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Lkhaasuren Batbold • Davaanyam Batnasan

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Recycling and collection of waste material with system dynamics analysis

Lkhaasuren Batbold[1], Davaanyam Batnasan[2*]

[1]Mongolian University Science and Technology, School of Applied Sciences,
[1]batbold.lkh@must.edu.mn
[2]Mongolian University Science and Technology, School of Applied Sciences
[2]dbatnasan@must.edu.mn

***Abstract*—** We witness the accelerating effects of climate change, pollution, and resource depletion, the need for effective management strategies has never been more urgent. On the other hand, re-manufacturing of used merchandise presents a compelling opportunity for Original Equipment Manufacturers (OEMs) to enhance their environmental footprint, bolster customer satisfaction, and optimize production costs. We are investigating and evaluating the system behavior of a mining manufacturing company as a case of study, by using System Dynamics (SD). VENSIM PLE software developed the simulation model. The research method presented offers a valuable tool for examining the intricacies of Closed-Loop Supply Chain (CLSC) systems. By simulating these systems, one can gain insights into their potential benefits and drawbacks before committing to real-world implementation. This pre-emptive analysis allows for informed decision-making, mitigating the risks associated with implementing complex systems without a thorough understanding of their dynamics.

***Keywords*—**system dynamics; (CLSC) systems; supply support; supply chain

1. INTRODUCTION

Ulaanbaatar, the capital of Mongolia, faces a growing challenge in managing its urban waste. The city's population has increased in recent years, leading to a surge in waste generation. This has negatively impacted the city's appearance and cleanliness, contributing to environmental pollution and dissatisfaction among residents.

The increasing waste production has also resulted in the loss of valuable natural resources that could be conserved through recycling. This loss of resources has implications for future generations.

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* Corresponding author: Lkhaasuren Batbold

Numerous studies have been conducted on urban waste management, focusing on topics such as waste generation, classification, segregation, disposal, and incineration. These studies have also explored the role of advanced technologies in waste volume reduction and management. However, there is a gap in research regarding viable solutions for reducing waste production and its associated consequences [1].

This research aims to address this gap by presenting a systematic and comprehensive approach to urban waste management in Ulaanbaatar. It utilizes a system dynamics model to predict urban waste quantities and devise suitable waste volume reduction solutions. The goal is to promote sustainable urban development and resource conservation [2].

This study adopts a descriptive-causal approach for its applied purpose and employs a survey method for data collection. The study's statistical population consists of experts and administrators of Municipality, selected through the snowball sampling method, totalling 32 individuals. Information and documents available within Isfahan Municipality related to various investigated variables have been utilized to gather the necessary data.

In tackling issues concerning urban waste volume, this study employs the system dynamics approach. System dynamics was introduced by J. Wright Forrester in 1960 to address industrial challenges [6]. It is valuable in addressing linear and nonlinear interactions within large-scale, intricate, and dynamic systems [7]. The system dynamics model comprehensively analyzes the structure, interactions, and behavior of complex systems, evaluating and forecasting their effects in an integrated manner [8]. System dynamics aims to identify system variables and their temporal interplay [9]. This approach adeptly handles the configuration assumptions and dynamic structures of systems, enabling the management of changes within subsystems and interrelationships across the complete system [10].

System dynamics is a technique for analyzing intricate systems over time, facilitated by computer simulation software [11]. Variables are perceived as system components interconnected through mathematical mappings established by differential equations, which are numerically solved via simulation [12]. The process of this research is outlined in Figure 1.

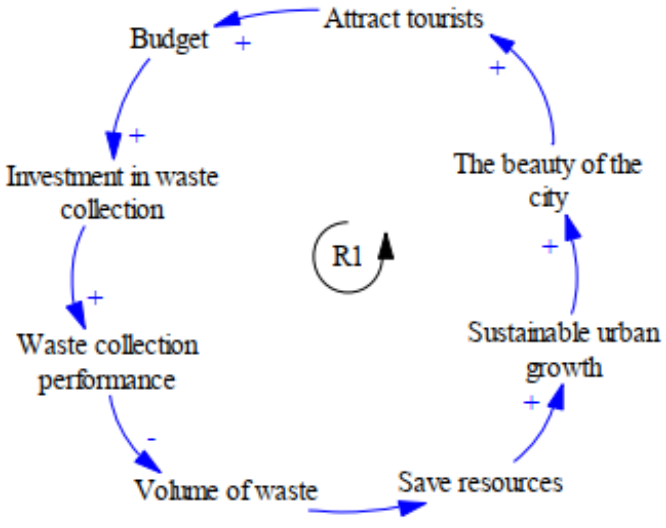

Figure 1. The feedback loop

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2. DYNAMIC HYPOTHESIS

This paper explores dynamic hypothesis, a conceptual model that utilizes reinforcing and balancing loops to analyze the relationship between key variables. This model serves as a foundational tool for understanding complex systems, particularly in the context of sustainable urban growth [2,3]. The dynamic hypothesis, illustrated in Figure 1, focuses on the relationship between investment in waste collection, waste collection performance, volume of waste, resource saving, sustainable urban growth, and city beauty.

Key Variables and Relationships:

H1: Investment in waste collection positively impacts waste collection performance.

H2: Waste collection performance influences the volume of waste.

H3: Volume of waste directly impacts resource saving.

H4: Resource saving contributes to sustainable urban growth.

H5: Sustainable urban growth enhances the beauty of the city.

The dynamic hypothesis reveals a positive feedback loop within the system. Increased investment in waste collection leads to improved performance, resulting in reduced waste volume [3, 4]. This, in turn, promotes resource conservation and sustainable urban growth, ultimately enhancing the city's beauty and attracting more tourists. This positive feedback loop highlights the importance of investing in waste management for the long-term well-being of city.

3. CAUSAL LOOP DIAGRAM

According to the determination of dynamic hypotheses and the identification of indigenous and exogenous variables of the model, the causal loop diagram is shown in Figure 2.

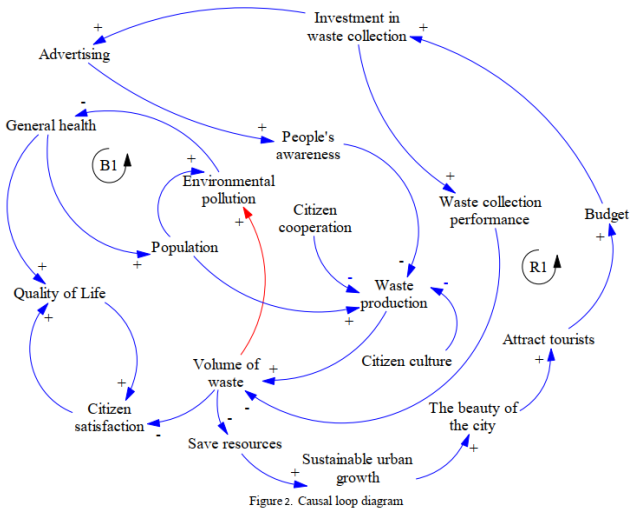

Figure 2. Causal loop diagram

4. STOCK AND FLOW DIAGRAM

The stock and flow diagram, presented in Figure 3, is a visual representation of the interactions between variables related to the volume of waste. It serves as a foundation for constructing a quantitative model that analyzes the system over a 10-year timeframe, evaluated at 12-month intervals. This diagram was developed by establishing relationships and mathematical equations among the variables under investigation.

The diagram encompasses a total of 35 variables, with six being stock variables. These variables represent the key elements of the system, and their relationships are depicted through flows and connections. The development of the diagram involved careful consideration of both quantitative and qualitative relationships, as well as numerical functions.

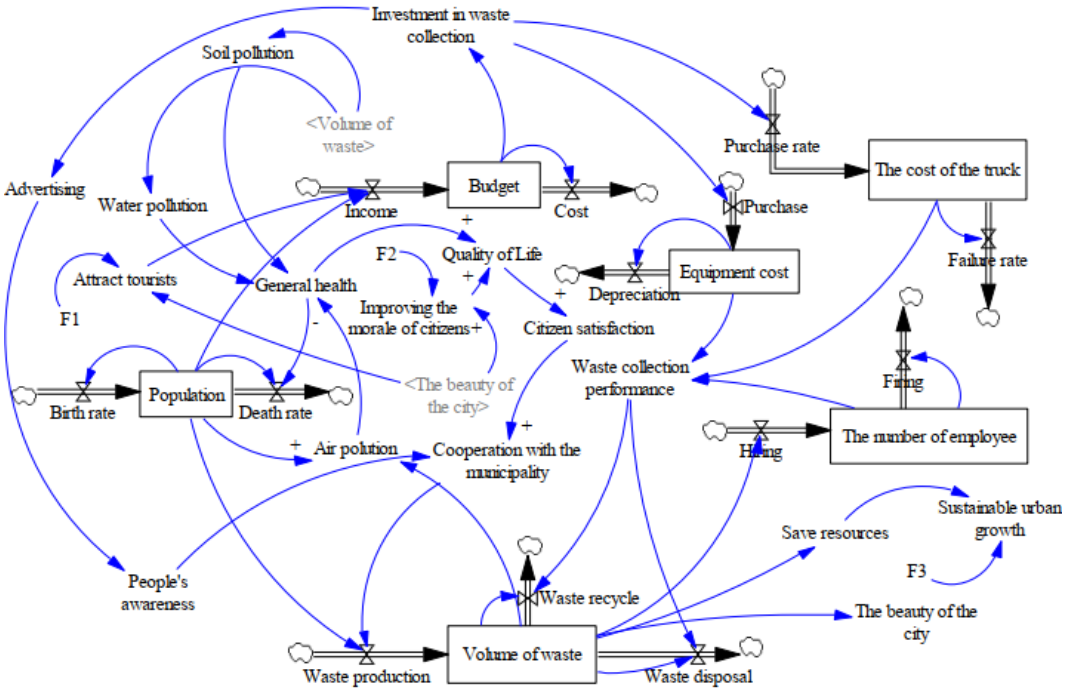

Figure 3. Stock and flow diagram

We found the process of creating the stock and flow diagram to be a valuable exercise in understanding the complex dynamics of waste generation and management. The diagram provides a clear and concise representation of the system, allowing for a more comprehensive analysis of the factors influencing waste volume [5]. The use of mathematical equations and numerical functions ensures that the model is grounded in data and can be used to make informed predictions about future trends.

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5. MODEL VALIDATION

The model's validation process is conducted in three phases, as outlined below.

5.1. Model structure evaluation test

This evaluation aims to align the model's structure with the existing knowledge within the system. In this research, urban waste management was initially identified based on the research context and subsequently refined through insights from experts and administrators in Isfahan. Ultimately, the structure of the designed model was validated by incorporating the feedback and opinions of Isfahan's experts and administrators.

5.2. Parameter evaluation test

The parameter evaluation test ensures the congruence between parameter values and their counterparts. Since the variables in this study were derived from the research context, related literature, Isfahan Municipality's documents, and expert opinions, the values align with those presented in pertinent documents and research.

5.3. The limit condition test

The assessment was conducted to evaluate the logical behavior of model variables under extreme scenariosIn this test, the value of a specific model variable gradually decreases toward zero while observing the resulting behavior of other variables that are influenced by the changed variable. For this research, the income variable has been selected to be reduced to zero, and the subsequent behavior of certain impactful variables from the budget is illustrated in Figure 5.

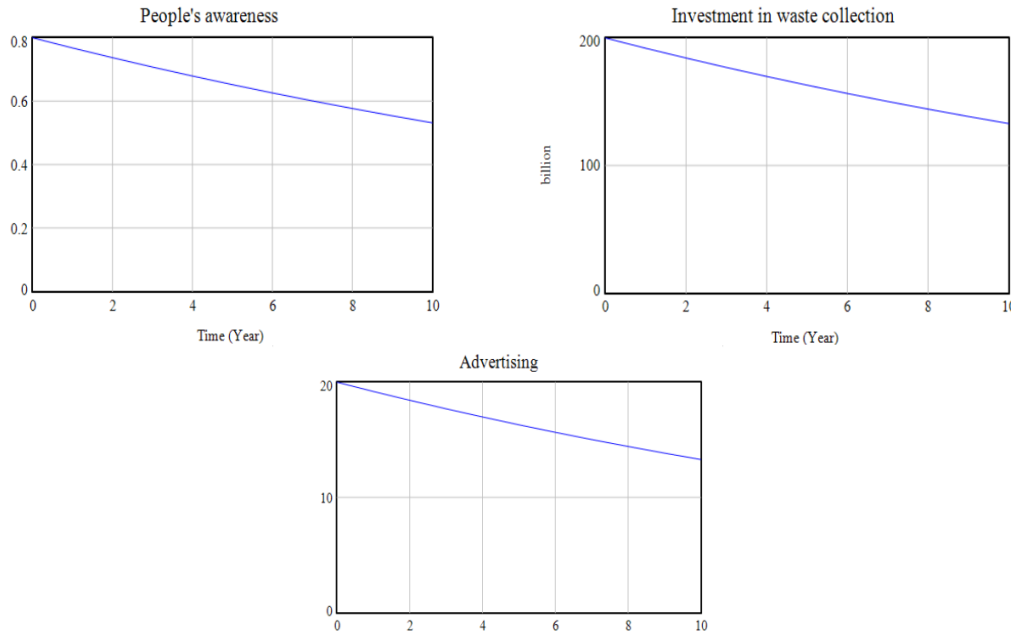

Figure 5. Model testing and validation

As shown in Figure 5, if the income amount approaches zero, the waste collection, advertising, and public awareness investment will gradually diminish over time. It demonstrates how changes in income can directly impact the allocation of resources towards waste management activities and initiatives.

5.4. Behavior reproduction test

In order to verify the correctness of the model's behavior, this test will compare the simulation results with actual data. The figures' findings demonstrate how well the researched variable may be replicated. The results are shown in Figure 6.

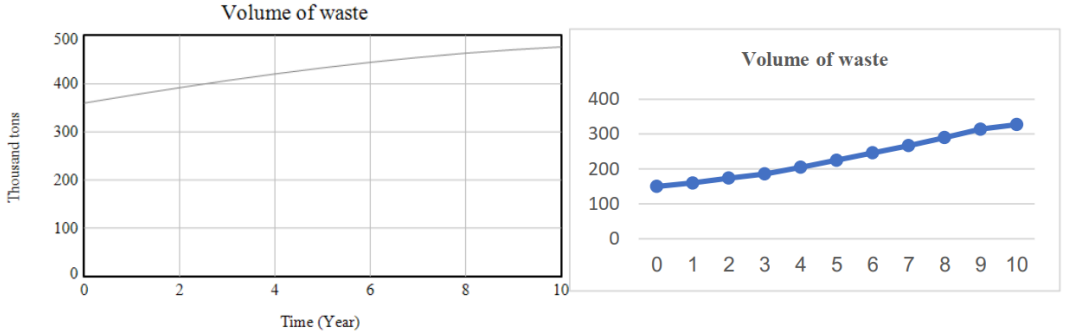

Figure 6. Comparison test with reference behaviour

6. SIMULATION RESULTS

The model has produced the following results as a consequence of the behavior of the key factors and key indicators in the volume of waste by the relationships between the model's variables that were indicated.

Implementation and evaluation of policies

This section presents the simulation results and analysis of three carefully designed scenarios. It is worth noting that in this research, three specific scenarios are developed: one that increases investment allocation in the equipment sector, another that enhances investment in advertising to boost people's awareness of waste management and urban waste, and a third scenario that simultaneously increases investments in both advertising and equipment.

The policy of increases investment allocation in the equipment sector

Figure 7 illustrates the behaviors of variables associated with waste volume when there is an increase in investment in the equipment sector for waste collection.

Figure 7. Result of policy of increases investment allocation in the equipment sector Figure 7 shows that the amount of urban waste in Isfahan will gradually decrease as investment in the sector of waste collection equipment rises. Consequently, the demand for employees in waste collection will decrease gradually, leading to increased budget allocation

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due to reduced investment needs in the waste collection sector. Moreover, the increased investment in the equipment sector for waste collection and pollution reduction is a foundation for enhancing public health. As a result, the mortality rate due to environmental pollution will decrease over time, fostering population growth. Furthermore, the outcomes of increased investment in waste collection equipment indicate that other aspects will also witness improvement. These include the storage and sustainability of resources, the aesthetics of the city, and the attraction of tourists.

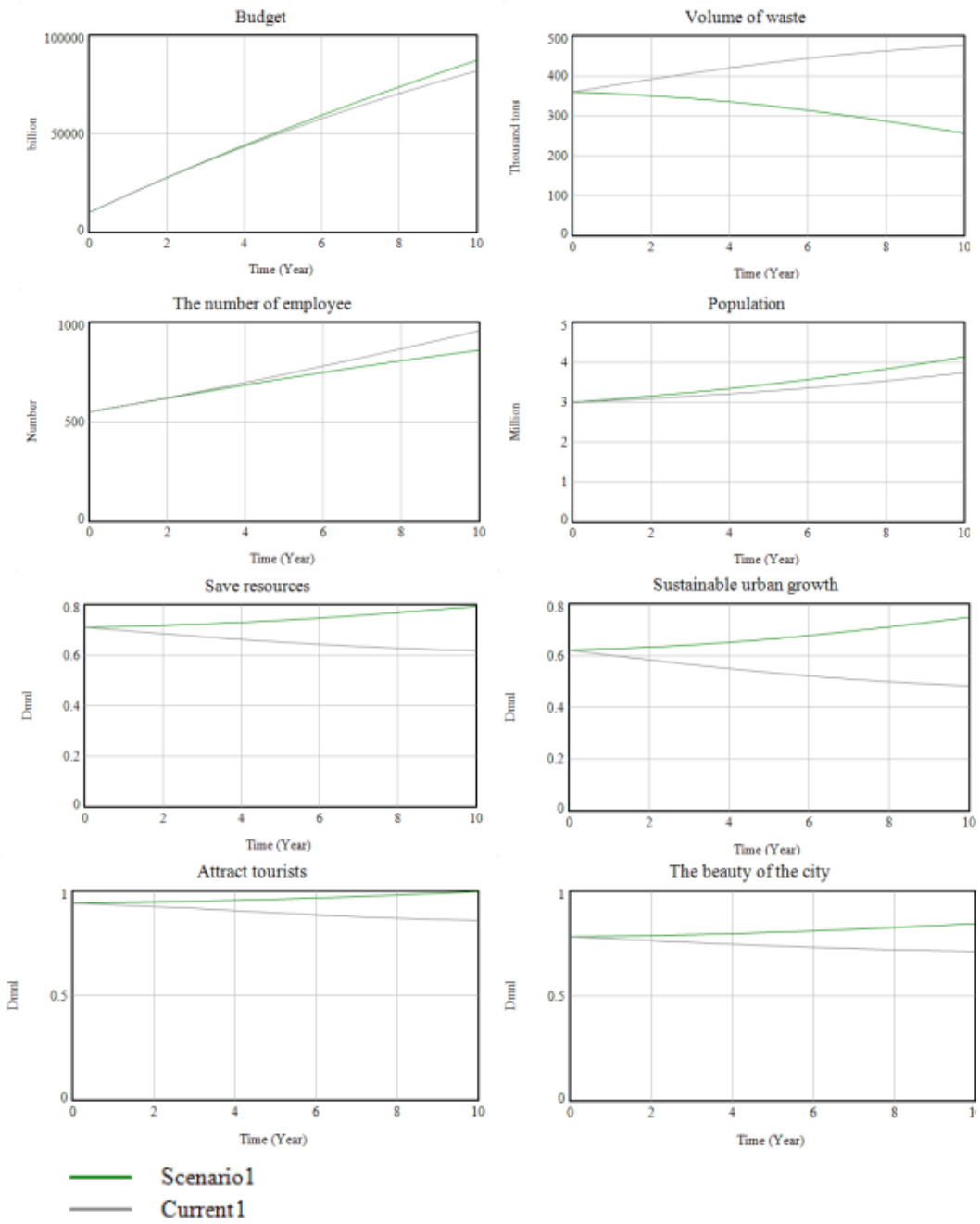

Figure 7. Result of policy of increases investment allocation in the equipment sector

In today's world, effective urban waste management holds significant importance for various societies. Neglecting waste management and urban conditions can have numerous consequences, including escalated environmental pollution and compromised citizen health. Additionally, it can diminish the beauty of the city and attractiveness, resulting in citizen dissatisfaction, resource depletion, and a decline in tourist attraction, among other issues.

This research aims to develop a simulation model that predicts the volume of urban waste in Isfahan over the next ten years and assesses its consequences. In order to achieve this goal, the research literature was analyzed to identify the factors influencing the volume of urban waste. Subsequently, the identified factors were adapted to the local context of Isfahan through the valuable insights of experts and administrators. The research investigated the dynamics and behavior of each identified factor in urban waste management through the system dynamics approach.

7. CONCLUSION

This research, conducted using the system dynamics approach, aimed to optimize waste and urban waste management in Ulaanbaatar. The study began by identifying variables influencing waste volume, drawing upon existing literature and research. These factors were then refined and localized by incorporating insights from experts and city administrators in Ulaanbaatar. Dynamic hypotheses and causal loop diagrams were constructed based on the combined knowledge from literature and expert opinions.

The study developed a stock and flow diagram by designing the causal loop diagram, exploring the quantitative relationships among the identified variables. This research established a comprehensive framework to reduce waste volume in Ulaanbaatar by formulating various scenarios. The research outcomes indicated that waste production and volume could be effectively controlled within the city, promoting resource conservation and sustainable growth.

I believe that future research should expand beyond the factors examined in this study. It could investigate additional aspects, such as the impact of immigration on waste production, considering waste generated by newcomers, and analyzing the potential role of government assistance in supporting the municipality's waste control efforts. By broadening the research focus, a more holistic understanding of waste management dynamics can be achieved, leading to the development of even more comprehensive strategies.

REFERENCES

[1] Y. Ge , J. B. Yang, N. Proudlove, etc. “System dynamics modeling for supply-chain management: A case study on a supermarket chain in the UK,” DIGITAL OBJECT IDENTIFIER (DOI): 10.1111/j.1475-3995.2004.00473.x.

[2] A.J., Gujar, A. V., Mophare, D. N., Deomore and P. M., Khodke, “System Dynamics Approach for Strategic Supply Chain Management. ICFAI Journal of Supply Chain Management,” 2007, 4(1): 40-48.

[3] GJB4355-2002, “Spares provisioning requirements,” 2003, 2.

[4] K.M. Klinger. “The Application of A Readiness-based Sparing Model to Foreign Mining Sales.” 1994, AD-A280629, USA.

[5] E. Akcali, M. Davis, D. Randall, et al. “A Decision Support System for Spare Parts Management in a Wafer Fabrication Facility.” IEEE Trans. on Semiconductor Manufacturing, 2001, 14(1): 76-78.

[6] Forrester, J.W. and Brink, H.M., 1961. *Industrial Dynamics*, MITPress. Cambridge, MA.

[7] Kollikkathara, N., Feng, H. and Yu, D. A system dynamic modeling approach for evaluating municipal solid waste generation, landfill capacity and related cost management issues. *Waste management*, 2010, *30*(11):2194-2203.

[8] Jung, J.U., 2017. Reducing Subjectivity in the System Dynamics Modeling Process: An Interdisciplinary Approach. In *Intelligent Data Engineering and Automated Learning–IDEAL 2017: 18th International Conference, Guilin, China, October 30–November 1, 2017, Proceedings 18*,pp. 365- 375.Springer, Cham. https://doi.org/10.1007/978-3-319-68935-7_40.

[9] Wolstenholme, E.F., 1990. *System enquiry: a system dynamics approach*. John Wiley & Sons, Inc.

[10] Sukholthaman, P. and Sharp, A. A system dynamics model to evaluate effects of source separation of municipal solid waste management: A case of Bangkok, Thailand. *Waste management*, 2016, *52*:50-61.

[11] Richardson, G.P. and Otto, P., Applications of system dynamics in marketing. *Journal of Business Research*, 2008, *61*(11):1099-1101.

[12] Kunc, M., 2017, December. System dynamics: A soft and hard approach to modelling. In *2017 Winter Simulation Conference (WSC)* (pp. 597-606). IEEE.

[13] T. Spengler, M. Schröter, "Strategic Management of Spare Parts in Closed-Loop Supply Chains-A System Dynamics Approach," 2003, 33(6):7-17, DOI: 10.1287/inte.33.6.7.25179.

[14] M. Schroter, T. Spengler, "Designing control management systems for parts recovery and spare parts management in the final phase within closed-loop supply chains," International Journal of Integrated Supply Management, 2017, 1(2):158-179.

[15] J.Sterman, "Business Dynamics", McGraw-Hill; First Edition (January 1, 2017)

[16] D.Badarch., B.Ochirbat, "Fundamentals of System Dynamic Modeling," Ulaanbaatar: SHUTIS, 2003, p. 124.

[17] K.Havalbolat, "Mining Logistics". -UB.: 2005.

AUTHOR'S INTRODUCTION

1. First Author and Corresponding author

Lkhaasuren.BATBOLD batbold.lkh@must.edu.mn

Doctorate student in Mathematics, Mongolian University Science and Technology, Mongolia
Work: Senior lecturer, Mongolian University Science and Technology, School of Applied Sciences
Work field: Education, Applied mathematics, System dynamics, Operational research

2. Co-Author

Davaanyam BATNASAN dbatnasan@must.edu.mn

2010 PhD in Mathematics, National University of Mongolian
Work: Senior lecturer, Mongolian University Science and Technology, School of Applied Sciences
Work field: Education, Applied mathematics8 System dynamics, Operational research