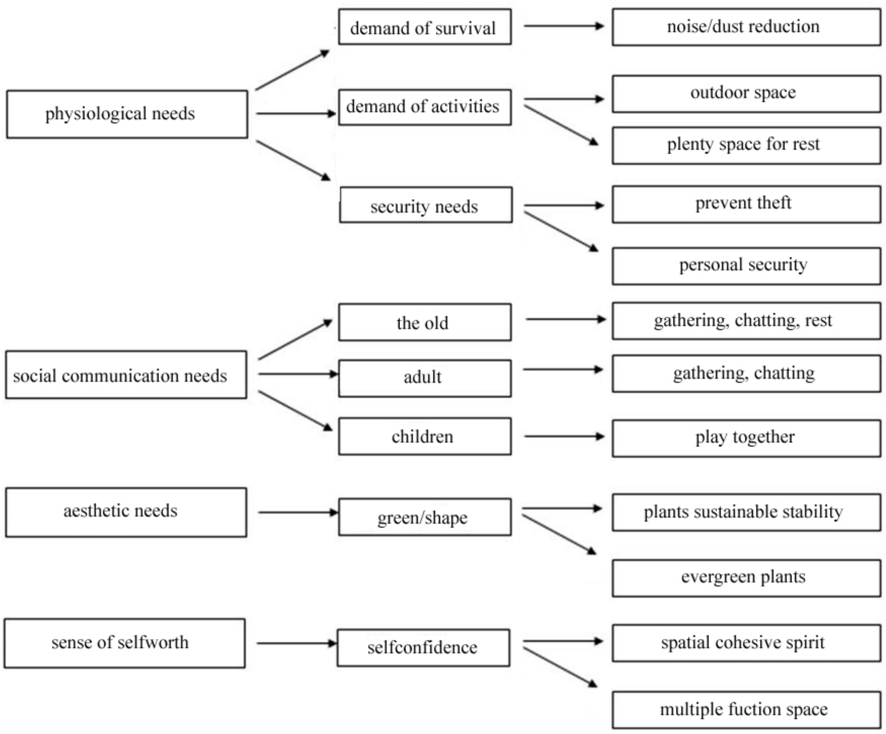


Figure 3. Living needs between indoor and outdoor spaces in the study area

4.2 Physiological Needs

Physiological demand is the physical priority demand of human beings for survival, which is also the basic requirement for a living environment. It includes fresh air, good ventilation, plenty of sunshine, suitable climate, no interference noise and so on.

4.2.1 Survival Needs

First of all, the residents do have many dissatisfactions with the current environment. 10 of the 11 interview responders think the problems of current concern are related to the indoor space.

The core problem from the responders concentrates on the indoor space insufficiency as the indoor space is where the residents actually live. In small rooms filled with all kinds of stuff (See *Figure 4*), residents feel depressed by there being barely any room for sitting. This issue further influences on their communication with their visiting guests because of the physically impossible space, which is mentioned by more than half of the responders. The residents have no alternatives for this situation.

Figure 4. The insufficiency of the indoor space

There is no good building management, so indoor water leakage, water plugging and other problems were also highlighted during the interview. According to the interview, some of the first floors of the building always have water on the floor. As shown in *Figure 5* on the following page, there are drainpipes installed from the second or third floor because of water plugging.

Figure 5. The drainpipes installed from the second or third floor

4.2.2 Activity Needs

Space is demanded for all kinds of outdoor activities in residential environments. In the daily life of the residents, outdoor activities may widely include rest, sports, recreation, fitness and a series of other activities that are done in the outdoor space environment.

In low-rent housing, the majority of the residents belong to the elderly population who like to stay with their grandchildren in outdoor spaces, therefore more outdoor space for both sitting and being active is needed. In the interview, seven elderly people suggested that there should be more space for their sedentary and outdoor activities. If possible, they would like to spend the day time outdoors instead of watching TV at home.

At the same time aged people were asked about their state of fatigue when they go out in the yard for outdoor activities. Due to personal preferences of walkable distance for different elderly people, the existing residential area has no reasonable spaces for rest according to the interview responses because they are concerned with the distance of how far or how long they can manage before they may fatigue. Similarly. if they go out for purposeful activities (chatting, and playing chess etc.) as shown in *Figures 6* and *7*, usually they will have to bring their own small stool as they can't stay long in a standing position.

Figure 6. The residents need to prepare small chairs to go out for a rest

Figure 7. The residents play chess at the curbside

4.3 Social Communication Needs

Whether low-rent housing settlements or ordinary residential areas, the social communication demand of human activities is essential. In the study area, the proportion of elderly people is higher than in ordinary residential communities. The outdoor environment can be the most important communication place for the elderly population since normally they will not travel long distance and the elderly would not like to be segregated from the community. However, every interior space of low-rent housing is limited, thus it is a limitation of the residents' indoor communication ability. For communication, there should be a strong sense of encouraging and strengthening communication behavior in the planning and design work.

In addition, the need of visiting spaces for adults who are the working population cannot be ignored, they are important members of low-rent housing families. They visit for talks with colleagues, friends and neighbors. For less than fifty square meters of low-rent residential interior space, receiving a visitor in the home is very tight and the residents would like to have some conversation place outdoor as shown in *Figures 8* and *9*.

*Figure 8.*There is no space to meet residents' strong demand of communication

*Figure 9.*There is no space to meet residents' strong demand of communication

5. REVIEWING PLANNING REGULATIONS FOR IMPROVEMENT OF HOUSING SPACE INSUFFICIENCY

After analysing the current condition of the study area, we attempt to figure out how to solve the problems which are brought up by the indoor space insufficiency in the low-rent housing environment. In the case study area, the total area of low-rent housing is 100,000 square meters with 2222 households; the total area of interior space of each household is less than 50 square meters with two types of housing models. Moreover, the floor area ratio is set as 3.0; greening space rate is 30% and bicycle usage is set at three bicycles for each household. This study area is subject to a high-rise residential building, tied in part with commercial facilities and public facilities. According to the housing conditions, we employed an evaluation standard, namely *Chinese Green Construction Standard*, GB/T 50378-2006. We employed six aspects of the standard to review the current situation of this area, which are: *Land-saving and outdoor environment, Energy saving and energy utilization, Water saving and water resource utilization, Material Saving and resource utilization, Indoor environment quality and Operation management.*

Some of the six contents of the standard are not related to the topic of this paper, we partly selected the relevant options from all the related standards. A preliminary assessment table, shown as *Table 2* and *3*, in which the standard of regulations are for the indoor and outdoor indicators, is applicable for reviewing if the current housing situation qualifies meeting the standards. A preliminary judgment towards the Standard was made: the initial determination of qualification is marked as a tick "√"; the unqualified options are marked as "X"; the Standard provisions temporarily unable to be judged are marked as "-". All the evaluations shown in the two tables were summarized from the discussion on the related standard provisions in a meeting between six experts of Nankai University in Tianjin after the field survey explained in this section.

Table 2. Land-Saving and outdoor environment

Standard Provisions	Result
4.1.1 Site construction does not destroy local cultural relics, natural drainage, wetland, basic farmland, forest and other reserves.	√
4.1.4 Residential building layout ensuring indoor and outdoor sunshine environment, daylight and ventilated requirements, meet the national standard "urban residential district planning and design specification of GB 50180 in the residential building sunshine standard requirements.	√
4.1.6 The rate of the residential area not less than 30%, per capita public green area of not less than 1㎡	√
4.1.9 Residential public service facilities according to plan, reasonable use of comprehensive building and sharing and its surrounding areas.	√
4.1.11 Residential environmental noise conforming to the national standard "urban regional environmental noise standard of GB 3096 regulations.	—
4.1.12 Residential outdoor daily average heat island intensity is not higher than 1.5 ℃.	√
4.1.13 Residential wind environment conducive to winter outdoor walking is comfortable and transitions different seasons, for example, natural ventilation in summer.	√
4.1.14 According to the local climate conditions and plant natural distribution characteristics, planting a variety of types of plants, constructed by combining multi-level planting, every 100m ² of green space has not less than three planted trees.	√
4.1.15 Location and residential gateway setting is convenient for residents to make full use of public transport networks. Residential gateway to public	√

transportation sites walking distance is less than 500m.	
4.1.16 Residential non-road motor vehicles, the ground parking lot and other hard floors using permeable ground, and the landscapes provision of shade. Outdoor permeable surface area ratio is not less than 45%.	√

Table 3. Indoor environment quality

Standard Provisions	Result
4.5.1 Each house has at least one living space to meet the requirements of sufficient sunlight. When there are four or more living spaces, there are at least two living spaces that meet the requirements of sufficient sunlight.	√
4.5.2 Bedroom, living room (hall), study, kitchen set up with windows, the daylighting of the room coefficient is not lower than the national standard "architectural lighting design standard" of GB 50033 regulations.	√
4.5.4 Living space has natural ventilation, ventilation openings in hot summer and warm winter areas. Hot summer and cold winter area is not less than 8% of the area of the room floor, in other areas is not less than 5%.	√
4.5.5 Indoor area is free of formaldehyde, benzene, ammonia, radon and TVOC and air pollutant concentrations according to the national standard "civil building indoor environment pollution control norm" GB 50325 regulations.	—
4.5.10 By the adjustable outer shading device, there is prevention of summer sun radiation through window glass directly into the indoor space.	—
4.5.12 Bedroom and living room (hall) use materials with energy storage, humidity or improve indoor air quality functions. (design stage, this not eligible)	—

After reviewing the standard, we have a clear understanding that there are provisions issued for indoor and outdoor spaces, however, although the standard provisions are not related directly to the housing space insufficiency, it is possible for designers to consider how to use the outdoor space to compensate for indoor space insufficiency. In the next section, we will try to find a solution to the design and planning in the study area that fits the requirement of the necessary facilities in outdoor space, and to a maximum extent, that shares the functions of indoor space.

6. SUGGESTIONS AS DESGIN GUIDELINE FOR HOUSING SPACE INSUFFICENCY

In this section we attempt to solve the main problems of housing space insufficiency of the low-rent housing in this case study area. For considering how to use public space for activity needs and social communication needs, instead of housing space, this was clarified in Section 4. Some of the design guidelines related to indoor and outdoor environments are suggested as follows according to the suggestions from experts in Nankai University.

6.1 Interlaced Functional Outdoor Space according to the Guidelines

Based on the discussion in the last section, low-rent housing, with the majority group of the elderly and disabled, should provide sufficient sitting space and activity space for incontinent people, to meet their demands of quality of living and communication.

For the elderly population, there should not be long distances designed as green belts because they are non-sitting spaces. It is important to design the space for old people to rest and avoid large areas of green planting because of high maintenance. These thoughts about indoor and outdoor use have been put into the design principle as shown in *Figure 10*.

Besides the elderly people, although child activity facilities differ from those of the elderly population, the safety precautions of the activity space are similar. Thus, it is possible to combine the activity/sitting space of the elderly population and children, scattered as different zonings in the area.

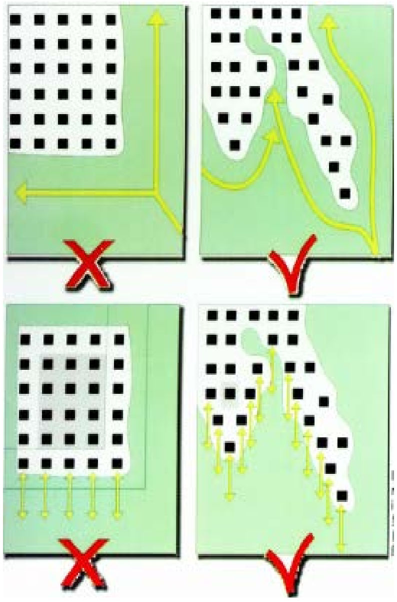


Figure 10. The interlaced pattern of functional outdoor space

Figure 11. An example of interlaced functional outdoor space

6.2 The Establishment of the "Private" Yard according to the Guidelines

In order to make up for the space deficiency of sitting space indoors, some half-closed private space is necessarily established in the residential district, which is equivalent to transferring the indoor function to a courtyard space for receiving visitors as shown in *Figure 12*.

The spatial arrangement of the private yard facilitates entry to each residential area for convenience, consisting of several half-closed places for conversation and discussion. It avoids the main road, preventing traffic interference. In the space division, trees and shrubs are the soft isolation belt, which are 0.8m to 1.3m in height, in order to provide conversation space privacy. In this way the sitting room function is moved to the outdoor environment, allowing individual communication to happen in an outdoor environment and promoting neighborhood relationships. At the same time, the space also scatters space, achieving a variety of functions for old peoples' rest.

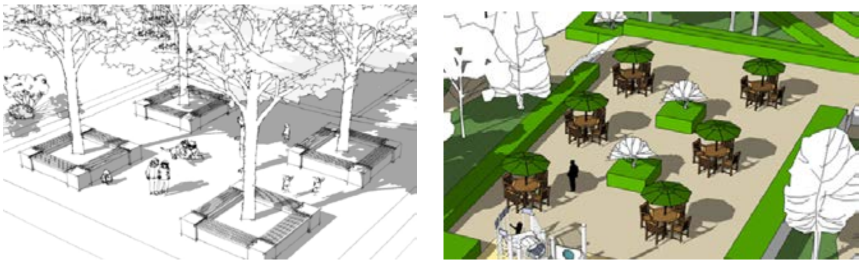


Figure 12. The example of the “private” yard

In order to provide a comprehensive consideration of the public space for housing space insufficiency, first, full use of the first floor space of the building must be made, combining with the landscape design and public services. Second, the needs of different age classes should be taken into consideration carefully in landscape design. Third, the open space of public activities should be combined with relatively independent groups, such as: the children’s activity space and fitness equipment playgrounds. Finally, to differ from commercial residential design, the design concept should aim for low maintenance. Besides that, it is important to increase community-supported commercial facilities for improving the use of public space in the central community area for solving the problem of housing space insufficiency.

From reviewing the residential environment and related design standards that are the Chinese Green Construction Standards from a view of housing space insufficiency, it is possible to add related new guidelines to the standard provisions for using public space to solve the problem of housing space insufficiency.

7. CONCLUSION

The contribution of this research is to explore an alternative to solve the indoor space insufficiency of low-rent housing development. This research may help the housing department of the government consider which elements of the public space may have a higher facilitation of indoor residential activities for solving the problem of housing space insufficiency.

Instead of redesigning the building, this work addresses the point that by reorganizing the residential environment to shift some insufficient indoor functions to the outdoor space, an improvement for low-rent housing can be achieved. This is easier to implement than rebuilding the whole area for residential improvement. From the result of this research, some provisions for considering public space as solutions to housing space insufficiency could be taken into consideration in low-rent housing development. In the future we will try to explore other alternatives within acceptable financial budgets in order to help low-income groups own sustainable housing environments.

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