International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-7 Issue-2, November 2017

Emission Control and Route Optimization in Municipal Solid Waste Collection and Transportation using Agent-Based Model

Khanh Nguyen-Trong, Van Dinh-Thi-Hai, Anh Nguyen-Thi-Ngoc, Doanh Nguyen-Ngoc

Abstract: The amount of municipal solid waste (MSW) has been increasing steadily over the last decade by reason of population growth and waste generation rate. The management of municipal solid waste collection and transportation is a challenge. Efforts should be made to provide these systems with the best methods to improve their overall efficiency, thus to reduce fuel consumption, pollutant emissions and costs. In this paper, a model for optimizing municipal solid waste collection and also pollutant emissions will be proposed. Firstly, the optimization plan is developed in a static context, and then it is integrated into a dynamic context using multi-agent based modelling and simulation. A case study related to Hagiang City, Vietnam, is presented to show the efficiency of the proposed model. From the optimized results, it has been found that the cost of MSW collection and the pollutant emissions (CO_2, CO, NO_x, PM, HC) are respectively reduced by 15.8 % and 16 %.

Keywords: Municipal solid waste management, Route optimization, Environmental modelling, Dynamic modelling, Agent-based model Equation-based model, Vehicle routing model.

I. INTRODUCTION

Waste management is a particularly sensitive subject, since it affects the everyday life of the population. Nevertheless, efforts should be made to provide these systems with the best methods to improve their overall efficiency, thus by reducing fuel consumption, pollutant emissions and costs. These procedures imply the existence of considerably high fuel consumption and pollutant emissions, since the activities involved are performed by heavy road vehicles. Thus, significant benefits can be derived from the optimization of MSW collection and transportation routes as well. Recently, many models have been proposed in order to optimize the collection and transportation on the whole garbage truck network, however some of them are multi-objective. For instance, Anghinolfi *et al.* [1] presented a study related to the dynamic optimization of materials collection and recycling management. The objective of this work is: (i) to minimize the sum of vehicles costs (travelling and fixed costs); (ii) to minimize costs due to the waste volume variation over time in each cell, for example the quantity of waste remaining in the cells at the end of the planning period; and (iii) to maximize the revenue for collected waste.

Manuscript published on 30 November 2017.
***Correspondence Author(s)**
Dr. Khanh Nguyen Trong, Lecturer, Telecommunications Institute of Technology, Hanoi, Vietnam.
Dr. Dinh Thi Hai Van, Lecturer, Faculty of Environment, Viet Nam National University of Agriculture, Hanoi, Vietnam.
Nguyen Thi Ngoc Anh, Lecturer, University of Technology Vietnam.
Dr. Doanh Nguyen Ngoc, Lecturer, Thuyloi University, Hanoi, Vietnam.

According to the authors, the remaining waste in cells can be considered as a cost because, if the waste is collected, it could be sold and become a benefit. The authors proposed a multi-objective framework by a MILP model in which both commensurable costs and incommensurable objectives can be considered.

Chalkias *et al.* [2] also based on a GIS analysis tool (ArcGIS) to propose a methodology for the optimization of the waste collection and transport (WC&T) system. The objective of this work is to improve the efficiency of WC&T in the Municipality of Nikea (MoN), Athens, Greece via the reallocation of waste collection bins and the optimization of vehicle routing in terms of distance and time travelled and CO2 emissions. This work contains 3 main steps: (i) Spatial database collection of the study area; (ii) Reallocation of waste collection bins with the use of GIS spatial analysis functions; (iii) Waste collection routing optimization for minimum time, distance, fuel consumption and gas emissions.

The objectives of these proposed approaches are usually considered in a static state, i.e. minimizing the travelling cost, but not considering on the traffic flow; minimizing the quantity of the remaining waste but skipping the increase of waste in time; or optimizing the CO2 emission of vehicles but ignoring the pollution caused by the waste and so on. The dynamic and temporal issues; i.e. the traffic flow, the generation of waste; also have an important role in the optimization of the waste collection and transportation [3].

There have been many models and tools proposed to deal with this problem, many of them are agent-based models [4] in which, intelligent agent and multi-agent system seem to be suitable for dynamic processes like transportation network, CO2 emissions, waste generation at a micro level. Each traffic participant can be modelled as an intelligent agent. It can observe others and obstacles to change its own speed as well as direction to go to its destination as fast as possible. Therefore, the travel distance and also the CO2 emission can be influenced.

For instance, [4] presented a model to deal with the complexity of the field. The authors based on the integration of GIS data and Multi-Agent Simulation to create an intelligent decision supporting the system. JAVA/SWARM (a Multi-agent modelling and simulation platform and ArcView GIS software) is used to build the system. The garbage truck, the most important one, is modelled as an agent that has four important characteristics and behaviors: limited waste capacity, limited time on the field, collection of waste bins, and assigned paths.

In the work[5], a decision supporting the system for municipal waste collection is proposed in order to find an optimized travel plan for waste collection. The system is based on the integration of three components: information system map, smart devices and agent-based model. Firstly, the authors applied K-Mean and Ant Colony Optimization algorithm to find the optimal route for vehicles. Secondly, the optimal route is simulated with a multi-agent system, that is GAMA [6] platform, in order to observe an impact of traffic network on the travel distance.

In general, the combination of GIS and Multi-agent modelling and simulation complements and enriches the optimized solution of the MSW collection and transportation in urban areas. It allows us to not only capture the situation of waste collection, but also to test in different scenarios of waste management, including the routing, the position of landfills and so on [7].

Generally, existing works in the literature just propose solutions in a static context (the fixed traffic flow, and CO2 emissions) or just focus on a specific objective. This paper addresses a multi-objective optimization in which, the cost (via a travel distance and time) and air emissions will be taken into account. Firstly, an optimized plan is developed in a static context, then it is integrated in to a dynamic context using multi-agent based modelling and simulation.

II. MULTI-OBJECTIVE OPTIMIZATION MODEL

In general, the collection and transportation of municipal solid waste (MSW) can be divided into 2 steps, as show in Fig. 1. Firstly, the MSW, generated by different sources (S) (households, markets, offices and so on) is collected and conveyed to the nearest collection centre (Ci). Each centre is composed of a number of bins which have the same capacity (in m^3). Then, vehicles that start from depot (D) move through collection centres as per scheduled route, collect MSW and finish at the landfill (L).

We are interested in the latter part of the process when municipal solid waste is collected by the trucks to the depot. Because, as proposed by [3], in contemporary MSW management systems, the total management cost is mainly used for waste collection and transportation, namely, 80-90% in low-income countries, and 50-80% in middle-income countries.

In fact, the problem relates to the Heterogeneous Capacitated Vehicle Routing Problem (HCVRP) that is a generalization of CVRP to the setting of multiple vehicles having no-uniform capacity.

In this paper, we assume these following statements:

- The landfill is also the depot.
- The distance between any two nodes is well-defined.
- The demand of each waste collection centre is known

A. The Optimization Model

The problem of the MSW collection and transportation can be considered as a conventional vehicle routing problem in which the shortest path used by the vehicle from the waste sources to disposal sites will be found [8], [9], [3], [10], [11], [12]. However, it has some properties that are different from the conventional one: (i) the vehicles that are used to collect the waste have a limited capacity; and (ii) the quantity of waste at each collection point is unpredictable [13].

Let $G = (V, A)$ be the directed graph that indicates the route of a vehicle, where V is a set of collection centres, i.e. $V = \{v_0, v_1, \cdots, v_n\}$ and A is a set of arcs representing path connecting vertices, i.e. $A = \{(v_i, v_j) \parallel v_i, v_j \in V; i \neq j\}$.

Let v_0 be the depot (also the landfill). $V' = V \setminus \{v_0\}$ is the subset of V that includes n collection centres. Let S be a subset of V' containing all routes that satisfy all constraints of our objectives. Let C be the matrix of non-negative travel costs, where c_{ij} denotes the cost of travel from v_i to v_j. Let m be the number of vehicles available. Each vehicle has a different capacity of q. All vehicles stop at the landfill.

We define some relevant variables as follows:

- Let $A(S) = \{(v_i, v_j) \in V' \parallel v_i \in S, v_j \in S\}$ be the set of edges joining all pairs of collection centers in S.
- Let x_{ij} be the number of times that edge (v_i, v_j) is traveled. X is a matrix of x_{ij}, $X = [x_{ij}]_{i,j=0,n}$
- Let a positive q_i be the weight of solid waste in collection centre i, i = 1, ..., n.

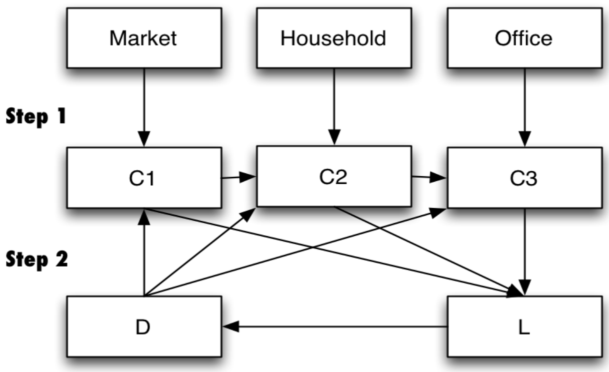

Figure 1. Architecture of the MSW Collection and Transportation

Our objective function based on the transportation cost, which is given by

$$min \sum_{i=0}^{n} \sum_{j=0, i \neq j}^{n} c_{i,j} x_{i,j}, \quad (1)$$

B. The Algorithm

We applied meta-heuristic algorithm [14] in order to find the optimized route, which is based on ruin-and-recreate principle. It is a large neighborhood search that combines elements of simulated annealing and threshold-accepting algorithms. Essentially, it works as follows: starting with an initial solution, it disintegrates parts of the solution leading to (i) a set of jobs that are not served by a vehicle any more and to (ii) a partial solution containing all other jobs. Thus, this step is called ruin step. Based on the partial solution (ii) all jobs from (i) are re-integrated again, which is therefore referred to as recreation yielding to a new solution. If the new solution has a certain quality, it is accepted as the new best solution, whereupon a new ruin-and-recreate iteration starts.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

These steps are repeated over and over again until a certain termination criterion is met (e.g. computation time, iterations, etc.).

C. Method to Estimate Pollutant Emissions And Fuel Consumption

In this paper, we apply the COPERT method [15] that is a computer program that calculates road vehicle emissions. COPERT also includes a framework for estimating fuel consumption. Besides considering specific vehicle parameters, COPERT also takes into account different driving conditions such as types of the driving situation, vehicle load and road gradient. In the present study, the authors used the data available in COPERT for the category of diesel heavy duty vehicles.

We are interested in five pollutants: NO_x, PM, CO, HC and CO2. The total exhaust emissions of NO_x, PM, CO, HC are calculated as the sum of hot emissions (when the engine is at its normal operating temperature) and emissions during transient thermal engine operation (termed ”cold-start” emissions).

$$E_{TOTAL}=E_{HOT}+E_{COLD} \qquad (2)$$

where,

- E_{TOTAL}: total emissions (g) of any pollutant for the spatial and temporal resolution of the application,
- E_{HOT}: emissions (g) during stabilized (hot) engine operation,
- E_{COLD}: emissions (g) during transient thermal engine operation (cold start).

According to the method, for the diesel heavy duty vehicle we do not need to calculate the emission during transient thermal engine operation E_{COLD}. Therefore, in our study, the total emission is equal to E_{HOT} that depends upon a variety of factors, including the distance that each vehicle travels, its speed (or road type), its age, its engine size and its weight. This emission is calculated by the means of following formula:

$$E_{HOT;i,k,r} = N_k * M_{k,r} + e_{HOT;i,k,r} \qquad (3)$$

where,

- $E_{HOT;I,k,r}$: hot exhaust emissions of the pollutant *i[g]*, produced in the period concerned by vehicles of technology *k* driven on roads of type *r*,
- N_k: number of vehicles *[veh]* of technology *k* in operation in the period concerned,
- $M_{k,r}$: mileage per vehicle *[km/veh]* driven on roads of type *r* by vehicles of technology *k*,
- $e_{HOT;I,k,r}$: emission factor (*EF*) in *[g/km]* for pollutant *i*, relevant for the vehicle technology *k*, operated on roads of type *r*.

Besides, corrections need to be made in the case of uphill/downhill driving and waste loading. In our work, the studied site is urban, thus the corrections related to the slope can be ignored. Therefore, *EF* of *CO* in the case no-load are calculated as Formula 3, and Formula 4 while loading. Regarding to NO_x, *HC*, *PM*, in two cases, *EFs* are calculated by the same Formula 5, 6, but with different coefficients.

$$EF_{CO} = a - b*exp(-c*V^d) \qquad (4)$$

$$EF_{CO} = a + b/(1 + exp(-c + d*ln(V)+ (e*V))) \qquad (5)$$

$$EF_{NOx,HC} = a*b^V*V^c \qquad (6)$$

$$EF_{PM} = a*V^3 + b*V^2 + c*V + d \qquad (7)$$

where,

- *V*: speed of vehicles,
- *a, b, c, d, e*: coefficients of the functions provided by COPERT.

The mass of CO_2 emitted can be calculated as:

$$E_{CO2} = 3.137* FC \qquad (8)$$

where,

- *FC*: the fuel consumption of vehicles for the considered time period, which is calculated by Formula 5 in the case of non-loaded, and by *(6)* while loaded (with different coefficients). The correction for the vehicle load is also realized by different coefficients.

D. The Agent-Based Model

In fact, after applying the previous algorithm, we can obtain the total distance that each vehicle will travel. But, this value is calculated in a static context. Therefore, we develop an agent-based model (ABM) to situate the optimized plan in a dynamic context. This ABM models the dynamic of the traffic network which has an impact on the total distance of the vehicles. In the ABM, we model five types of agent: *Road agent, Garbage agent, Transport agent, Garbage truck agent, and Depot agent*, as shown in Fig. 2:

1) Road agent: This agent represents the real road. The real data is derived from GIS files. So this kind of agent has all geometry attributes: position, length, etc. Each agent represents a short segment of the road. This kind of agent has no behavior.

2) Transport agent: A transport could be a truck, a bus, a car (including taxi), a motor. It has some attributes, behaviors and ability to move. The transport has an important impact on the effectiveness of the MSW collection and transportation. So we need to model it as an agent in our system. We consider the whole driver and his transport as an unique transport agent. The behavior and attributes of this agent are adapted from our previous work, presented in [16].

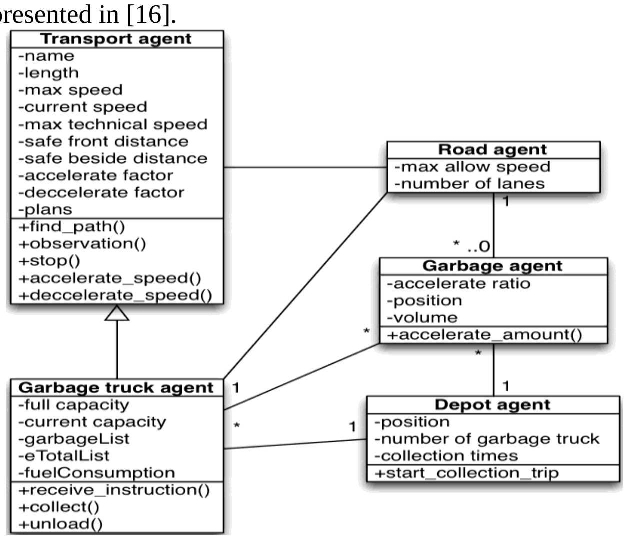

Figure 1 Modelling of Agents

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

3) Garbage agent: The garbage agent represents collection centres that are generated from GIS data. This agent has a special behavior that represents the increase of the waste amount in time. If it is not in the collection time, the amount of waste will be increased accordingly to its ratio.

4) Garbage truck agent: The garbage truck agent repre sents vehicles that transfer the garbage from the collection centres to the landfill. This agent is basically the same as transport agents on the attributes and the movement behaviors. Besides, it has some special attributes dedicated to a garbage truck:

- *full capacity*: an attribute represents the maximum amount of garbage that it can store.
- *current capacity*: an attribute represents the amount of garbage that it can store, at the current moment.
- *garbage list*: a list of collection centres that the agent must visit during a trip.
- *eTotalList*: a list of total emissions of NOx,PM,CO,HC and CO2 that is accumulated after each movement. These emissions are calculated by (2) to (6) that depend on the current speed and the status of vehicle load at each step.
- *fuelConsumption*: the fuel consumption of vehicles that is determined by (5) (non-loaded) and (6) (when loaded).

The garbage truck agent has two main behaviors:

- *collection and cleaning*: when arriving at the collection centres, it collects and cleans the garbage. If it is full of waste, it will return to the landfill for unloading.
- *unloading*: when the garbage truck agent is full of waste, it will return to the landfill and unload the waste. Then if there are still collection centres for collection, it will go to the next centre as in the plan; if not, it will return to the depot.

The behaviors, related the movement of this agent, are inherited from the behaviors of the transport agent. These behaviors make our model dynamic and different from the others.

5) Depot agent: This agent manages a set of garbage and garbage truck agents. At the beginning of a collection trip, it will initiate the plan for each garbage truck agent. This agent has the following attributes:

- *position*: the position where it is situated.
- *number of garbage trucks*: the number of available garbage trucks.
- *collection times*: the times that the garbage truck starts to collect.

This agent has a behavior:

- *control garbage truck agents*: at the beginning of a collection period, it initiates the plan for each garbage trucks agent, and demands them to collect the garbage following the plan.

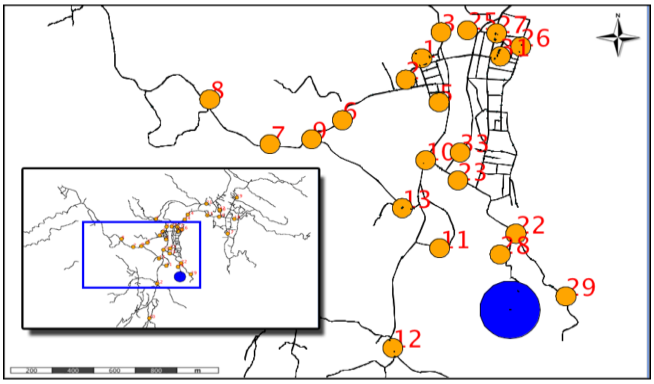

Figure 3. GIS map of the collection centres and the depot of Hagiang.

6) Simulation platform: Our simulation of the MSW collection and transportation is implemented in the simulation platform GAMA [6]. GAMA is integrated and generic tools to support the representation of features usually associated to real complex systems, namely rich, dynamic and realistic environments or multiple levels of agency. It allows modelers, thanks to the use of a high- level modeling language, to build, couple and reuse complex models combining various agent architectures, environment representations and levels of abstraction.

III. CASE STUDY

Hagiang is a mountainous province, which is located at the northernmost border of Vietnam, with an important position. Hagiang have one city, 10 districts, 05 wards, 13 towns and 177 communes. Hagiang has 33 collection centres as shown in Fig. 3 (the smaller map inside describes the locations of overall investigated region; the bigger map is a zoomed view of a smaller part; the yellow circles denote the collection centres, while the bigger blue circle indicates the location of depot). Its depot and landfill is the same one. The waste generation rate of Hagiang is 181.4 tones or 365.4 m3 for each day.Hagiang has two vehicles (35m^3 and 50m^3) that are responsible for the collection and transportation at two regions. Each vehicle collects twice a day (in the morning and in the afternoon).

In the morning the plan of vehicle 1 is 0 → 31 → 26 → 27 → 23 → 21 → 20 → 32 → 18 → 19 → 16 → 15 → 24 → 27 → 33 → 23 → 0, while it is 0 → 28 → 29 → 22 → 5 → 1 → 3 → 4 → 2 → 6 → 7 → 8 → 9 → 13 → 23 → 30 → 12 → 11 → 10 → 5 → 1 → 23 → 0 for the vehicle 2.

In the afternoon, the plan for vehicle 1 is 0 → 26 → 27 → 33 → 23 → 24 → 14 → 15 → 16 → 17 → 18 → 19 → 20 → 21 → 25 → 0, and 0 → 28 → 22 → 5 → 4 → 3 → 1 → 2 → 6 → 7 → 8 → 9 → 13 → 12 → 11 → 10 → 23 → 0 for the vehicle 2.

In this case study, we apply the proposed method in order to compare the obtained result with the real one.

After applying the proposed algorithm, in the morning, the optimized plan of the vehicle 1 is 0 → 24 → 15 → 16 → 18 → 17 → 19 → 20 → 32 → 21 → 4 → 3 → 10 → 28 → 0;

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

and in the afternoon it is 0 → 4 → 21 → 20 → 19 → 17 → 18 → 16→ 15 → 14 → 24 → 0. While in the morning, the plan of the vehicle 2 is 0 → 30 → 12 → 11 → 9 → 8 → 7 → 6 → 2→ 1 → 5 → 33 → 31 → 27 → 26 → 29 → 22 → 13 → 23 → 0; and in the afternoon its plan is 0 → 13 → 9 → 7 → 8 → 6 → 2 → 1 → 3 → 5 → 22 → 10 → 12 → 11 → 23 → 28 → 33 → 25 → 27 → 26 → 0. These plans are then used as the input for the agent-based model in order to calculate the travel distance, travel time, collection time and pollutant emissions in a dynamic context.

The comparison of the obtained results for the real plan and the optimized plans of each model are presented in Tab. I and Fig. 4. In Fig. 4, the left columns indicate the results on current plan, while the right columns indicate the results after being optimized.

Substantial differences can be observed in the obtained values, from both the optimization of routes for distance, pollutant emissions and fuel consumption, when compared to the ones estimated for the actual plan.

From the optimized results, it has been found that the cost of MSW collection and the pollutant emissions (CO2, CO, NOx, PM, HC) are reduced by 15.8 % and 16 %, respectively.

IV. CONCLUSION

This paper proposes a model to optimize the collection and transportation of municipal solid waste, in term of cost and pollutant emissions (NO_x,PM,CO,HC and CO_2). In fact, the collection and transportation of MSW relates to the vehicle routing problem. In our work, we apply the meta-heuristic algorithm to find the optimal solution.

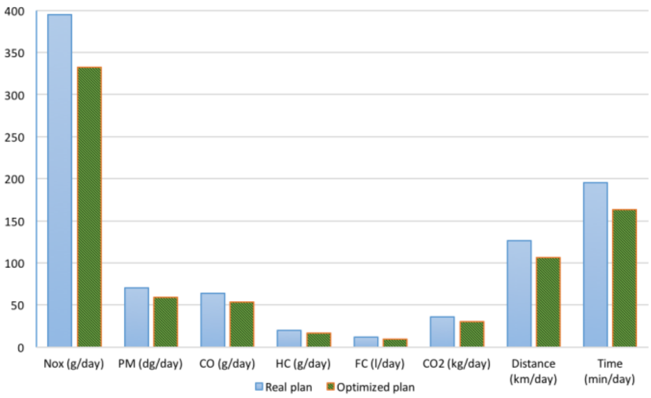

Figure 2 Comparison the Results for the Real and Optimized Plan.

TABLE I. Comparison of the Travel Distance and Time, Fuel Consumption, and Pollutant Emissions Amounts for the Real and the Optimized Plan.

	Real plan	Optimized plan
Travel distance (km/day)	126	106
Travel time (min/day)	195	163
Fuel consumption (l/day)	11.4	9.6
NO_x (g/day)	395	332.3
PM (g/day)	7	5.9
CO (g/day)	63.5	53.5
HC (g/day)	19.4	16.3
CO_2 (kg/day)	35.7	30

We applied the proposed method in the case study of Hagiang, Vietnam. The experiment results show that the optimized solution is better than the current plan. From the optimized results, it has been found that the cost of MSW collection and the pollutant emissions (*CO_2, CO, NO_x, PM, HC*) are reduced correspondingly by 15.8 % and 16 %.

Future developments regard the limitation of time for each collection (Time Window), Vehicle Routing Problem with Time Windows can help us to resolve the problem.

ACKNOWLEDGMENT

This work is funded by the AI Program with the Vietnam National University of Agriculture (VNUA) (2014- 2019).

REFERENCE

1. D. Anghinolfi, M. Paolucci, M. Robba, and A. C. Taramasso, “A dynamic optimization model for solid waste recycling,” Waste Manage- ment, vol. 33, no. 2, pp. 287 – 296, 2013.
2. C. Chalkias and K. Lasaridi, “A GIS based model for the optimisation of municipal solid waste collection: The case study of Nikea, Athens, Greece,” WSEAS Transactions on Environment and Development, vol. 5, no. 10, pp. 640–650, 2009. [Online]. Available: http://www.scopus.com/inward/record.url?eid=2-s2.0-71449113236&partnerID=40&md5=2b62a0a667c0b3241644d767d4b04cc2
3. S.DasandB.K.Bhattacharyya,“Optimizationofmunicipalsolidwaste collection and transportation routes,” Waste Management, vol. 43, pp. 9 – 18, 2015.
4. N. V. Karadimas, G. Rigopoulos, and N. Bardis, “Coupling multi-agent simulation and gis: An application in waste management,” in Proceedings of the 10th WSEAS International Conference on Systems, ser. ICS’06. Stevens Point, Wisconsin, USA: World Scientific and Engineering Academy and Society (WSEAS), 2006, pp. 656–660.
5. T. M. Hua, T. K. Nguyen, H. Van Dinh Thi, and N. A. N. Thi, “Towards a decision support system for municipal waste collection by integrating geographical information system map, smart devices and agent-based model,” in Proceedings of the Seventh Symposium on Information and Communication Technology, ser. SoICT ’16. New York, NY, USA: ACM, 2016, pp. 139–146. [Online]. Available: http://doi.acm.org/10.1145/3011077.3011129
6. A. Drogoul, E. Amouroux, P. Caillou, B. Gaudou, A. Grignard, N. Mar- illeau, P. Taillandier, M. Vavasseur, D.-A. Vo, and J.-D. Zucker, GAMA: A Spatially Explicit, Multi-level, Agent-Based Modeling and Simulation Platform. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013, pp. 271–274.
7. S.-H. Huang and P.-C. Lin, “Vehicle routing scheduling for municipal waste collection system under the ’keep trash off the ground’ policy,” Omega, vol. 55, pp. 24 – 37, 2015.
8. M. A. Maimoun, D. R. Reinhart, F. T. Gammoh, and P. M. Bush, “Emissions from {US} waste collection vehicles,” Waste Management, vol. 33, no. 5, pp. 1079 – 1089, 2013.
9. M. Mes, M. Schutten, and A. P. Rivera, “Inventory routing for dynamic waste collection,” Waste Management, vol. 34, no. 9, pp. 1564 – 1576, 2014.
10. H. Haghshenas, M. Vaziri, and A. Gholamialam, “Evaluation of sustain- able policy in urban transportation using system dynamics and world cities data: A case study in isfahan,” Cities, vol. 45, pp. 104 – 115, 2015.
11. O. Buenrostro-Delgado, J. M. Ortega-Rodriguez, K. C. Clemitshaw, C. Gonzlez-Razo, and I. Y. Hernndez-Paniagua, “Use of genetic algo- rithms to improve the solid waste collection service in an urban area,” Waste Management, vol. 41, pp. 20 – 27, 2015.
12. L. H. Son and A. Louati, “Modeling municipal solid waste collection: A generalized vehicle routing model with multiple transfer stations, gather sites and inhomogeneous vehicles in time windows,” Waste Management, vol. 52, pp. 34 – 49, 2016.

13. S. K. Nambiar and S. M. Idicula, "A multi-agent vehicle routing system for garbage collection," in Advanced Computing (ICoAC), 2013 Fifth International Conference on, Dec 2013, pp. 72–76.
14. G. Schrimpf, J. Schneider, H. Stamm-Wilbrandt, and G. Dueck, "Record breaking optimization results using the ruin and recreate principle," Journal of Computational Physics, vol. 159, no. 2, pp. 139 – 171, 2000.
15. D. Gkatzoflias, C. Kouridis, L. Ntziachristos, and Z. Samaras, "Copert 4. Computer Program to calculate emissions from road transport." European Environment Agency, no. February, 2012.
16. M. H. Nguyen, T.-V. Ho, T. K. Nguyen, and M. D. Do, "Modeling and simulation of the effects of landslide on circulation of transports on the mountain roads," International Journal of Advanced Computer Science and Applications(IJACSA), vol. 6, no. 8, 2015.
17. E. N. Arifin and A. Ananta, Older Persons in Southeast Asia: An Emerging Asset. Institute of Southeast Asian Studies, 2009.
18. N. R. Ministry of and Environment, "Report of environmental situation in vietnam, chapter 6: Solid waste," Ministry of Natural Resources and Environment, Tech. Rep., 2010

Dr. Khanh Nguyen Trong was born in 1982. He received his Bachelor degree in Information Technology (IT) at Hanoi University of Science and Technology in 2005, his Master degree in IT at the L'Institut de la Francophonie pour l'Informatique (old IFI) in 2008, and his Ph.D. in IT at the University of Paris VI , France, in 2013. He is currently a lecturer at Posts and Telecommunications Institute of Technology, Hanoi, Vietnam. His domains of interest are Distributed System, Computer Support Collaborative Work, Modelling and simulation of the complex system, Collaborative Simulation and Modelling.

Dr. Dinh Thi Hai Van, was born in 1975. She received her Bachelor degree Biology (Special in Ecology and Environment), Hanoi University of Science, Vietnam in 1997, her Master degree in Environmental Engineering and Management Asian Institute of Technology (AIT), Thailand in 2005, and her PhD in in Global Agricultural Sciences, The University of Tokyo, Japan, in 2010. She is currently a lecturer at Faculty of Environment Viet Nam National University of Agriculture.

Nguyen Thi Ngoc Anh, is Ph.D in Artificial Intelligence at University Pierre and Marie Curie Paris VI, France, in 2014. She is a lecturer in University of Technology Vietnam. She is also a member of UMMISCO UMI 209, IRD/UPMC, France. Her research concentrates on multi-agent system, simulation in the complex system.

Dr. Doanh Nguyen Ngoc, was born in 1981. He received his Bachelor degree in Mathematics at Hanoi National University of Education in 2003, his Master degree in Applied Mathematics at Hanoi National University of Education in 2006, and his PhD in Computer Science at University Pierre and Marie Curie Paris VI, France, in 2010. He is currently a lecturer at Thuyloi University, Hanoi, Vietnam. He is also a member of UMMISCO UMI 209 Lab, IRD/UPMC, France. His domains of interest are Dynamical Systems, Computer Support Collaborative Work, Modelling and simulation of the complex system.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)