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SUSTAINABLE PLASTIC RECYCLING IN MONGOLIA

ESCM

FEASIBILITY ASSESSMENT OF THE PROPOSED PLASTIC WASTE COLLECTION SCHEME FOR ULAANBAATAR CITY AND BULGAN AIMAG

FINAL REPORT

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ABBREVIATION

AOA	Apartment Owners Association
BGD	Bayangol District
BZD	Bayanzurkh District
BND	Baganuur District
CHD	Chingeltei District
CVRP	Capacitated Vehicle Routing Methodology
CWDS	Central waste disposal site
GCP	Garbage collection point
GDP	Gross Domestic Product
KHUD	Khan Uul District
MNT	Mongolian tugrik
ND	Nalaikh District
NGO	Non-Governmental Organization
SBD	Sukhbaatar District
SKHD	Songinokhairkhan District
TUK	Municipal (government and private) Service Company
UFE	University of Finance and Economics
VRP	Vehicle Routing Methodology

1 INTRODUCTION

As part of the SWITCH-Asia program, Caritas Czech Republic is implementing the "Sustainable Plastic Recycling in Mongolia (SPRIM)" project (05/2020 – 04/2024) in collaboration with four project partners: the Environmental and Security Center of Mongolia, Eco Soum, Mongolian Sustainable Development Bridge, and T.G. Masaryk Water Research Institute. Based on European Union best practices and research results, the project seeks to develop plastic waste collection routes suitable for urban and rural environments and evaluate the practical implementation of the proposed systems.

The consulting service team was awarded the contract to assess the feasibility of a plastic waste collection scheme for Ulaanbaatar city and Bulgan aimag. During the meeting on May 6, 2023, the team and the tender committee reached an agreement on the technical and financial proposals, which the team accepted and reflected in the plan. The agreement No. SC_MN20F23050101 was signed with Mongolia's Environment and Security Center on May 23, 2023.

T. Oyungerel, associate professor at the UFE, leads the consulting service team, which includes senior lecturers G. Sainbileg, B. Bayarsaikhan, and lecturer B. Bayartsetseg. May 22, 2023, at 10:30 a.m., the parties met online to discuss the initial report, present the expected results, scope of the project, and methodology, and determine the delivery period for the report.

There will be two phases to the assessment over a period of four months. Two sets of evaluations were planned after reviewing the project's objectives and expected results. It includes:

Evaluation 1. The first evaluation will be conducted from May 10 to June 30, 2023, covering the first and second outcomes. This assessment aims to evaluate and identify opportunities for improving plastic waste collection and transportation routes in Ulaanbaatar and Bulgan aimag.

Evaluation 2. An evaluation of feasibility will be conducted by August 30, 2023, and it will include the third and fourth outcomes. This evaluation will be used to conduct a situational study and develop recommendations for the proposed route's implementation.

Throughout the report, professional terms such as "route" and "POI - point of interest" are used. In this report, the Mongolian name TUK is used to represent the organization responsible for Municipality service company.

An assessment of the feasibility of the baseline study and recommendations for further improvement are included in this final report.

Consequently, we are able to determine whether the baseline research methodology and calculations are appropriate for the current situation and develop recommendations for improving the baseline research data and improving the route.

2 EVALUATION METHODOLOGY, PRINCIPLES AND PROCESSES

2.1 Scope of the Consulting Services

Objectives

1. Analysis of the alternative collection methods at the level of Ulaanbaatar city and Bulgan aimag, including the used information, methodology, data, program and economic calculations.
2. Identifying the feasibility of the route.
3. Identifying the obstacles to immediate implementation of the project's target direction, as well as the conditions for eliminating them.
4. Providing recommendations for improving routes and alternatives for their implementation.

Expected deliverables

1. The entire plastic waste collection and transportation system developed in Bulgan aimag and Ulaanbaatar city, its route map, and optimization are reviewed and concluded.
2. Additional data and information necessary to upgrade the scheme and methodology for improving simulations are provided.
3. Identifying whether it can be applied in other aimags and cities through an economic efficiency analysis.
4. A feasibility study of the implementation of a route at the aimag and municipal levels, with recommendations for implementing the optimal alternative (the recommendations should address the issue of efficient collection of plastic waste from remote communities and khoroo.)

Scope of assessment

In accordance with the terms of reference of the consulting services, assessment work will include:

1. Geographically, the assessment covers Ulaanbaatar, its 8 districts (BND, BGD, BZD, ND, SKHD, SBD, KHUD, CHD) and Khishig-Undur soum and Bulgan soum of Bulgan aimag.
2. Reviewing the route proposed by the "Clean environment and eco-solutions" NGO in its research paper "Development of the optimal route for plastic waste collection: Ulaanbaatar city and Bulgan aimag".
3. Among the stakeholders are Municipal Service Company (TUK), recycling plants, private enterprises that collect recycling, and Apartment Owners Associations (AOA).
4. In this study, only formal waste collection channels were examined; informal waste collection channels are not included.

2.2 Assessment scheme

The assessment phase and expected results are outlined below.

Table 1. Assessment phase

Assessment / Phase		Expected results	Deadline
1	Route assessment	1. The entire plastic waste collection and transportation system developed in Bulgan aimag and Ulaanbaatar city, its route map, and optimization are reviewed and concluded. 2. Additional data and information necessary to upgrade the scheme and methodology for improving simulations are provided.	From May 22 to June 30, 2023
2	Feasibility assessment	3. Identifying whether it can be applied in other aimags and cities through an economic efficiency analysis. 4. A feasibility study of the implementation of a route at the aimag and municipal levels, with recommendations for implementing the optimal alternative (the recommendations should address the issue of efficient collection of plastic waste from remote communities and khoroo.)	August 30, 2023

2.2.1 Methodology

In order to assess the baseline research methodology, data, software, routes, vehicles, capacity, collection points, road conditions, congestion, fuel consumption, and labor costs estimates, the consulting team used the Optimization methodology for waste collection and transportation[1] *(Table 2)*, as well as the Model for Route Optimization Problem in a Municipal Multi-Landfill Waste Collection System[2].

Table 2. VRP model specifications

Summary of Studies on the Robust Optimization of VRP with Uncertainties											
Study	Uncertainty Sources	VRP *Features*^{a}							Objectives		
		TW	MD	HF	RC	MDT	TG	P	C	NV	Others
Singur et al. (2008)	Demand								√		
Aguirre et al. (2011)									√		
Counaris et al. (2016)									√		
Sun (2004)									√		
Cao et al. (2014)									√		Unsatisfied Demand
Trikolaee et al. (2017)		√	√	√	√	√			√	√	Penalty Cost
Manisri et al. (2011)	Time	√									Time

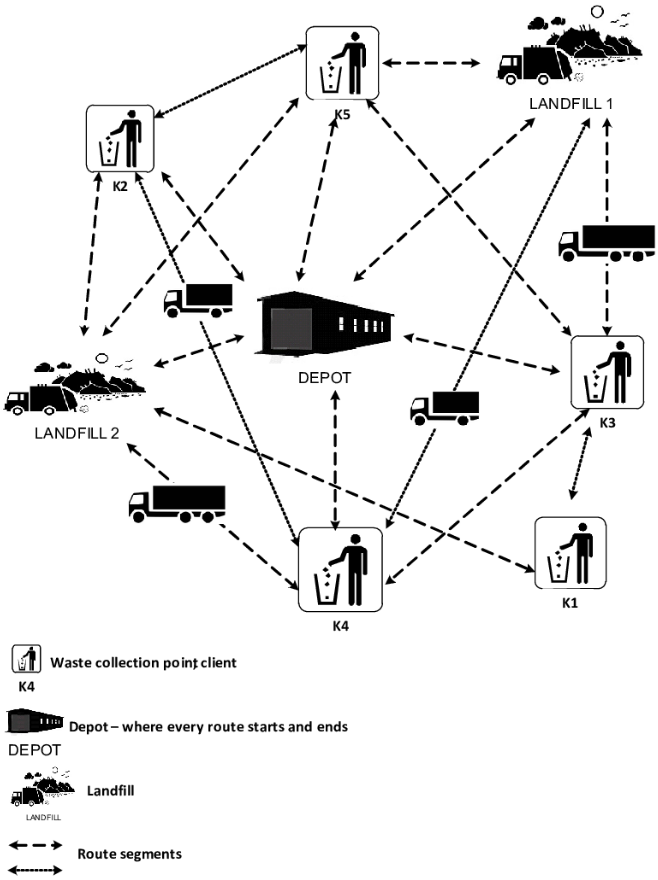
[1] *Robust Optimization of Municipal SolidWaste Collection and Transportation with UncertainWaste Output*

[2] *A MILP Model for Route Optimization Problem in A Municipal Multi-Landfill Waste Collection System*

Wu et al. (2017)						√	√	√	Time
Solano-Charris et al. (2015)	Cost						√		
Sungur et al. (2010)		√				√	√		Time, Penalty Cost
Solano-Charris et al. (2016)	Demand, Time						√		
Hu et al. (2018)		√					√	√	Distance
Liu et al. (2018)		√	√	√	√		√		X Unsatisfied Demand

Time Window; MD = Multi-Depot; HF = Heterogeneous Fleet; RC = Route Capacity; MDT = Multi-Disposal Trips; TG = Type of Goods; eriodic C = Cost; NV = Number of Vehicles, VRP =Vehicle Routing Methodology

Figure 1. A scheme of a single-depot multi-landfills capacitated waste collection problem



2.2.2 Plastic waste collection and transportation system

As part of our study, we examined the plastic waste collection system, how it works, and who is involved and what their roles are. In order to assess whether the current proposed route is compatible with these systems, we used the following international model of plastic waste collection and transportation.

Figure 2. Solid waste management

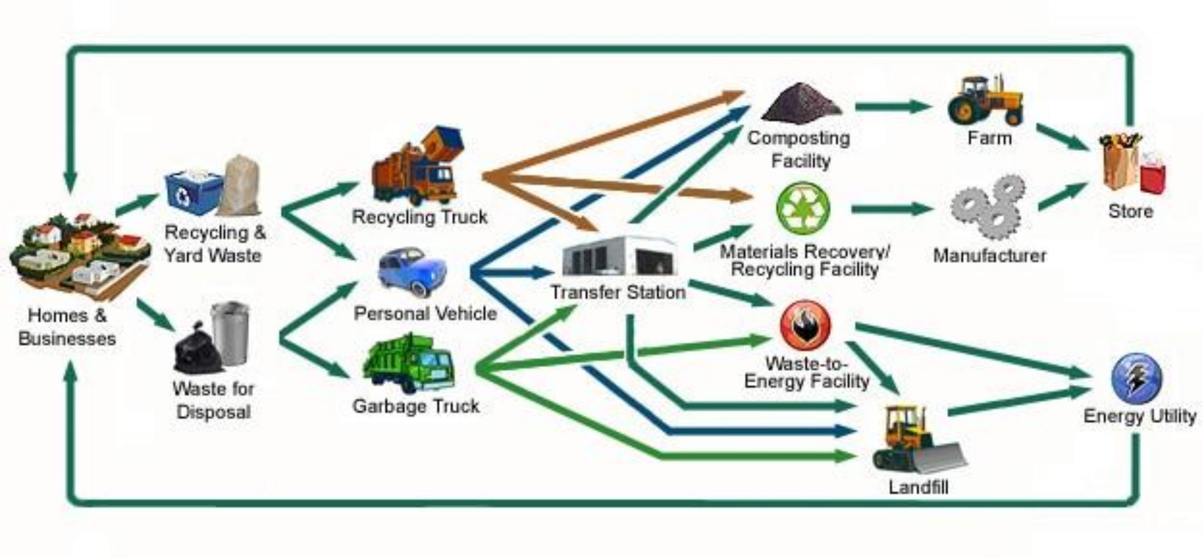
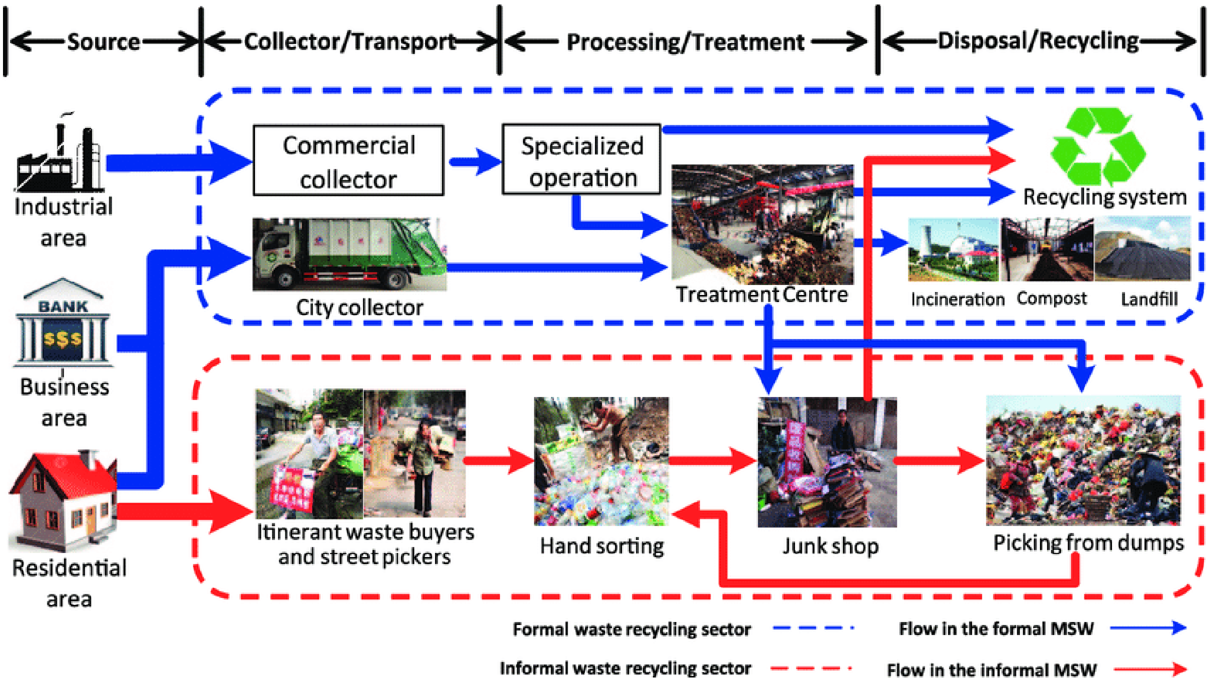


Figure 3. Contribution of formal and informal solid waste systems



2.3 Data collection and analysis

The collection and transportation of plastic waste in Ulaanbaatar and Bulgan aimag was evaluated using both primary and secondary data sources. It includes:

1. **Reports and other documents:** Legislation, regulations, financial documents, research work, all types of projects and programs, activities and other documents pertaining to plastic waste;

- Data collected from the TUK of Bayangol district on the collection of waste for May 2023 was analyzed.
- From June 2, 2023, a detailed analysis of the route mapping and calculation simulation was conducted, along with an assessment of the results of the baseline research methodology and the results of the collection and transportation of plastic waste in Ulaanbaatar and Bulgan aimag.

2. **Official statistics:** Official statistics and other relevant documents issued by the National Statistics Committee, the Ulaanbaatar City Mayor's Office, the aimag and district governors, and the Ministry of Environment and Tourism, the official website of the district Governor’s,
3. **Observational study:** An observational study was conducted to assess the current situation of the garbage collection point (GCP) and the level of waste classification. Therefore, an observation sheet was developed within the framework of "Waste Management UCS 1701A:2022-88" and "Management of Waste Collection, Sorting, Storage, and Transportation Methodology" and information on the real-time situation was collected. A total of 94 GCP locations were observed in six districts of Ulaanbaatar city: apartment and ger residential area, and remote ger districts. These were divided into 17 points in each of the four Bayangol District (BGD), Bayanzurkh district (BZD), Sukhbaatar district (SBD), and Khan Uul district (KHUD), and 13 points in each of the two Songinkhairkhan district (SKHD) and Chingeltei district (CHD), of which 44 were apartment area, 40 were ger area, and 10 were from remote ger area. Observations and questionnaires were analyzed using frequency analysis.
4. **Case study:** In order to analyze the actual process of loading, transporting, and unloading waste, the consulting team conducted a case study on the selected route. The case study was carried out on June 6, 2023, in the territory of the 22nd khoroo of the district, with the permission of the Songinokhairkhan District TUK. Throughout the route, waste collection activities were to be documented, data collected, and relevant information recorded on checklists. A detailed description of stops and queues along the route, the names and addresses of stops, the type and amount of waste collected, arrival and departure times, and noteworthy observations and incidents are included in this report.
5. **Observation**. In this investigation, we observed the daily routines of the garbage collection brigade's driver B. Gantur as well as the loader B. Enkhtur. We also filled out a checklist and observed the collection and transportation of plastic waste.
6. **Interviews with stakeholders**: The questions for the interviews with the main stakeholders in the waste collection and loading process will be prepared on May 29, 2023. As a part of the interview process, the Apartment Owners Association, SKHD, BGD, KHUD, ND TUKs of Ulaanbaatar, the Waste Management Center of Khishig-Undur soum, the Bulgan aimag Governor, and the Plastics Union representatives were interviewed. Individual and semi-structured interviews were conducted with participants in the plastic waste collection system, who have an understanding of the activities, difficulties, and ways to resolve the problems. The interview results were

used to determine whether the route calculation basis was realistic and whether it could be implemented in the future based on the results of the interviews.

Table 3. List of interviewees

№	Organization	Participant name	Position	Contact number
1	BGD TUK, UB	Batchuluun.B	Waste specialist	99006945
2	KhUD TUK, UB	Ganchimeg.B	Human resource specialist	88105116
3	SKHD TUK, UB	Otgonbat	Manager	89899116
4	ND TUK, UB	Uugankhvv	Specialist	81811516
5	KhUD 15th khoroo BUTI Condominium Association, UB	Enkhtushig.M	Executive Director	88856051
6	KhUD 15th khoroo Khanswill Condominium Association, UB	Nandintsetseg.J	Manager	90977172
7	Mongolian National Waste Recycling Association NGO	Batjargal.D	Head, National Waste Advisor	89116570
8	Bulgan soum TUK, Bulgan aimag	Altantsetseg.Kh	Senior specialist in municipal service	99120861
9	The Waste Management Center of Hishig-Undur Soum, Bulgan aimag	Nyamsuren.Ts	Project officer of Ecosoum NGO	80443090
10	Governor of Hishig-Undur Soum, Bulgan aimag	Munkh-Erdene	Governor of Hishig-Undur Soum	
11	SKHD TUK, UB	Gantur.B	Garbage truck driver	80010752
12	SKHD TUK, UB	Enkhtur.B	Loader	80195167
13	SKHD TUK, UB	Bat-Erdene.E		80938191

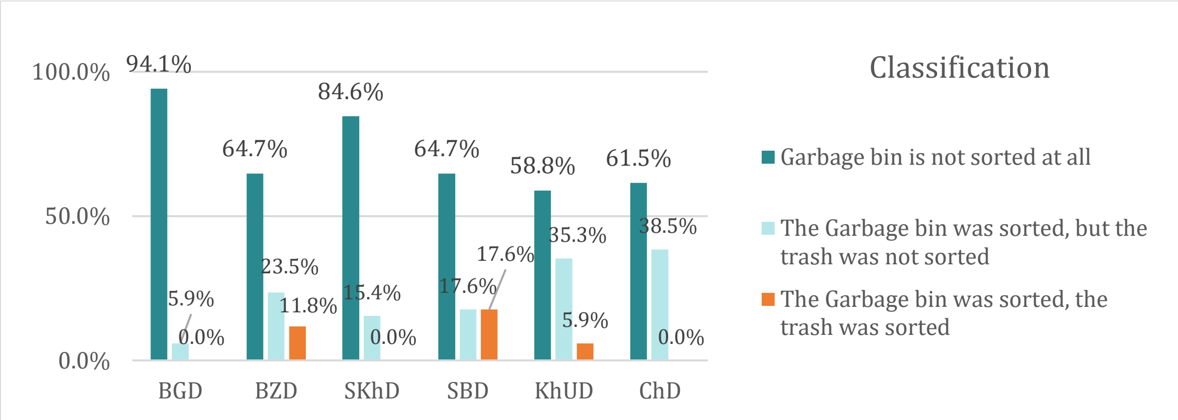
3 PLASTIC WASTE COLLECTION PROCESS STUDIES IN ULAANBAATAR CITY AND BULGAN AIMAG

3.1 Observational study of points of interest

A total of 94 GCP were observed in 6 different districts of Ulaanbaatar city, including apartment and ger residential areas. The purpose of the observation was to determine whether the classification and distinguishing symbols of the waste bins at the GCP were in accordance with the standards. Following the framework of the "Waste Management UCS 1701A:2022, Methodological Management of Waste Collection, Sorting, Storage, and Transportation" standard an Observation Sheet was developed, and data was collected.

Only 6 points out of a total of 94 GCP, have garbage bins that can be sorted and sorted by color, and waste is sorted at those points. In about 70% of the observed points, there were no segregated bins at all, they were not colored and marked. The graph below shows by district and neighborhood type.

Chart 1. Whether or not the point classifies the garbage bins according to the type of disposal



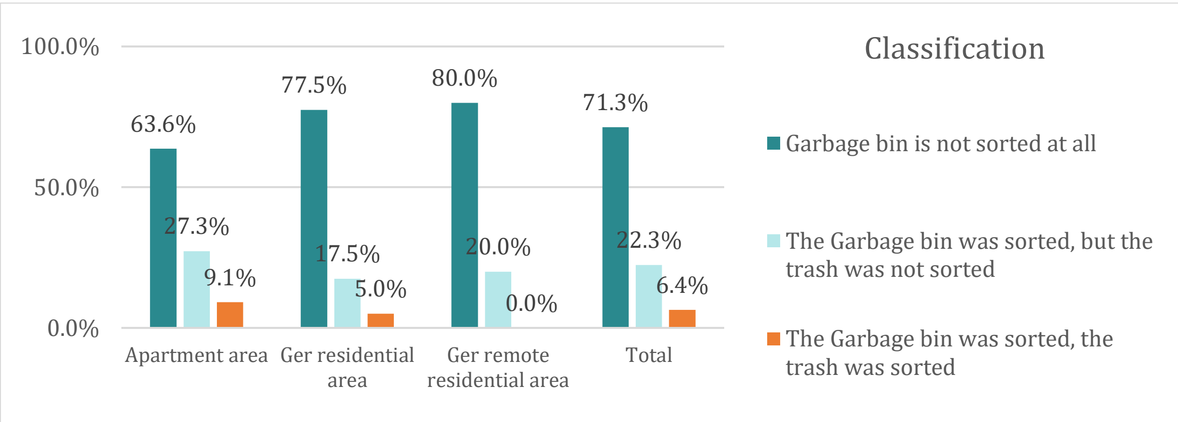
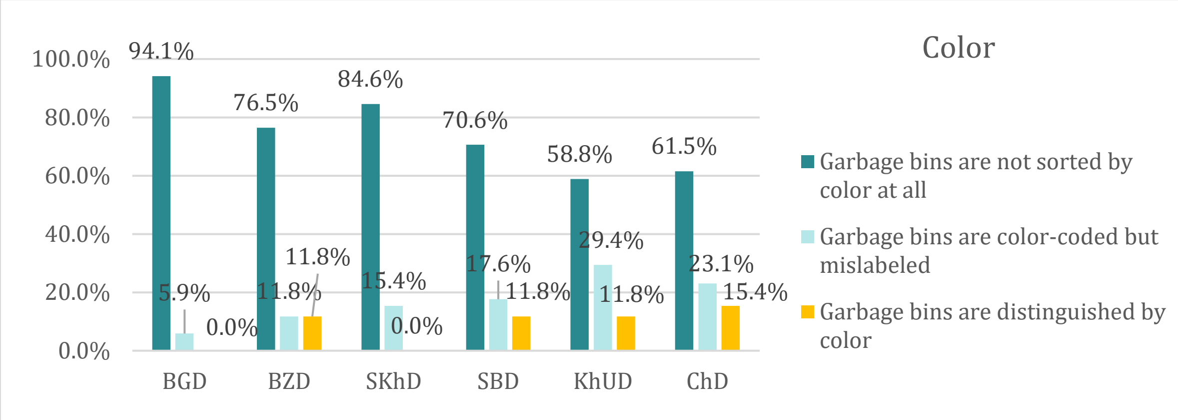


Chart 2. Whether or nor the point's garbage bin is color-coded



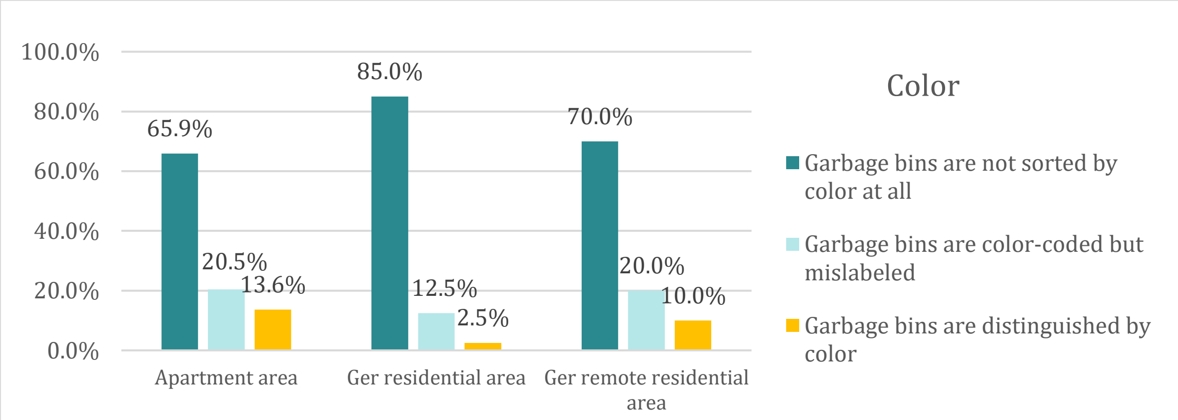
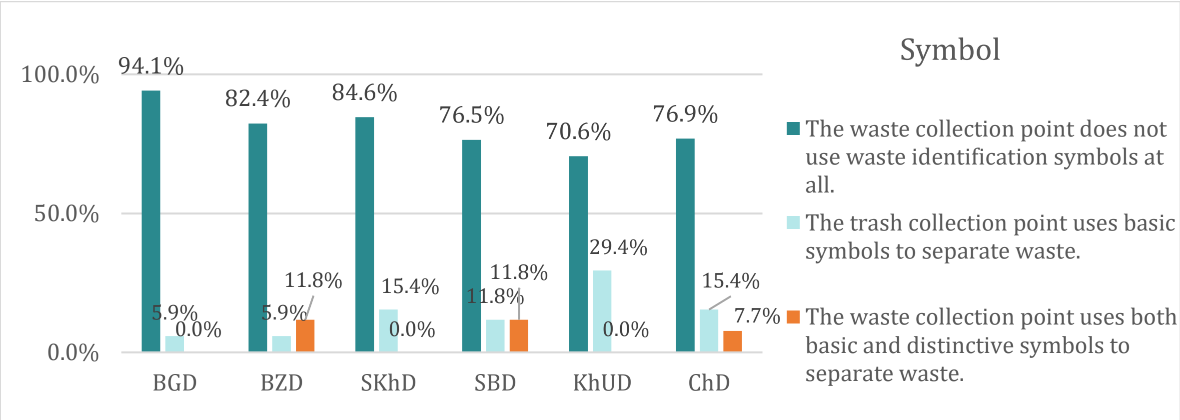
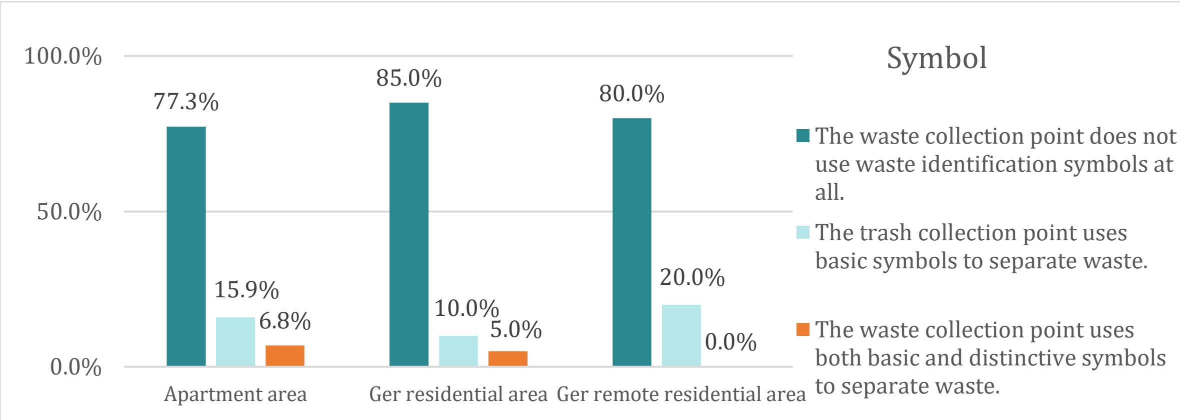


Chart 3. Whether the waste point correctly uses waste classification symbols





About 65% of the observed points are organized in a way that is incompatible with waste collection, loading and transportation technologies.

Chart 4. Whether garbage bins follow waste collection and loading technologies

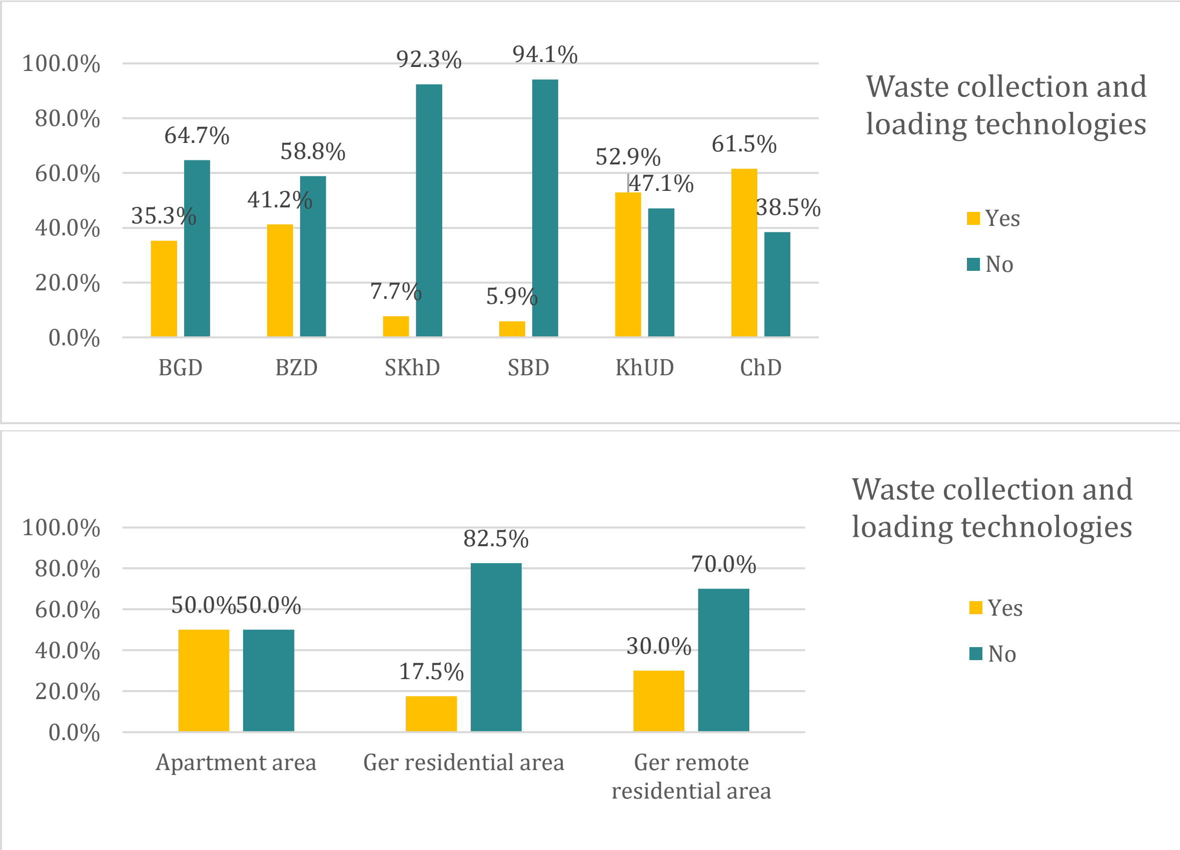
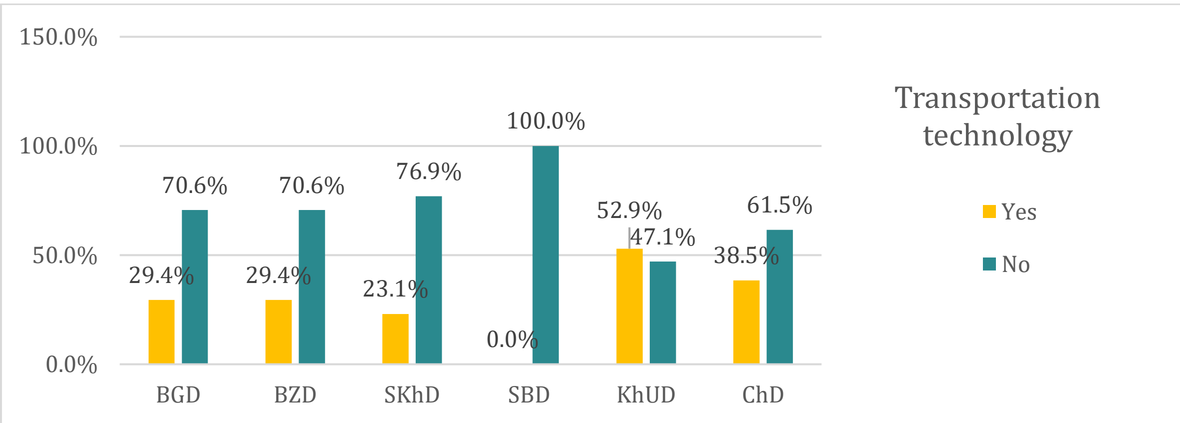
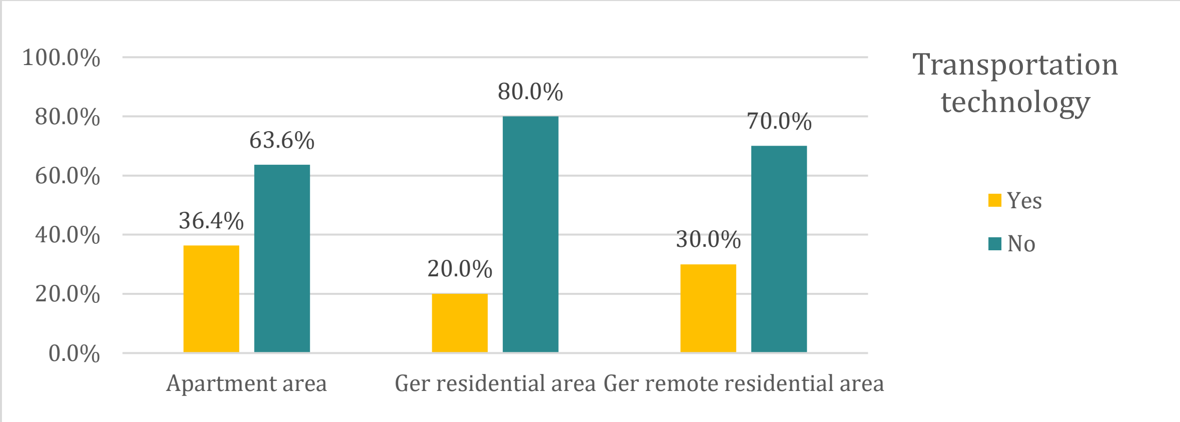


Chart 5. Whether garbage bins are following waste transportation technology





In this study, A price analysis of domestically produced garbage containers has been conducted. A small bin manufactured by Khainag Metal Construction Company is sold for 242,000 MNT. On the other hand, MSB manufactures larger and more specialized garbage bins.

Figure 4. Plastic waste collection bin of Khainag Metal Construction Company

Figure 5. MSB LLC garbage bin

Research conducted on the targeted GCP of apartment and ger residential areas revealed that plastic waste is insufficiently sorted at the primary source of waste. As a result, sorting and collecting plastic waste becomes inefficient and discouraged.

3.2 In-depth interviews with Ulaanbaatar's municipal waste management authorities and Municipal Service Companies (TUKs)

In order to determine the current situation of the waste collection process in Ulaanbaatar, interviews were conducted with staff members of the TUKs in BGD, KHUD, SKHD, and Nalaikh District (ND).

Human resources and employees. There are two main functions of TUKs: municipal maintenance services and waste transportation, with a staff of 64-298 employees depending on the district's population and area. As part of waste transportation, BGD has 117 employees, KHUD has 36, SKHD has 153, and ND has 30. For a small truck, one driver works with one loader, and for a large truck, one driver works with two loaders.

Each district has its own wage structure. The salaries of KHUD and ND are fixed, while the salaries of BGD and SKHD are based on the number of trips. In addition, BGD and KHUD pay a daily food allowance of 15,000 MNT, a daily transportation allowance of 5,000 MNT, and SKHD pays 110,000 MNT in canteen and shop vouchers each month. ND does not pay any additional allowances. Additionally, employees are provided with uniforms in both winter and summer.

Technical equipment. For waste collection, BGD has 21 trucks, KHUD has 12 trucks, SKHD has 52 trucks, and ND has 8 trucks. Most districts lack waste trucks that can shred or melt waste, while only a few have compacting machines. BGD and SKHD waste trucks do not have waste turnover functions, so an open-scoop truck follows them.

TUKs transport waste with garbage trucks capable of carrying 3-18 tons (BGD 3 and 5 tons, SKHD 2 and 5 tons, KHUD 3 and 18 tons, ND 5, 8 and 12 tons). Trucks have an average lifespan of 12-15 years. KHUD also provides shovels, brooms, and 50-liter barrels as waste collection equipment, depending on the number of collectors.

On average, each waste collection truck consumes 50 liters of diesel fuel per day. The Daewoo truck of SKHD, however, consumes only 8-9 liters. In TUKs, there is no special budget for vehicle maintenance, and the costs of repairing damages considered irreparable by the TUK's own technicians and repairmen are covered from the operating budget. They do not have a regular contract with a repair body shop and employ 1-3 technicians and repairmen. Generally, district TUKs do not receive additional funding and are underfunded, with most funding going toward spare parts.

Workload. TUKs do not provide waste loading and transportation services to points without contracts. BGD has signed contracts with 300 AOAs, 2,500 enterprises, HUD - 137 AOAs, SKHD - 60,000 households, and 2,000 entities. KHUD and ND work seven days without holidays, while BGD and SKHD work six days.

The district's citizens' meeting approved the waste collecting and transporting tariff. The fee in apartment residential areas is 2,000 MNT, while in ger residential areas it is 2,500 MNT. Plans are underway to change the existing tariffs and calculate the tariff per resident (1,500 MNT) rather than per household. There is no separate plastic waste collection tariff included in these tariffs.

Information registration. In the case of BGD, the collected and disposed waste data is recorded at the Central waste disposal site (CWDS) and also in TUKs, and a forecast plan is developed based on the past periods. The KHUD plans based on the number of contracted households and the size of waste bins at the POI, which are recorded daily by the Accountancy Office. In spite of SKHD's and ND's waste being registered at the dispatcher day by day, it is not possible to make calculations or forecasts based on them.

Each TUK maintains the route and mileage information of each truck, as well as the waste information and records of each khoroo. Unlike BGD, TUKs do not register and release waste types according to the type of waste.

Point of interest and round-trip sequence. There is no integrated statistical data or analysis of waste, and the amount of waste varies. BGD collects an average of 700 tons of garbage per day, while KHUD's 8 khoroos collect an average of 78 tons. Districts issue routes and round trips based on the number of khoroos and aim to have one truck per khoroo. On average, 1 truck makes 2-4 round trips per day depending on the size of the khoroo's territory, the number of entities/organizations and households. On Public Clean-up Days and during festive seasons, additional round trips are made as deemed necessary. Waste is not collected from other khoroo.

On average, 1 truck in BGD loads and transfers waste from 6 apartment residential areas, 10-12 entities, 1 point in ger residential areas, in KHUD from 4-5 areas, in total, 20-24 points per day, while in SKHD and NDs, 10 points are collected per day.

Plastic waste. Plastic waste statistics are not available in the districts. Even though they partner with a plastic collection company, BGD with TML, and KHUD with two other companies, they have yet to receive reports regarding waste collected from them.

BGD, KHUD, and SKHD TUKs do not collect plastic waste specifically, do not classify and sell it, rather they collect and transport all waste to their designated CWDS. KHUD provides on-call waste collection and transportation services. In the case of BGD, entities earn income by sorting their own waste and selling plastic waste directly to relevant organizations. Waste specialists in the Nalaih district pay special attention to plastic waste and collect it separately. During waste collection and transportation, loaders and drivers earn income by collecting and selling recyclable waste, but TUKs do not earn income from it.

In most districts medical waste is collected and disposed of by a specially contracted company called Elements. Unlike other districts, BGD's TUK collects and transports safe medical waste and household/ waste within the exisitng contract.

3.3 Observation of waste collection and transportation operations

The team observed the process of loading, transporting, and unloading waste at 35th and 36th Hilchin Streets, 22nd khoroo, SKHD with permission from the SKHD's TUK. One driver and two loaders worked with a DAEWOO dump truck. Khoroo do not have CWDS, and waste is collected from outside yards or from streets and collected once a month. Approximately 15-20 waste trucks operate in one khoroo at the same time, and the operation takes between one and two days to complete. Every day, one truck makes six round trips.

Within 2-3 minutes, they collect 15-20 bags of household waste (Figure 6). After traveling 200-250 meters (Figure 7), it will take 30-40 minutes to collect 200-300 bags of waste. Next, the truck goes 30 minutes to Naran Enger Davaa's CWDS, where it delivers the secondary raw materials collected during the waste loading process, weighs the truck, enters the landfill, and unloads the waste.

Figure 6. Beginning and end of waste loading

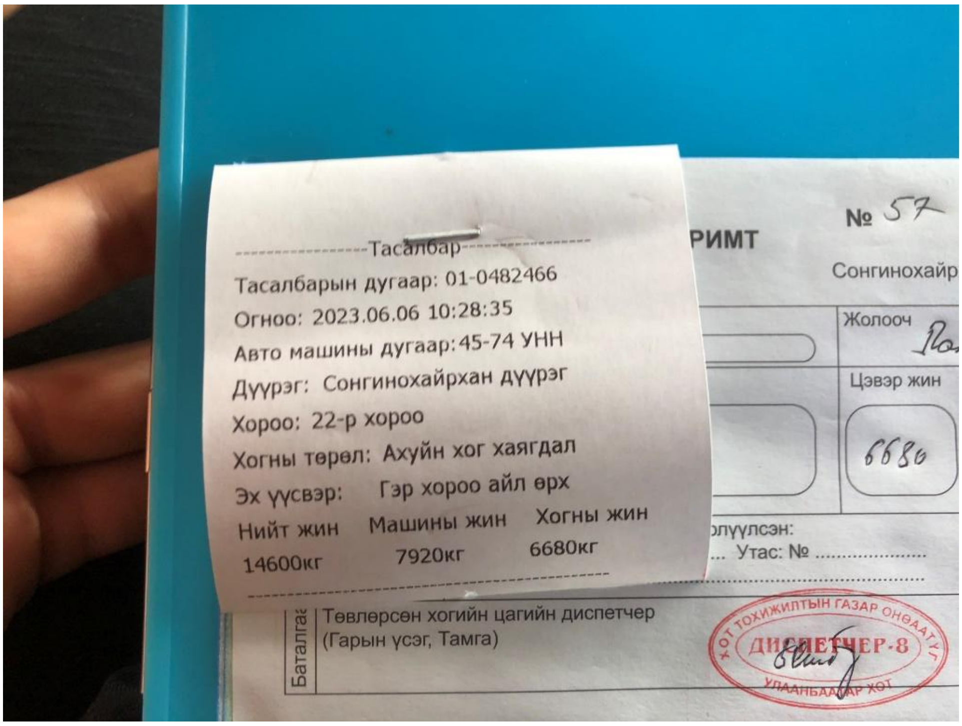
Waste loading started at 09:37 AM *Waste loading finished at 10:06 AM*

Table 4. Duration of each step of the operation (2 round trips)

№	Action	Start	Finish	Time spent /minutes/
1	Going from the landfill to the district	9:20:00 AM	9:37:00 AM	17
2	Load waste	9:37:00 AM	10:06:00 AM	29
3	Go to the landfill	10:06:00 AM	10:28:00 AM	22
4	Weighing	10:28:00 AM	10:31:00 AM	3
5	Go to the drop-off area	10:31:00 AM	10:37:00 AM	6
6	Unload	10:37:00 AM	10:40:00 AM	3
7	Go to the weigh-in	10:40:00 AM	10:44:00 AM	4
8	Weighing	10:44:00 AM	10:47:00 AM	3
9	Going from the landfill to the district	10:47:00 AM	11:08:00 AM	21
10	Load waste	11:08:00 AM	11:46:00 AM	38
11	Go to the landfill	11:46:00 AM	12:08:00 PM	22
12	Weighing	12:08:00 PM	12:12:00 PM	4
13	Go to the drop-off area	12:12:00 PM	12:17:00 PM	5
14	Unload	12:17:00 PM	12:22:00 PM	5
15	Go to the weigh-in	12:22:00 PM	12:25:00 PM	3
16	Weighing	12:25:00 PM	12:28:00 PM	3
	Total			**188**

Figure 7. The distance traveled until the garbage truck is full is about 200m

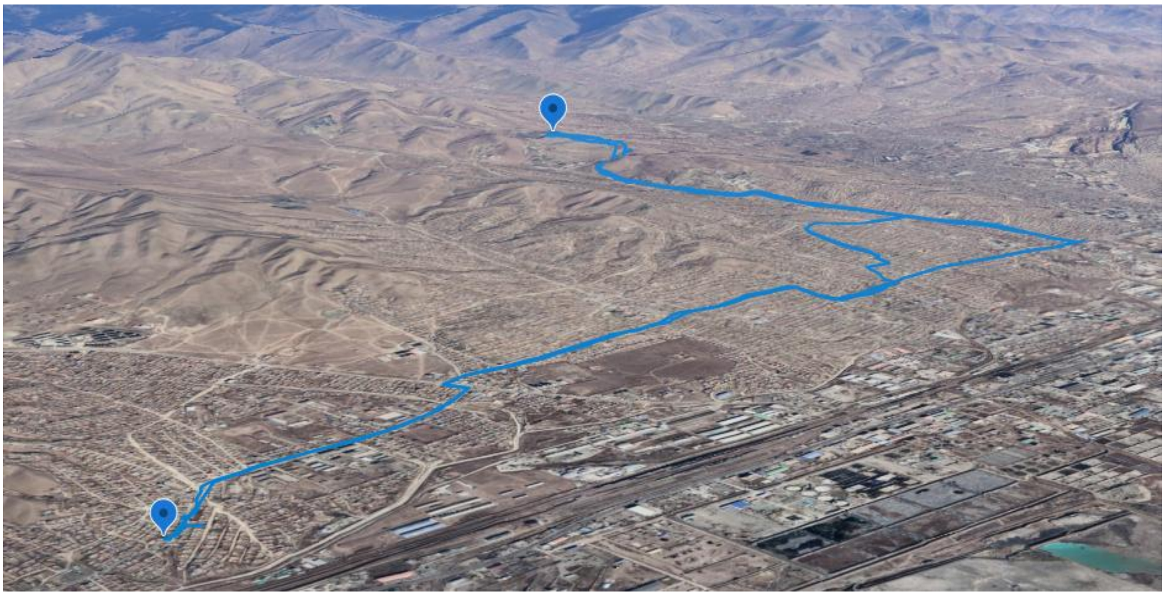
Figure 8. Registration form



It is about 20 kilometers (*Figure 9, 10*) from Narang Enger CWDS to the 35th Hilchin Street, khoroo 22, and it takes about 30 minutes for the waste truck.

Figure 9. The route of the waste truck from the Naran Enger CWDS

Figure 10. Route from Naran Enger CWDS to 35th Khilchin Street of SKhD's 22nd khoroo



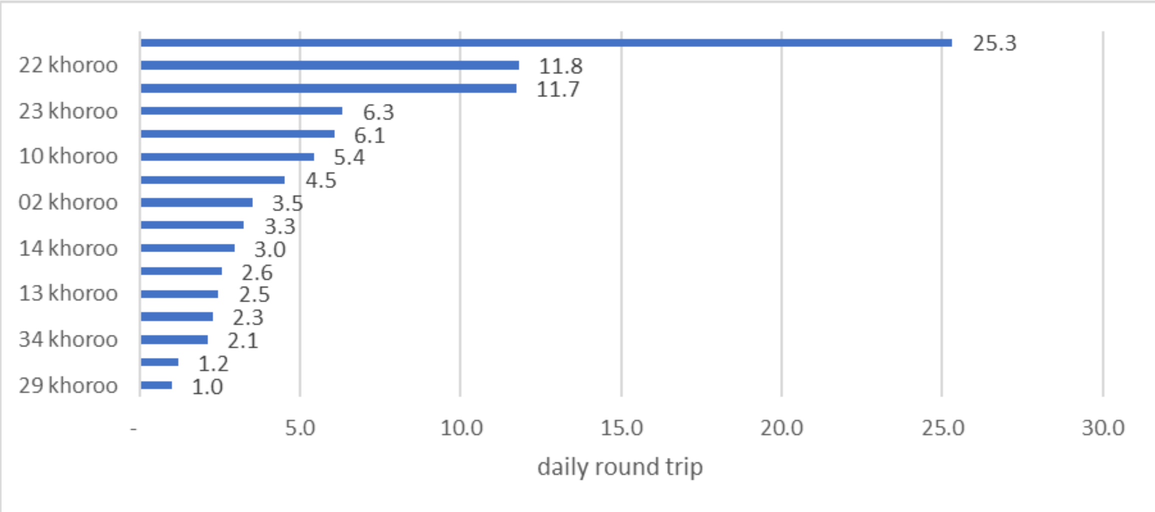
3.4 Study of the volume of waste and the number of rounds in the Bayangol district

TUK of Bayangol district of Ulaanbaatar city issued the file "BGD waste report, by khoroo, by round trips - Analysis" to consulting team. Using the log file, the team analyzed the number of wastes collected and trips taken.

Between May 1 and May 31, 2023, BGD's TUK accumulated 3,839 round trips and 23.1 million kilograms of waste on the territory of 34 khoroo. Each trip carries an average of 4,000 kg of cargo. On average, 3.4 round trips are made per day. Daily waste collection averages 15.0 thousand kg and reaches a maximum of 249.0 thousand kg.

Waste is collected from one khoroo per day in a maximum of 45 round trips and a minimum of 1. There are 5.1 round trips per day on average, and the standard deviation is 3.4.

Chart 6. Daily round trips BGD



One round trip per day is planned in the baseline study. According to the baseline study, the number of trips is calculated by multiplying the total amount of waste by the population of the khoroo, and by 32g per person per day.

Table 5. Estimation of round trips and wastes for BGD in the baseline study

Route	Coverage Khoroo		Population	Waste size
number	number	no	number	kg
1	3	8,18,19	31,777	1016.9
2	2	1,3	27,595	883.0
3	4	10,20, 22,23,	32,143	1028.6
4	4	2,15,17, 24	31,687	1014.0
5	2	4, 25	25,093	803.0
6	3	7,9,21	26,731	855.4
7	5	11,12,13,14,16	32,434	1037.9
8	2	5,6	28,925	925.6
8	**25**		**236,385**	**7,564**

Analyzing the data of BGD, the following conclusions are drawn:

1. The estimated amount of garbage differs from the actual amount. According to the baseline study, each individual produces 400 grams of garbage per day, eight percent of which is plastic waste. It is estimated that out of the 94.5 thousand kilograms of

garbage that are generated every day in the district, 7564 kilograms are plastic, which is equivalent to one round trip per route every day based on the population of the district. As per the actual figures of the BGD, 655,500 kg of garbage is produced every day in the district, which includes all commercial establishments, households, and factories. **Considering the coexistence of households and small businesses, there will be more plastic waste, so more than one round trip can be made each day.**

Table 6. Comparison of the quantitative data of the baseline study and BGD data

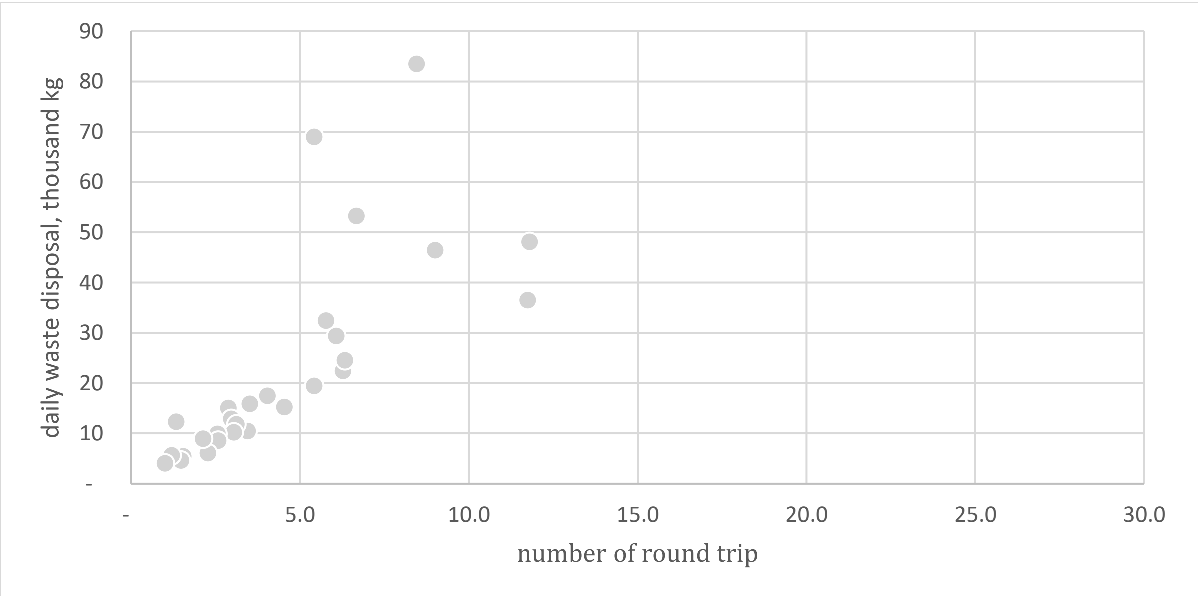
	Population	Volume of waste per person/day/g	Total waste
Baseline study[a]	236,385.00	400	94,554
BGD data[b]	236,385.00		655,500

a Household waste volume

b Enterprise and household waste volume

2. Base study calculations are based on population statistics. The amount of garbage and the number of round trips is not correlated when analyzing the numerical data of BGD.

Chart 7. The correlation between daily waste disposal and the number of round trips per day



3. Based on the actual performance of the BGD's Waste Report for May 2023, we have recalculated the amount of plastic waste that can be generated in BGD. Table 7 shows the total amount of waste generated by BGD, which includes waste generated by households, entities, and shopping centers. The amount of waste per route was adjusted in the baseline study to 11-13 percent based on the principle of equalizing the population of the khoroos. A comparison of the actual performance of the BGD with the baseline research shows that the average amount of waste per day is divided into eight routes, and the percentage results are different. For this reason, it is considered inappropriate to omit the number of entities in the khoroos when making

calculations. This is due to the coexistence of business organizations and entities at the same location. Together, entities and households may release 52.4 thousand tons of plastic waste per day.

Table 7. Comparison of baseline research and BGD's actual waste

	Calculation of base study				Actual performance of BGD		
Route	**Khoroo**		**Volume of plastic waste, per day**	**Percent**	**Average waste for a day**	**Plastic waste 8%**	**Percent**
	Number	no	kg	%	kg	kg	%
1	3	8,18,19	1016.9	13%	26,014	2,081.1	4%
2	2	1,3	883.0	12%	61,209	4,896.7	9%
3	4	10,20, 22,23,	1028.6	14%	327,721	26,217.7	50%
4	4	2,15,17, 24	1014.0	13%	68,537	5,483.0	10%
5	2	4, 25	803.0	11%	13,422	1,073.8	2%
6	3	7,9,21	855.4	11%	69,678	5,574.2	11%
7	5	11,12,13,14,16	1037.9	14%	52,541	4,203.3	8%
8	2	5,6	925.6	12%	36,408	2,912.7	6%
Total	**25**		**7,564**		**655,531**	**52,442**	
Average					**81,941**	**6,555**	

Population number. We compared the number of round trips and the average amount of waste produced per day with the population of the khoroos. Four of the 34 khoroos deviate from the average, while the majority make 200 round trips per month to collect waste. A typical khoroo produces a maximum of 50,000 kilograms of waste each day.

Most of the waste is concentrated in Bayangol district's 20th khoroo. On average, 250,000 kg of waste is collected per day, regardless of the number of residents in the khoroo. As can be seen from the map, the region has a higher level of industrial development. The amount of waste in one khoroo of the district varies between 13-15 thousand kilograms per day, without considering the load of the 20th khoroo of BGD. Furthermore, the 10th and 4th khoroos of BGD are significantly larger in terms of waste disposal.

Chart 8. Monthly amount of waste in BGD's khoroo, thousand kg

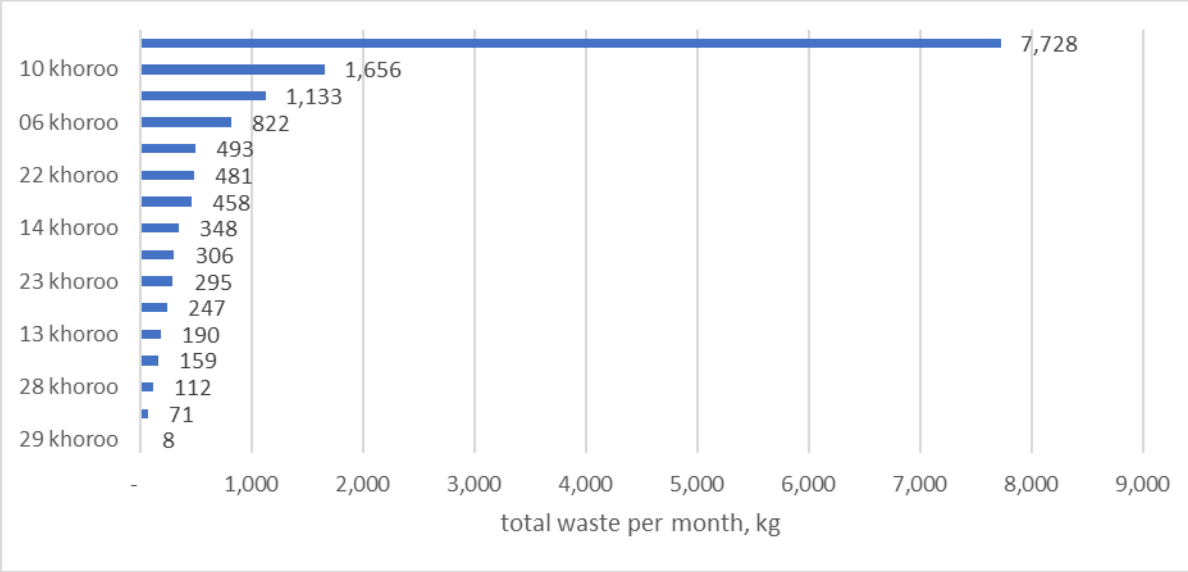


Figure 11. Territory of BGD's 20th khoroo

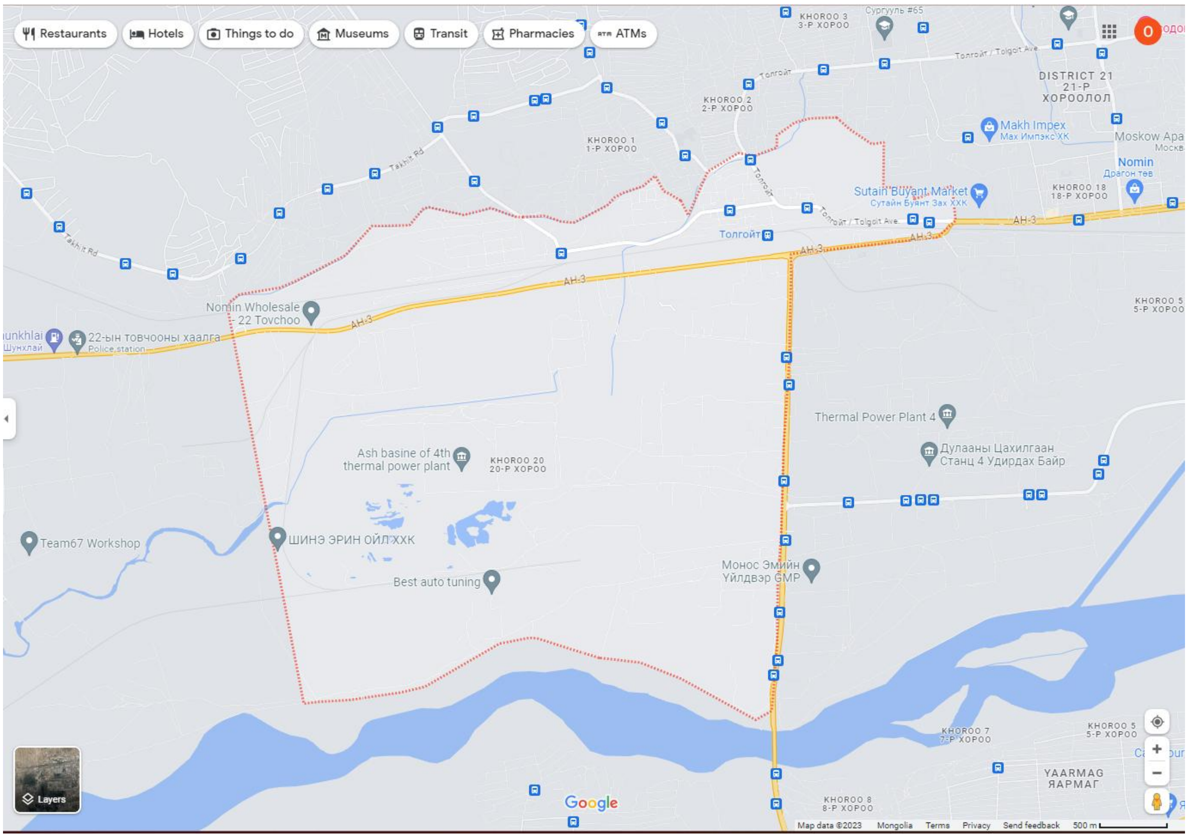
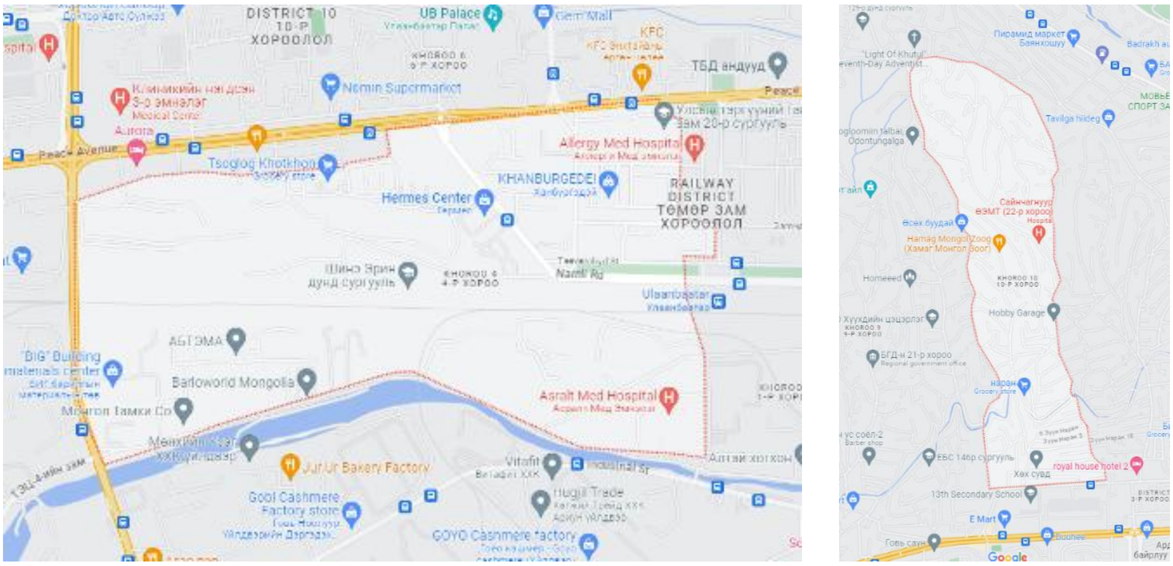
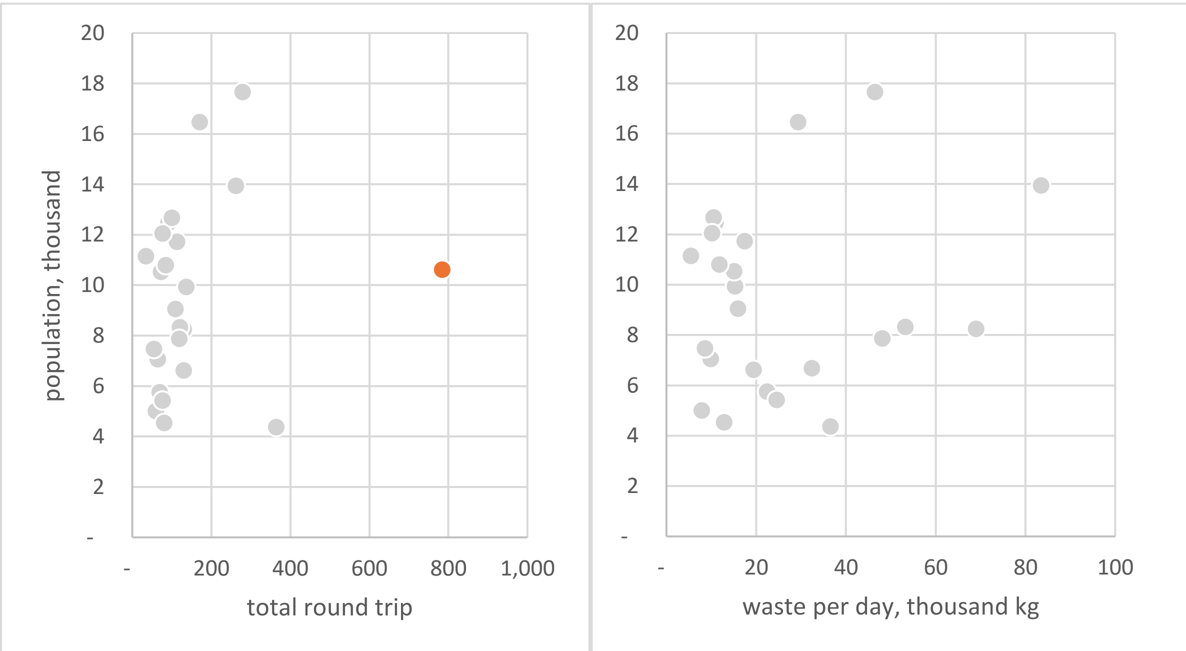


Figure 12. Territories of 10th khoroo and 4th khoroo of BGD



We examined the number of people living in the khoroos in relation to the average number of round trips made and the amount of waste disposed of on a daily basis. There is no direct correlation between either of these indicators and the size of the population.

Chart 9. Correlation between the population size, the number of trips, and the number of wastes per day generated by the khoroo.



From the above calculations, it is not appropriate to base the route of plastic waste collection and transportation based on the population size. Other factors such as road conditions, remoteness of the khoroos' locations, and the operating entities/organizations may have consequences to consider

3.5 Study of recycling /recyclable waste/ collection points

There are no facilities for re-sorting and transfer of plastic waste in Ulaanbaatar, and all waste is sent to CWDS. For BGD and SKHD's TUKs, they are disposing their waste at Narang Enger CWDS, for KHUD at Morin Davaa CWDS, and ND is disposing their waste at Bayalag Khonkhor CWDS. In other words, there is no step in the waste system of Ulaanbaatar city to officially classify the waste generated at the source as well as re-classification and transfer at the CWDS.

The primary waste sorting operation is being carried out at the following collection points. About 60 people hand-separate plastic waste at the CWDS of Narang Enger and sell it to the nearby secondary raw material collection point for 400 MNT per kilogram. The secondary raw material collection point buys it for 500 MNT per kilogram at the raw material collection point of the processing plant.

Formal and informal channels of plastic waste collection. TUK employees, individuals, AOAs and recycling organizations collect plastic waste. If the percentage of plastic waste collected by them is ranked, individuals and TUK employees / informal channels / collect the most.

Frequency of individual/informal/ plastic waste collection and disposal: TUK employees and individuals collect 50 kilograms of plastic waste per day, with an average of 25 kilograms per disposal twice a day, 14 times a week. About 200 kilograms of plastic waste is delivered from AOAs once a month.

The "Altain Baraa" AOA is working with the Mongolian Sustainable Development Bridge NGO in training and methodology as part of the "Sustainable Plastic Recycling in Mongolia (SPRIM)" project, funded by the European Union (SWITCH-Asia program).

Purchase price of plastic waste: Buyers buy plastic waste in 2 categories: clean (water, beverage bottles, etc.) for 400 MNT per kilogram, and dirty (dishwasher and water bottles, etc.) for 500 MNT per kilogram. The raw material collection point of the recycling plant buys only clean plastic for 500 MNT per kilogram.

As for the type of operation: It is a private business and is not registered by the State, but it pays a fee of 120,000 MNT once a year to the National Association of Waste Recycling of Mongolia.

The National Waste Recycling Association of Mongolia was founded in 2015 and joined the International Waste Association in 2018.

Figure 13. Manual sorting of plastic waste at central waste disposal site

Figure 14. Secondary raw material collection point

Figure 15. Raw material receiving point of a plastic recycling plant

3.6 Interview with the Municipal Service Company (TUK) of Bulgan aimag

We visited the site and familiarized ourselves with the operational conditions of Bulgan aimag and Khishig-Undur soums' TUK.

Bulgan soum. Bulgan soum Municipal Maintenance Service Department is an organization under the control of the Bulgan soum Governor. The department has 38 employees, including 7 waste loaders, 7 drivers, and 7 trucks that make three to four round trips per day. Even though waste is sorted at the POI for recycling and other purposes, it is further reclassified, pressed, and purchased by organizations at the central disposal facility as part of the goal of becoming a zero-waste soum.

Khishig-Undur soum. There is no TUK in Khishig-Undur soum, but there is a Waste Management Center in operation. Ecosoum NGO established the center with the support of the soum administration as part of the "Sustainable Plastic Recycling in Mongolia (SPRIM)" project, funded by the European Union (SWITCH-Asia program). The governor of Khishig-Undur soum believes that it is appropriate for NGOs to implement the activities of the waste management center due to the lack of budget and manpower in the soum administration. The waste management center has a total of 10 employees, including 9 project employees and 1 driver. There is no set schedule for plastic waste collection, households and entities bring their plastic waste to the center or the center collects it on call.

Figure 16. "Waste Management Center" in Khishig-Undur soum, Bulgan aimag

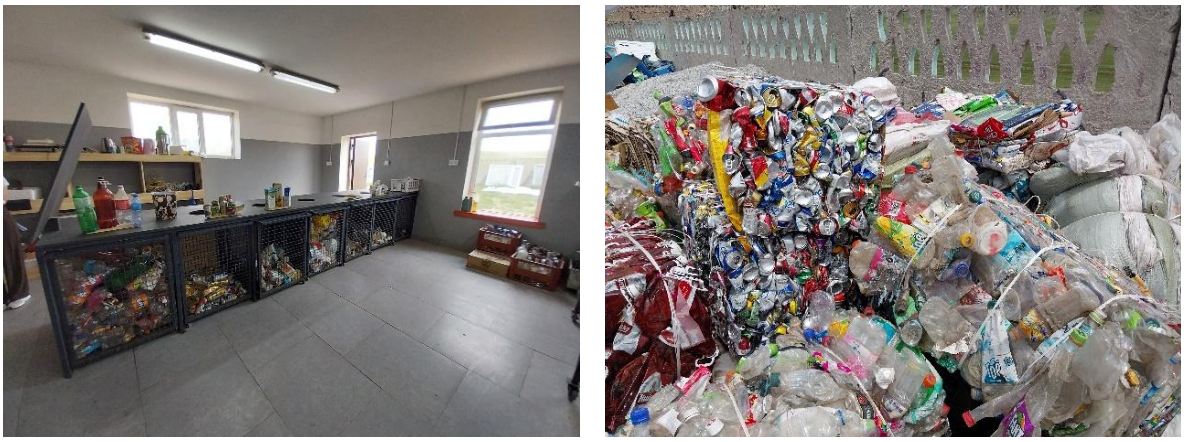


Figure 17. Central waste disposal site in Bulgan soum, Bulgan aimag

Technical equipment. There are seven waste collection trucks in Bulgan soum, of which four are KAMAZ trucks with an 8 m^3 capacity, two are porters with a 4 m3 capacity, and one is a crane. The trucks are approximately 6-7 years old. Khishig-Undur soum has one CWDS due to its small population. There is one Porter with a capacity of 4.5 tons, one KAMA, and one Bongo in the soum. Equipment is available for sorting, pressing, crushing glass, washing, drying, shredding, and melting plastic bottle caps. At the present time, recycled waste is transported by project trucks and sold to the city of Ulaanbaatar for recycling.

It is estimated that a truck consumes an average of 12-18 liters of diesel fuel per day in both soums. In Khishig-Undur soum, vehicle operating costs, maintenance costs, and workers' salaries are accurately calculated in detail, while in Bulgan soum, the costs are not accurately calculated in detail.

Points of interest and number of round trips. The Bulgan soum collects waste from POI locations 22 days a month, with extended hours on public Clean Up Days and weekends as necessary. In the soum, there are 24 waste bins on the streets, 3625 door-to-door waste bins, 152 waste bins in apartment areas, and one integrated waste bin. The amount of waste is calculated by multiplying the number of households by the average amount of waste disposed per household each day. Generally, contracted entities and AOAs have their waste collected twice a week, while custom waste is collected once a week. A single truck travels seven kilometers in one trip and loads between 120 and 148 cubic meters of waste each day. It is estimated that seven trucks load waste from 20-30 points each day. The route for waste collection is calculated based on the estometer readings, i.e. Porter 4L and Kama 5L diesel fuel would be spent. The route taken by each truck, the length of the road traveled, the waste disposal point, and information regarding the waste are recorded on paper.

Khishig-Undur soum representatives are also of the opinion that it is appropriate to calculate the amount of waste per members of household in comparison with the number of families/households. Paper records are also made for the soum, but the amount of waste collected and disposed is not recorded, records made only before sorting.

Plastic waste. Plastic waste in two soums is not collected and transported separately. Waste is classified as recycling and other from the point in the Bulgan area, and at the CWDS it is classified into glass, cans, paper, plastic bags, plastic, plastic bottle caps, and hard plastic. 40% of the total waste collected is plastic and hard plastic waste.

There are 270 waste bins for sorting waste in the Khishig-Undur soum territory. There are 9 types of waste in this waste bins, but in reality, there are occasions where the waste is used for other purposes without sorting.

The TUK of Bulgan soum submits a monthly report to the Ministry of Environment and Tourism, while the CWDS of Khishig-Undur soum submits a report once a year to the donor organization and the state registry office.

Funding. Bulgan soum collects 120,000-150,000 MNT per month from contracted organizations/entities and 2,000 MNT per month from households. As for Khishig-Undur soum, there are 685 households in total, and each household pays a fee of 500 MNT per month.

The Waste Management Center in Khishig-Undur soum has signed a contract to receive $30 million a year from the Government's Office, but in reality, only 367,000 MNT per month and 4.4 million MNT per year is recieved from the state budget. The employees are given a fixed salary and 10-20% skill bonus. The funding is sufficient, and the proceeds from the sale of plastic are being accumulated ans stays unused. The amount of necessary annual funding for the Khishig-Undur soum Waste Management Center has been estimated to be 90 million MNT.

For two soums, the collected plastic is sold. And it is sold at the Bulgan soum's CWDS for 800-1000 MNT per kilogram. In the case of Khishig-Undur soum, it is transported to Ulaanbaatar city and sold to related organizations for 600 MNT per kilogram.

The assessment team concludes that collecting ONLY plastic waste is not economically optimal and may face opposition from households and public, entities.

4 AN ANALYSIS OF THE METHODOLOGY, DATA, AND SOFTWARE USED FOR THE BASELINE STUDY (DELIVARABLE 1)

4.1 Evaluation of baseline study

The consultancy team has evaluated the following content in the baseline study. (See attachment for detailed evaluation report) It includes:

1. Evaluation of baseline research methodology, data and software to develop optimal collection routes for plastic waste

    a. Evaluation of baseline research methodology and estimation
    b. Evaluation of baseline research data
    c. Evaluation of baseline research software

2. Evaluation of baseline study estimations regarding vehicles, their capacity, collection points, road conditions, congestion, fuel consumption, and manpower requirements

    a. Evaluation of baseline research estimation on vehicles and it's capacity
    b. Assessment of waste collection points (POI) for baseline research
    c. Evaluation of baseline estimates of road conditions, congestion, fuel consumption and manpower costs

Based on the findings of the baseline research and the results of additional research by the consulting team, the evaluation was based on the following criteria:

Table 8. Checklist 1: Methodology and assumptions baseline data

№	Criteria (score 1 if yes, 0 if not)	Yes	No
1	TW - Time window		0
2	MD - Multi depot		0
3	HF - Heterogenous fleet	1	
4	RC - Route capacity	1	
5	MDT - Multi-disposal trip	1	
6	TG - Type of goods		0
7	P - Periodic		0
8	Sensitivity analysis		0
9	Data Limitation		0
10	Optimization algorithm		0
	Total score	**3**	

According to the evaluation conducted on the baseline research methodology, assumptions, and base data, three indicators out of the total of ten indicators have been adequately implemented, including multi-type transportation, route work capacity, and waste disposal routes. While the other seven indicators are not met to the criteria, there is a need for improvement.

Table 9. Checklist 2: Economic evaluation

№	Criteria (score 1 if yes, 0 if not)	Yes	No
1	How well does it reflect the peculiarities of collection, storage, sale, settlement, and local markets		0
2	Whether the number of plastic waste collection points is taken into account	1	
3	Whether the calculation of fuel costs is realistic		0
4	Inclusion of additional costs		0
	Total score	**1**	

According to the evaluation conducted on the baseline research on economic estimation, one indicator to take into account the number of plastic waste collection points is met to the criteria, while the other 2 indicators are not met, so it is necessary to make improvements.

Table 10. Checklist 3: Technical Assessment of the route

№	Criteria (score 1 if yes, 0 if not)	Yes	No
1	Whether or nor the number of cars and their capacity have been calculated	1	
2	Whether or nor the demand and supply of human resource is taken into account		0
3	Whether or nor traffic jams are taken into account		0
	Total score	**1**	

In terms of the technical assessment of the route of the baseline research, one indicator for the number of vehicles and their capacity is met, but the other two are not, so improvements are required.

Figure 18. An illustration of the base study optimization model and process

OBJECTIVE

Shortest route to travel

CONDITIONS

Calculation conditions used for TSP simulation:

- ***District of Ulaanbaatar city:*** Garage – Points of interest – Garage
- ***Bulgan aimag:*** Bulgan soum– Points of interest – Bulgan soum

Calculation conditions used for CVRP simulation:

- ***District of Ulaanbaatar city:*** Garage – Points of interest – Garage
- 5a. Truck capacity- 8m3, 5:1 injection machine
- 5б. Truck capacity- 19m3, 14m3, 8m3, 6m3 ; 5:1 injection machine
- 5в. The population density was averaged to be evenly distributed in shopping centers and supermarkets in the district.
- ***Bulgan aimag:*** Bulgan soum– Points of interest – Bulgan soum
- Soums: Truck capacity- 12 tn, 10:1
- Bulgan city: Truck capacity- 3m3 ; 5:1 injection machine

Calculation conditions used in VRP simulation:

- ***Bulgan aimag:*** Bulgan soum– Points of interest – Bulgan soum
- Soums: Truck capacity- 12 tn, 10:1

DATA

1. Amount of waste, g/person-day
2. Percentage of mixed plastic waste
3. Mixed plastic waste per person, g/person-day
4. The degree of compression of the waste collection machine
5. The unit from which distance calculations are made
6. Cargo volume calculation unit
7. Density of uncompressed mixed plastic, kg/m3
8. Press volume, cm
9. Pressed volume of mixed plastic, m3
10. Pressed weight of mixed plastic, kg
11. The degree of compression of the press machine
12. The size of the long-distance transport vehicle, m
13. Long-distance truck cargo weight, tons
14. Population of UB city, Bulgan province
15. Number of large markets and shopping centers
16. Point of interest
17. Simulation time

PROGRAM:

Google Developer

RESULTS / SOLUTIONS:

TSP simulation calculation results::

- Garbage truck's shortest route to travel one cycle through the khoroos, km
- Garbage truck's shortest route to travel one cycle through the markets and supermarkets, km

CVRP simulation calculation results:

- Number of garbage trucks transporting plastic waste and average weight of charge in Ulaanbaatar city
- Summary of plastic collection garbage truck routes and information for each truck
- Shortest route for transporting plastic waste by various types of garbage truck, km
- Shortest route of the road for the transportation of plastic waste collected from the shopping center, km

VRP simulation calculation results:

The shortest route for collecting plastic waste between the villages of Bulgan aimag, km

5 PROPOSALS FOR IMPROVING ROUTE MAPPING AND TRAFFIC CALCULATION SIMULATION (DELIVERABLE 2)

5.1 Optimization scheme

Waste management is primarily concerned with creating and implementing a schedule and route of activities that minimize costs without compromising the quality of service.[3] The optimization model allows to calculate and find the optimal route with the least cost of transportation for a network with a certain number of users (destination points).

It is important to distinguish between two different systems: waste collection and waste transportation. ONLY transport along the route has been optimized assuming that plastic waste is collected at certain points in the current baseline survey. The report also considers only the transport system, assuming that the plastic waste collection system is performed separately.

5.2 Components of the optimization model

An optimization model has 3 main components.[4] There is a proposal being developed by each component to improve the optimization calculations for plastic waste collection and transportation routes in Ulaanbaatar city and Bulgan aimag.

1. Optimization goals. Identify the problems for which an optimal solution should be sought.

A baseline research study was conducted in order to determine **the shortest transport route** for extensive waste collected in Ulaanbaatar city and Bulgan aimag. This calculation determines the "shortest route to travel" after passing the POI once and returning to the origin. Results of projects may look more important if they are viewed from a low-cost perspective rather than just from an optimal or short-cut perspective. Plastic waste collection and transportation routes can be optimized by using Multi-Objective Optimization[5] in order to review the problem, challenges and solutions of these routes. Optimization may include reducing vehicle travel distances, increasing vehicle utilization, and optimizing workload distribution.

In order to improve the calculation, the following objectives can be included in the calculation:

Option 1. Minimize the number of vehicles in use
Option 2. Maximize the number of POI to be covered per route
Option 3: Minimize variable travel expenses
Option 4. Meet all three goals simultaneously

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[3] Antoni KORCYL, Roger KSIĄŻEK, Katarzyna GDOWSKA. A MILP MODEL FOR ROUTE OPTIMIZATION PROBLEM IN A MUNICIPAL MULTI-LANDFILL WASTE COLLECTION SYSTEM

[4] Optimization Model Basics - Optimization - Mathematics Library User's Guide - Documentation - Math, Statistics and Matrix Libraries for .NET in C#, VB and F# (extremeoptimization.com)

[5] An Overview of Agent-Based Models for Transport Simulation and Analysis (hindawi.com)

2. Values of the optimization solution. The purpose of the optimization calculation is to determine the optimal value of each variable. In order to accomplish this, upper and lower values are set for each variable.

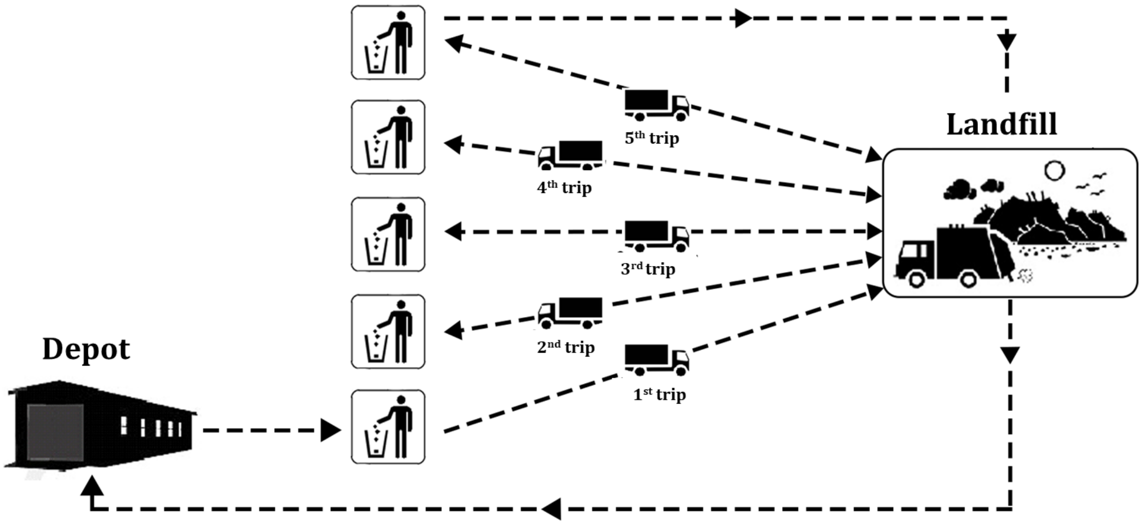
In the baseline research, the number of POI and the coverage area of one truck were taken into account in the calculation. Our proposal is to include the travel time between the points and the waiting time at the POI. In the observational study, it was found that the distance between the point and the waiting time in the apartment neighborhood and the ger residential neighborhood differed, so the variable could be adjusted according to the characteristics of each neighborhood.According to the correlation analysis of BGD quantitative data, the amount of waste and the number of routes are not related. As a result, depending on the optimization objective, it may be necessary to change the number of vehicles for regular routes, or to take the number of routes with fixed vehicles as a variable.

3. Constraints. It is important to identify the decision variables and their constraints. The identification of controllable and uncontrollable factors and the baseline data to which they can be adjusted is a prerequisite for optimizing a scheme.

For the baseline study, the basic constraints were that one POI would be included on one route, that the vehicle's capacity would not be exceeded, and that the vehicle would leave the depot and return to the depot.In addition, it is proposed to include the following constraints.

- Work time limits should be determined by taking into consideration the starting and ending times of service, as well as the departure and arrival times at the depot separately;
- Due to the fact that the number of vehicles directly affects the amount of investment required, the number of vehicles and their costs could serve as a constraint to optimization.
- As observed, the vehicles collect the waste and drop it off at the centralized station before returning to the next point. As a result, it is necessary to incorporate a condition that requires the vehicles to dispose of waste at the CWDS before returning to the depot. Each route could include the nearest CWDS as a point of interest in the optimization calculation.

Figure 19. Modeling of the observation route



The calculation of conditions for the optimization of plastic waste transport are summarized as follows:

- Multiple vehicles should be used
- A single vehicle is allocated to each route
- Ensure that the vehicle's capacity is not exceeded
- Each vehicle belongs to a single depot
- Enter "start and end of working hours only" in the condition field.
- The available vehicles can only be utilized within the specified zone or section
- There are a number of waste collection points in the area
- The service will be provided to the customer within the working hours
- Service will be provided to all users within a certain period of time
- When the vehicle has collected the waste from the last point on the given route (given section), it should proceed to the nearest CWDS to dispose of the waste.
- The vehicle will be returned to the depot once the waste from the last route has been unloaded at the CWDS.
- Ideally, the route's final destination should be located near a CWDS.

5.3 Data to be used in optimization calculations.

5.3.1 Population number

Several factors have been analyzed in relation to the population of BGD khoroos, including the average number of daily routes and the average amount of waste generated on a daily basis. Neither of these indicators is directly related to the size of the population. As a result, it is inappropriate to base the route of plastic waste collection and transportation on the size of the population. A number of other factors may need to be considered, including the condition of the roads, the remote location of the khoroos, and the type of entities operating the khoroos. The weight of each route in the baseline study was adjusted to 11%-13% based on the principle of equalizing the amount of waste per day (see Table 7). When the actual average amount of BGD waste per day is distributed to the 8 routes identified by the baseline research, different percentages are observed. When assigning khoroo to each route, please consider the actual amount of waste collected.

5.3.2 Number of Khoroo

Due to the fluctuation in the population and density of Ulaanbaatar city, the number of khoroos changes from year to year.

5.3.3 Quantity of waste – Demand

A baseline study was conducted using data derived from the "Ulaanbaatar Household Waste Structure Research Report" published by the Asia Foundation in 2019. The assumption is that each individual produces 400 grams of waste per day, of which 8 percent is plastic waste, but left out entities operating in khoroo.

As well as varying greatly depending on the neighborhood and type of apartment/ger area, the proportion of plastic containers and hard plastic waste varies significantly between winter and summer for ger neighborhoods.[6] As part of the Capacitated Vehicle Routing Methodology (CVRP) method, it is necessary to determine the amount of waste generated at each point so that realistic results can be obtained.

Rather than relying on population statistics when calculating plastic waste loading and transportation, it is proposed to use actual waste output and its percentage from the database of TUK operating in these districts. As well, it is advisable to include different amounts of waste based on the type of khoroo when performing optimization calculations.

5.3.4 Waste collection frequency

According to the baseline survey, there will be one collection point per khoroo, and collection will take place on a daily basis. Based on interviews and observational studies, each district has a unique situation as well as different district policies and the organization of daily waste collection activities. Khan-Uul District, for example, adheres to a daily waste collection schedule and the principle of once a day collection, while Bayangol District aims to reduce the number of waste points as much as possible and collects waste once a week.

5.3.5 Number of users – POI

In the baseline study, one waste collection point was allocated to each khoroo. After examining the waste collection points in Ulaanbaatar, Bulgan aimag and Khishig-Undur

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[6] Research on the structure of household waste in Ulaanbaatar, 2019

soum of Bulgan aimag, the consulting team concluded that one point could not be in each khoroo. There is a lack of clarity regarding the types and conditions of all POI in Ulaanbaatar city (for instance, whether there is or is not a point for collecting plastic waste, waste bins, etc.). A survey of the points of interest revealed that 70 percent of the locations do not have bins for collecting plastic waste or sorting other waste, and instead, all types of waste are collected in one container.

Based on interviews and case studies conducted with TUKs, it appears that there are on average 20-30 POIs in apartment area, and that the number of POIs equals the number of ger households. One route collects waste from 14 ger households.

The proposal is to differentiate between plastic gathering points according to the population's lifestyle and movement. Depending on the degree of centralization of apartments, ger area households, and entities, it may be necessary to differentiate optimization variables by large, medium, and small amounts of waste.

5.3.6 Distance and travel time between destinations

SKHD's TUK collects waste from 15-20 points or yards per route, working on the principle of door-to-door collection. In the case of ger residential areas, it is appropriate to take the number of POI as the number of households or yards. In the Ger residential neighborhood, 200-300 bags of waste are collected in 30-40 minutes without stopping for a distance of 200-250 meters.

5.3.7 Number of Central waste disposal sites – Number of recycling points

The city of Ulaanbaatar has four CWDS, and each district disposes of its waste at one of these sites. Similar studies include the location of the CWDS as a POI in their optimization model.

5.3.8 Travel distance from POI to Central waste disposal site

An initial baseline study recommended a route for transporting waste from one POI of one khoroo to the next khoroo's POI. From observation study, after collecting waste from 15-20 POIs of one khoroo in one route, the truck fills up, goes to the centralized waste point, dumps the waste, then continues to the next POI. Therefore, when proposing the route, the final POI should be the one closest to the CWDS. There is a 30-minute drive between SKHD and Naran Enger's CWDS.

5.3.9 Number of vehicles

As part of the waste transportation activities, BGD has 21 trucks, KHUD has trucks, SKHD has 52 trucks, and ND has 8 trucks.

5.3.10 Type of vehicles

Depending on the type of vehicle you select, the optimization calculation will differ. The results of interviews and case studies conducted with four TUKs in four districts of Ulaanbaatar revealed that all of them do not have waste compactors or presses and have open-bucket waste trucks. Moreover, plastic represents 8% of total waste, and the objective of this project is to concentrate only on pressing plastic waste rather than collecting and transporting other recyclable materials. Therefore, further research is necessary to determine whether the choice of a high-capacity compactor will be compatible with the actual situation.

As an alternative, a non-compressible, bulk machine option can be incorporated into the calculation based on the geographic location and target location. Even though compactors can be used in apartment complexes, it is not possible to separate plastic from compacted waste when it is collected together, since the plastic of apartment complexes is not separated at the source.

5.3.11 Vehicle capacity

The baseline study used 10:1 vehicle capacity in soums, 5:1 in Bulgan town, and 5:1 in Ulaanbaatar. In CVRP methodology, the Press Pack model of the Hyundai brand was chosen with a capacity of 8m3, with a 5:1 pressing ratio, while for multiple types of vehicles - 19m3, 14m3, 8m3, 6m3; a 5:1 pressing ratio was used.

Hyundai Motors Mongolia LLC, the official distributor, informed us that the production of 14m3 and 19m3 vehicles with a 5:1 compression ratio has been discontinued.

Transport of waste is arranged in TUKs with vehicles with capacities ranging from 3 to 18 tons (BGD 3 and 5 tons, SKHD 2 and 5 tons, KHUD 3 and 18 tons, ND 5, 8 and 12 tons).

5.3.12 Variable costs of waste collection (by type of vehicle)

A waste collection crew consists of one driver and two loaders, and the districts have different wage systems, which are either fixed or non-fixed - result-based. It is recommended that the experience of BGD and SKHD be considered when calculating the costs of human resources.

The majority of TUKs use open-bucket trucks and consume an average of 50 liters of diesel fuel per day, although this can vary from day to day.

5.3.13 Road conditions

According to the baseline study, "the shortest route will be calculated after passing the POI once and returning to the original location", and the closest points of interest (POIs) are calculated by Google Maps. The Google Maps platform, Python programming language, and Google developer platform were used to calculate route optimization, and open programs such as MAPS.ME and Open Street Map were used to define POIs. The use of Google Maps for route planning may be inconsistent with reality. The reason for this is that the public use systems have outdated maps that are updated every 1-3 years. Thus, it is more appropriate to use other systems that are updated in a timelier manner. Maps on OpenStreetMap Mongolia are updated more frequently than those on Google Maps. Further, it is concluded that random sampling should be used to determine the POIs and that the data should be verified for accuracy.

The GIS system used in the calculations should be able to connect with the databases of other public and private organizations or allow the data to be transferred to those databases. Combining real-time data with dynamic route planning methods based on real-time conditions such as traffic jams, road closures, and debris movement.

5.4 Optimization calculations

Sensitivity Analysis: It is necessary to perform a sensitivity analysis in order to determine the effect of small changes in the input data on the solution derived. As long as the solution remains stable when the estimation parameters are changed slightly, it can be considered to have a good value. A sensitivity analysis is strongly recommended, which involves varying input parameters such as waste volume, vehicle capacity, and collection frequency. Based on changes in the above parameters, this analysis will determine the overall performance of the system and its cost effectiveness.

Testing: In order to determine if the implementation process will succeed or not, a certain amount of actual testing must be conducted, or at least partially, to confirm the results of the simulation.

6 ECONOMIC ANALYSIS (DELIVERABLE 3)

In order to make a conclusion about whether it can be used at the level of other aimags and cities, an implementation calculation has been made. The baseline research data and calculation results were used for the calculation, and the summary is shown in Table 11.

Table 11. Baseline study calculation data and results

District	Khoroo	Population	Waste size	The road to travel	Truck	Route	Per route		
	number	number	kg	km	number	number	Number of populations	Waste size	The road to travel
BGD	25	236,385	7,564	160	8	8	29,548	946	20
BZD	17	383,892	12,285	255	13	13	29,530	945	20
BND	5	29,433	942	12	1	1	29,433	942	12
BKhD	2	4,459	143	13	1	1	4,459	143	13
ND	8	38,929	1,246	87	2	2	19,465	623	44
SBD	20	144,542	4,625	130	5	5	28,908	925	26
SKhD	32	341,540	10,929	221	11	11	31,049	994	20
KhUD	21	209,524	6,705	147	8	8	26,191	838	18
ChD	19	150,548	4,303	48	5	5	30,110	861	10
Total	**149**	**1,539,252**	**48742**	**1073**	**54**	**54**			

Table 12. Data from baseline study

Indicator	Unit of measurement	Quantity
Mixed plastic waste per person	g/person-day	32
Truck capacity	m3	8
Working hours	Hour	8
Working day	Day	22
Number of employees per route	Number	2
Car fuel consumption[a]	l/km	1
Repair service	monthly frequency	1

[a] *Based on the average fuel consumption of districts' TUKs*

The following base prices are used for investment and financial calculations.

Table 13. Investments, current expenses, income base price, in MNT

Indicator	Unit of measurement	Quantity
I. Investment costs		
Indicator	**Unit of measurement**	**Quantity**
Truck price[a]	Unit	396,750,000
Accessories price	Unit	100,000
Landfill landscaping price[6]	Unit	5,000,000
II. Current costs		
Indicator	**Unit of measurement**	**Quantity**
Fuel price	Liter	3,490
Maintenance charges	MNT	100,000
Salary	Per day	60,000
Food and transportation allowance	Per day	10,000
III.Income		
Indicator	**Unit of measurement**	**Quantity**
Selling price	kg	500

a Hyundai brand car with 8.0m3 capacity

6 MSB company's trash can

The prices of Hyundai, Sinotruck, Howo, Dongfeng and Isuzu brand garbage trucks were studied as part of the baseline research.

Table 14. Price list of trucks by brand and model

Manufacturer	Model	Year of manufacture	Volume	Price, USD
HYUNDAI	HD72	new	6m3	$ 91,000
HYUNDAI	HD120	new	8m3	$ 115,000
Sinotruk HOWO	FYZZ5257	new	19m3	$ 58,500
HOWO	LHD	new	8m3	$ 22,990
Dongfeng	DFAC	new	8m3	$ 20,500
Isuzu	CLW	new	6m3	$ 19,800

The calculation includes the price of a Hyundai truck with a volume of 8m3.

Table 15. Specifications of Hyundai truck with a capacity of 8m3

Transportation vehicle	Engine	D6BR, D6GA
	Wheel base	Length: 3,795mm
	Size	7,100 x 2,240 x 2,950
Body	Size	3,485 x 2,030 x 1,485
	Drop type	Dumping
	Container volume	8.0m3
	Compressor volume	1.0m3
	PTO type	Transmission PTO

In order to create a plastic waste collection and transportation system, the price of large-sized specialized waste bins was selected based on the assumption that there will be a need to equip special plastic waste collection points. And, based on the market price research shown in Table 16, the selling price of the collected plastic waste was estimated to be 500 MNT on average.

Table 16. Comparative list of plastic waste sales price

Organization	Unit of measurement	Price, MNT	Contact number	Link
Ecocash	kg	400	7603 0125	Facebook
"Khongor Duulim" LLC /Bayankhongor aimag/	kg	150	8008 8565	Facebook
Sunkhbaatar Municipal Service /Sukhbaatar aimag/	kg	200	7051 8637	Facebook
Buy plastic/go buy/	kg	250	80032963	Facebook
Plastic Mongolia/go buy/	kg	250	80325522	Facebook
Tuvshin Saikhan Center	kg	400	9668 5858	Facebook
Sudalt LLC pickup point	kg	400	99105520	Facebook
TML LLC	kg	600	80052720	Facebook

Based on the POI and the number of vehicles given in the baseline study, the team has made an investment calculation. A total of 54 vehicles that 21 billion MNT are needed in 8 districts, 5.4 million MNT for accessories, 270 million MNT for the improvement of 54 CWDS, and a total investment of 21.6 billion MNT for the implementation of the project is needed.

Table 17. Total investment required, by district, MNT

District	Required equipment			Investment		
	Truck	Workers toolkits	Waste collection point	Truck	Workers toolkits	Waste collection point
	number	number	number	MNT	MNT	MNT
BGD	8	8	100	3,174,000,000	800,000	500,000,000
BZD	13	13	168	5,157,750,000	1,300,000	840,000,000
BND	1	1	20	396,750,000	100,000	100,000,000
BKhD	1	1	20	396,750,000	100,000	100,000,000
ND	2	2	40	793,500,000	200,000	200,000,000
SBD	5	5	140	1,983,750,000	500,000	700,000,000
SKhD	11	11	258	4,364,250,000	1,100,000	1,290,000,000
KhUD	8	8	84	3,174,000,000	800,000	420,000,000
ChD	5	5	57	1,983,750,000	500,000	285,000,000
Total	54	54	54	21,424,500,000	5,400,000	270,000,000

In the calculation of running costs the fuel, employee salaries and maintenance costs are included, and there will be a total running cost of 254.1 million MNT per month in 8 districts.

Table 18. Operation and maintenance cost, monthly, MNT

District	Types of expenditure						
	Truck fuel	Maintenance operation	Number of employees	Fuel	Maintenance	Salary	Food and transportation allowance
	liter	Times	Number	MNT	MNT	MNT	MNT
BGD	3,5 20	8	16	12,284,800	800,000	21,120,000	3,520,000
BZD	5,610	13	26	19,578,900	1,300,000	34,320,000	5,720,000
BND	264	1	2	921,360	100,000	2,640,000	440,000
BKhD	286	1	2	998,140	100,000	2,640,000	440,000
ND	1,914	2	4	6,679,860	200,000	5,280,000	880,000
SBD	2,860	5	10	9,981,400	500,000	13,200,000	2,200,000
SKhD	4,862	11	22	16,968,380	1,100,000	29,040,000	4,840,000
KhUD	3,234	8	16	11,286,660	800,000	21,120,000	3,520,000
ChD	1,056	5	10	3,685,440	500,000	13,200,000	2,200,000
Total	**23,606**	**54**	**108**	**82,384,940**	**5,400,000**	**142,560,000**	**23,760,000**
							254,104,940

Assuming that all collected plastic waste will be transported and sold, it will earn 536.1 million MNT per month.

Table 19. Estimation of income, MNT

District	Quantity of waste	Revenue/Income
	kg	MNT
BGD	7,564	83,207,520
BZD	12,285	135,129,984
BND	942	10,360,416
BKhD	143	1,569,568
ND	1,246	13,703,008
SBD	4,625	50,878,784
SKhD	10,929	120,222,080
KhUD	6,705	73,752,448
ChD	4,303	47,335,200
Total	**48,742**	**536,159,008**

Based on all the above calculations, if the model of plastic waste collection in 8 districts is implemented in Ulaanbaatar city, a monthly income will be 536.1 million MNT and current expenses will be 254.1 million MNT. Total profit/loss of 282 million MNT is the amount excluding fixed expenses and other taxes. This is because the enterprise that will organize the collection and transportation of plastic waste has not been defined.

Table 20. Income and expenditure by year and month, MNT

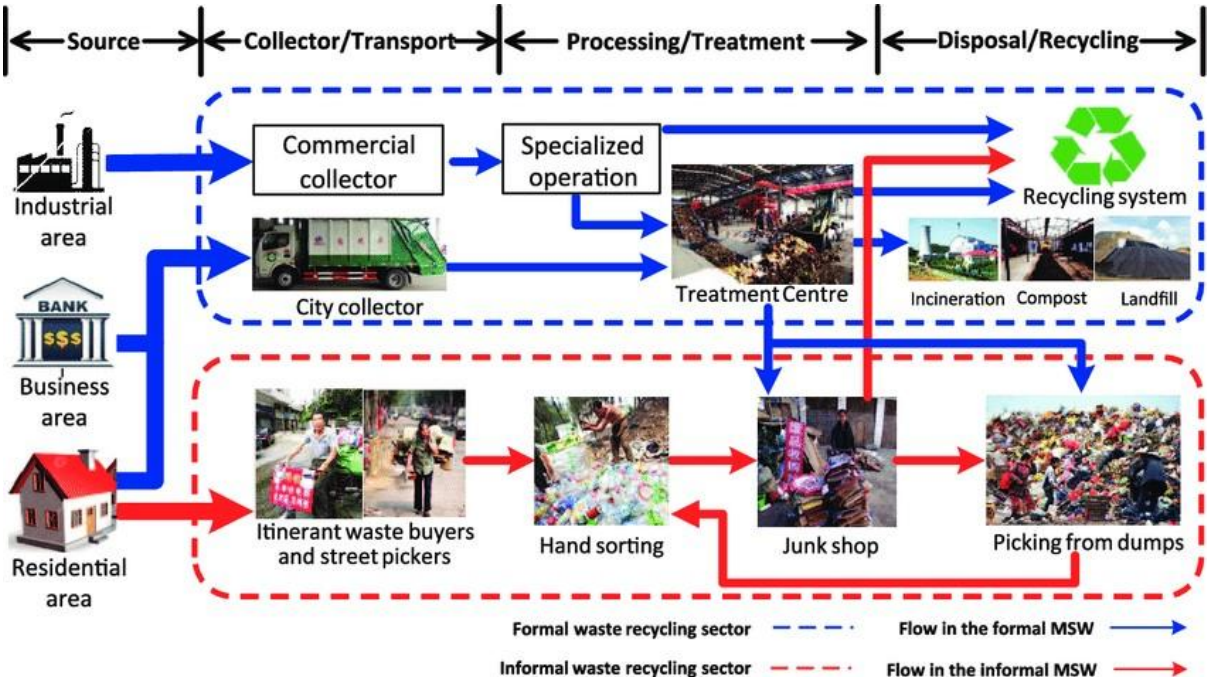
	Monthly	Yearly
Income	536,159,008	6,433,908,096
Expenditure	254,104,940	3,049,259,280
Gross Profit / Loss	282,054,068	3,384,648,816

7 FEASIBILITY ASSESSMENT (DELIVERABLE 4)

7.1 Plastic waste collection and transportation system

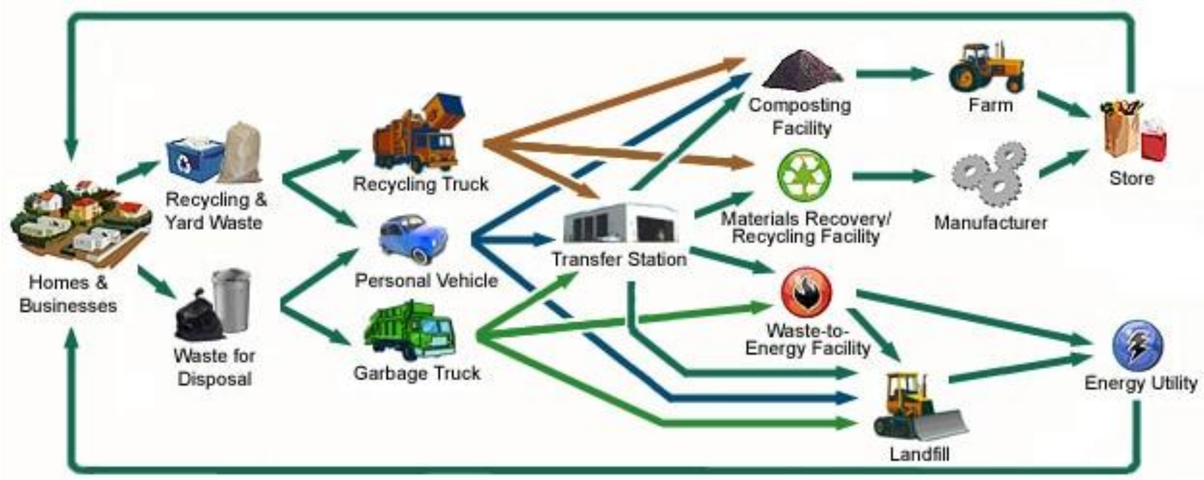
Compared with international schemes, the implementation of optimal collection and transportation of plastic waste within cities, aimags, and remote ger districts was evaluated. Figure 20 illustrates the four stages of the plastic waste system, from generation at the source to disposal: collection, sorting, disposal, and recycling. Plastic waste can be categorized into three types: industrial, commercial, and household waste. Plastic waste recycling and recovery is a final metric that is widely used in many countries. As can be seen, informal waste collectors play a significant role in maintaining this indicator and must be integrated with formal collection efforts. In some developing countries, labor-based activities limit the power of technology, but they also increase the recyclability of plastics.

Figure 20. Contribution of formal and informal solid waste systems



The figure 21 illustrates the seven stages within the waste system, each of which is based on the principle of shortest route as well as the principle of economic benefit to the stakeholder at each stage. Among the most important parts of the system is the transit station, where plastic waste is transported and sorted. In our case, two steps are skipped: the transit station and the recycling point, as well as going directly to the CWDS. As a result, this contradicts the shortest route optimization scheme. Additionally, many studies have shown that considering the two separate activities of waste collection and transportation as independent tasks increases efficiency.

Figure 21. Solid waste management



7.2 Feasibility of implementation of the scheme at aimag and municipal levels

On the basis of Bulgan aimag conditions represented in the baseline research, assess the feasibility of the scheme at the aimag and city levels, and make recommendations for issues to be considered, improvements to be made, and sustainable operations. In Chapter 2.3 of the baseline research report for Bulgan aimag, the Vehicle Routing Methodology (VRP) is not explained as to why the VRP method was used rather than other methods in Bulgan aimag. As a result, it is difficult to make recommendations and conclusions about whether to use it on the example of an aimag or a city. However, in order to determine whether the route scenario can be implemented at the aimag level, we can examine the population density of Mongolian cities and aimags over the past 3 years. As can be seen, it is an important variable in calculating the possibility of implementing the route.

Table 21. Data on population density, GDP, distance from Ulaanbaatar city, connectivity of soums with paved roads, by aimag, 2022

№	Aimag	Population density	GDP, thousand MNT	Distance from the city of UB, km to the center of the aimag[7]	Paved road connection arrow, in percentage[8]
1	Arkhangai	1.7	8842.9	430	37%
2	Bayan-Ulgii	2.5	5827	1425	23%
3	Bayankhongor	0.8	6027.8	630	20%
4	Bulgan	1.3	8787.4	318	38%
5	Gobi-Altai	0.4	7812.4	1336	6%
6	Gobisumber	3.3	9885.5	238	33%
7	**Darkhan-Uul**	**32.7**	11261.4	219	75%

[7] https://24barimt.mn/83127.html

[8] https://ikon.mn/n/2e32 Хатуу хучилттай замаар холбогдсон сумын тоог сумын тоонд харьцуулан тооцов.

8	Dornogobi	0.6	8581.9	463	43%
9	Dornod	0.7	13214.8	655	29%
10	Dundgobi	0.6	6827.1	260	27%
11	Zavkhan	0.9	8479.2	984	29%
12	**Orkhon**	**136.4**	6770.2	351	100%
13	Uvurkhangai	1.8	32174.6	430	21%
14	Umnugobi	0.4	9183.9	553	27%
15	Sukhbaatar	0.8	11986.4	560	23%
16	Selenge	2.6	8639.4	331	53%
17	Tuv	1.2	25931.1	43	44%
18	Uvs	1.2	7552.8	1336	11%
19	**Ulaanbaatar**	**360**	21639.7	0	100%
20	Khovd	1.2	10459.5	1425	59%
21	Khuvsgul	1.4	6450.5	671	17%
22	Khentii	1	8844.6	331	22%

Orkhon and Darkhan-Uul aimags have a larger population than other aimags, which can be compared with Ulaanbaatar's scenario of plastic waste collection and transportation as illustrated in Table 21. The GDP and the percentage of roads that are paved are also important indicators.

Suggestions for optimizing the route:

- Using a route algorithm that takes into account factors such as waste generation points, population distribution, highway network characteristics, and vehicle capacity.
- It is considered more appropriate to choose the above-mentioned algorithm in the case of too few or too many calculation solutions, depending on the size of the highway network.
- A clear understanding of the economic situation is necessary, such as whether to wait until a vehicle is full of waste in a small, populated area, or whether to include smaller waste hauling vehicles that are not included in the scheme.
- Involve stakeholders: freight transport companies, city and aimag master planning departments, TUKs, etc. Examples include: changes in the capacity of freight transport companies (repairs of vehicles, etc.), and anticipating future changes in the road network. The data collection process involves collecting information on actual waste volumes, vehicle use, fuel consumption, and costs, validating the results of the scheme, and identifying areas for improvement. Furthermore, it is believed that obtaining methodological advice from experts in the field of transport economics, transportation management and logistics will facilitate the realization of realistic research outcomes.
- Collaborate with local authorities: Collaborate with local waste management authorities, municipalities and other stakeholders to ensure accurate information is available, gain insight into local waste management practices, and implement effective waste collection and transportation strategies.

- Monitoring and evaluation: To establish a mechanism for the regular monitoring and evaluation of waste collection and transportation activities in aimags. This procedure involves gathering data on actual waste volumes, vehicle utilization, fuel consumption, and cost, validating the results of the scheme, and identifying potential improvement areas.
- Create a comprehensive cost scheme that incorporates various types of costs, such as fuel consumption, labor costs, vehicle maintenance and waste disposal charges. An accurate assessment of the financial implications of different waste collection and transportation strategies requires consideration of local economic conditions.
- An explanation of the economic situation in the scheme, such as whether to wait until the accumulation of waste can fill a vehicle in areas with a small population, or whether to include smaller size waste collection trucks that are not included in the calculation.

7.3 Feasibility Assessment Indicator

In accordance with the feasibility and conditions, a table summarizes the best options for collection and transportation of plastic waste based on observational studies and stakeholder studies.

Table 22. Feasibility assessment

Assessment indicator	Feasibility assessment
Relevance	• The issue is directly related, directly relevant and important to the country. • Project stakeholders would benefit directly from the proposed scheme, but it excludes parameters that reflect responsibilities. Adaptable concepts are based on traditional fixed concepts.
Productivity	• As the expected level of the project's goals and objectives is uncertain, it is hard to determine whether the goal of the base study on plastic waste collection and transportation routes was achieved. • There is no doubt about the level and type of benefits that will be provided, but little is clear about the method by which these benefits will be achieved.
Implementation practice	• The project and its proposal are simple and clear.
Recognition by government agencies	• It is not one of the primary functions of the Ulaanbaatar municipal administration or the local aimag administrative institutions. • There is no need for major changes to existing rules and regulations, but collecting and transporting plastic waste rarely falls under the responsibilities of governments.

Recognition by key stakeholders	• No full identification has been made of the parties involved in the collection and transportation of plastic waste. • Collecting and transporting are not regulated or coordinated. • There is only an oral agreement or internal deal between the parties regarding transportation.
Efficiency	• The proposed scheme does not include an efficient and high-return economic component. • The system is not integrated. • There is no distinction between profit-making and non-profit activities. • Significant investments are required for the establishment of plastic waste collection points and sorting stations.
Sustainability	• There is no assurance that TUKs will be able to sustain themselves due to uncertainties regarding their funding and sources of revenue. • There is no evidence that AOAs will be able to sustain the collection of plastic in the future since it is voluntary and depends on individual decisions.
Environmental and health impacts	• Public awareness is growing of the need to determine the best route to collect plastic waste, and of its significant impact on the environment, society, and the health of the population.
Compliance with existing waste management regulations	• There is no long-term waste management program, so there is no conflict. • It is possible to carry out activities and to receive funding since the goal is compatible with the objectives of international projects.
Impacts	• It will strengthen the recycling industry in the long run. • Contribute to global warming prevention.

As a result, each of the above-mentioned criteria was evaluated the requirements at three levels: certain, under risk, and uncertain.

Table 23. Results of the feasibility assessment

		Certain	Under risk	Uncertain	Total
1	Dependency	+			
2	Productivity		+		
3	Implementation practice	+			
4	Recognition by government agencies			+	
5	Recognition by key stakeholders		+		
6	Efficiency			+	
7	Stability		+		
8	Productivity	+			

9	Compliant with current waste management regulations	+			
10	Effects	+			
	Total	**5**	**3**	**2**	**10**

8 CONCLUSIONS

Our objective was to assess the feasibility of a plastic waste collection scheme for Ulaanbaatar and Bulgan aimag, as developed in the baseline study. We assessed the methodology, information, software, and economic efficiency of the proposed plastic waste collection scheme, evaluated its feasibility, and provided recommendations and inclusions regarding ways to improve routes relating to the project objectives.

A total of eight districts are included in the study (BND, BGD, BZD, ND, SKHD, SBD, KHUD, and CHD) as well as Kishig-Undur and Bulgan soums of Bulgan aimag. We conducted a desk review of official reports and official statistics, observed 94 GCPs, conducted case studies, and interviewed stakeholders.

The summary and brief result shown in table 24.

Table 1. The summary of the expected results

Evaluation / step		Expected results	Conclusion
1	Scheme evaluation	1. Evaluation of the plastic waste collecting and transportation plan created at the level of Bulgan Province and Ulaanbaatar City, including transportation route mapping, simulation calculations, and evaluation results	The objective of the basic research is to take the shortest route, leaving out a set of economic criteria. The multi-objective appraoch is recommended by team maximising the share of transportation utilization, spreading workloads, and reducing expenses (see Section 5.2)
		2.Make a list of the additional facts and data required to enhance the plan and the simulation technique.	To do this, the research process might be expanded to take time, cost and risk limits into account. As a result, the optimization solution's values or variables must be modified to account for the outcomes as well as the upper and lower bounds (see Figure 22).
2	Implementation feasibility evaluation	3.Report on the effectiveness of economic calculations with conclusions on whether it can be applied at the level of other provinces and cities.	The baseline study estimate required 54 vehicles in eight districts and no further economic calculations were performed. Based on the current scenario, an abstract investment amount of MNT 21 billion and other expenditures will be needed to invest MNT 21.6 billion (see Table 17). This means that the number of cars is large compared to the amount of waste generated, and the cost is high. (See Table 18) Based on this, it is concluded that there is a need to finalize the form of missing information on the implementation unit, responsible organization, manpower and equipment base, supporting system. To achieve this goal, it is necessary to create general conditions for operational cost data and waste service fee and other expenditures (see Chapter 5.2, page 34).
		4.Evaluation of the possibility of implementing this scheme at the provincial and municipal levels, and recommendations for the implementation of the best alternative.	The report on the basic research carried out on the VRP method at the level of the Bulgarian province mentioned in chapter 2.3 of the basic research, Bulgan Province, does not explain why the VRP method is used in the Bulgan Province and the methods not yet used as well as a recommendation on whether it should be applied or not. In other provinces and cities, the conclusions are complicated. However, it is possible to take into account important variables such as waste generation points, population distribution and road network characteristics of the provinces to calculate whether the route scenario is feasible at the provincial city level. or not. (See chapter 7.2, page 48)

Recommendations to determine the optimal scheme for collecting and transporting plastic waste:

1. Identify the economic values and metrics that require a solution that will provide optimal effectiveness. The project becomes more feasible if lower costs and less investment are considered rather than only the short route. We suggest that the project implementation team modify its objectives and expected deliverables.
2. Stakeholder interviews and observational studies indicate that it is possible to incorporate additional variables such as travel times between POIs and waiting times at POIs, as well as develop a model with different variables for different districts depending on their characteristics.
3. By simplifying some indicators for optimal decision-making, viable options can be easily selected. It is important to consider the timetables for leaving and arriving at the depot separately when setting working time constraints; and the number of vehicles and their costs can be considered as optimization constraints, since the number of vehicles directly affects the amount of investment required. The vehicles drop off the collected waste at the CWDS before returning to the next location. Therefore, it is important to include the condition that the waste must be disposed of at the CWDS before the vehicle returns to the depot in the optimization model.
4. Since the data in Figure 22 are different for each district, it is necessary to clearly state which data need to be kept constant and which parameters need to be calculated as variables in the optimization calculation.
5. It can be concluded that by varying parameters such as the amount of waste generated, vehicle capacity and collection frequency, it is necessary to conduct sensitivity analysis and actual testing to partially validate the simulation results.

Figure 18 summarizes the analysis performed in the baseline study. The consulting team made a proposal to expand the optimization model in Figure 22 by combining evaluation results and conclusions. The diagram identifies 4 objective scenarios, 12 assumptions and 3 constraints that can be used for optimization. In addition, 13 possible suggestions for using the data are also provided. Depending on the purpose of the model, according to optimal calculations, 4 solutions need to be implemented: (i) Variable costs, (ii) number of frequencies, (iii) number of personnel and (iv) journey time.

Figure 22. Proposal to extend the optimization scheme

OBJECTIVE

Option 1: Minimize the number of vehicles in use
Option 2: Maximize the number of POI to be covered per route
Option 3: Minimize variable travel expenses
Option 4: Meet all three goals simultaneously

CONDITIONS / LIMITATIONS

Нөхцөл:

1. Use multiple vehicles
2. One car is allocated per route
3. The capacity of the vehicle is not exceeded
4. Vehicles belong to one depot
5. A vehicle starts and ends its route only at its own depot
6. Available vehicles will only go in the given zone / section
7. There are many collection points for waste
8. Service will be provided to customers within working hours
9. Service will be provided to all users within a certain period of time
10. The vehicle collects the last user's waste on the given route (given section) and drops all the garbage at the nearest central waste disposal sites .
11. After the garbage of the last route is unloaded at the combined dump, the vehicle goes to the bus depot
12. The final destination of the route should be close to the POD

Хязгаарлалт:

1. Work time limits should be determined by taking into consideration the starting and ending times of service, as well as the departure and arrival times at the depot separately;
2. Due to the fact that the number of vehicles directly affects the amount of investment required, the number of vehicles and their costs could serve as a constraint to optimization.
3. As observed, the vehicles collect the waste and drop it off at the centralized station before returning to the next point. As a result, it is necessary to incorporate a condition that requires the vehicles to dispose of waste at the CWDS before returning to the depot. Each route could include the nearest CWDS as a point of interest in the optimization calculation.

DATA

1. Population number
2. Number of khoroos
3. Quantity of waste – Demand
4. Waste collection frequency
5. Number of users – POI
6. Distance and travel time between destinations
7. Number of Central waste disposal sites – Number of recycling points
8. Travel distance from POI to Central waste disposal site
9. Number of vehicles
10. Type of vehicles
11. Vehicle capacity
12. Variable costs of waste collection (by type of vehicle)
13. Road conditions

PROGRAM:

Google Developer

RESULTS / SOLUTIONS :

- Variable travel expenses
- Number top routes
- Number of human resources
- The length of the routes

6. Population, number of khoroo, waste amount, frequency of waste collection, users - POI, distance between POI, travel times and distances between POI, number of CWDS, number of recycling points, distance and travel time between POI and CWDS, vehicle capacity, variable waste collection costs (dependent on vehicle type, road conditions, and so forth) are all different for each district and khoroo. Therefore, when developing an optimization model for collecting and transporting plastic waste, it is necessary to separate constant variables from variable variables.
7. It is concluded that it is necessary to conduct a sensitivity analysis by changing the input parameters such as the amount of waste, the capacity of the vehicle and the frequency of collection. Furthermore, it is important to conduct real experiments in order to confirm the simulation results.

Determine the feasibility of implementing an optimal scheme for collecting and transporting plastic waste:

For the implementation of a shortest route scheme for Ulaanbaatar city and the aimags, the following recommendations are made:

1. It may be possible to implement the scheme in Ulaanbaatar, if the constraints and variables are improved in accordance with the situational analysis, and the scheme is developed to achieve economic efficiency.
2. The development and testing of options based on parameters relevant to aimags, such as population numbers, GDP growth, plastic waste output, and remoteness, will increase the feasibility of their implementation.
3. We evaluated the implementation of the proposed scheme by ten criteria, which can be divided into three levels, based on the results of studies concerning the current state of plastic waste collection and transportation, interviews with relevant stakeholders, and observations of the reality of the implementation conditions.

   - **Certain:** There is a certainty regarding the implementation of the Five Criteria. It has been determined that the conditions for implementing the proposed model have been established, and the future focus should be on intensifying the activities. There are many advantages to the proposed model, such as its simplicity, importance to the country, and its positive impact on stakeholders. However, their responsibilities and roles are still unclear. As long as the optimal scheme for collecting plastic waste has a positive impact on the environment, society, and health, the public will be aware that it is beneficial.
   - **Under risk:** According to the evaluation, three of the ten criteria are under risk, and some positive signs have already been observed. In the future, there will need to be a significant improvement in management and organization, as well as an increase in funding. It is necessary to conduct an additional assessment of the overall risk. Efficiencies and recognition by key stakeholders, such as TUKs, AOAs, and entities, modeling the revenue sources and related costs, are critical to the sustainability of a project.

- **Uncertain:** There may be a failure to meet the identified objectives and goals of the project, and it is unclear what the next steps will be. There is some uncertainty regarding two of the ten criteria. Legislation and regulations are not being incorporated into the core functions of government institutions, and economic schemes are not being implemented in a cost-effective manner.

The establishment of collection, sorting, and disposal facilities for plastic waste (POIs):

In Ulaanbaatar, there is no re-sorting or transfer station for plastic waste, and all waste is disposed of in a combined landfill. For Ulaanbaatar city, the following decisions need to be made: the location of disposal, sorting, and transfer points, the estimated quantity of plastic waste to be collected, the establishment of POIs, and who will manage them.

1. According to an analysis of 94 locations in 6 districts of Ulaanbaatar city: apartment residential areas, ger residential areas, and remote ger residential areas, 70% lack separate, color-coded basic waste sorting bins and have unmarked waste bins. Furthermore, approximately 65% of the waste bins are arranged so that they cannot be collected and loaded by means of transportation technology. It is therefore necessary to carefully plan in detail how collection points will be established and how they will be implemented.
2. Based on interviews conducted with the TUKs of BGD, KHUD, SKHD, and ND of Ulaanbaatar city, the TUKs are limited in both human and technical resources in their implementation of the plastic waste collection and transportation system. Plastic waste collection is economically inefficient and incompatible with current regulations. Thus, special regulations must be developed.
3. During the course of a case study conducted on 35th and 36th Khilchin Streets, 22nd khoroo, SKHD, it was determined that door-to-door collection occurs more often in ger area than in apartment area. It is important to take into consideration the difference when identifying points of interest.
4. Based on the analyses of the "BGD Waste Report by khoroo, by round trip - Analysis" file produced by the TUK of Bayangol District of Ulaanbaatar city, it appears that the estimation of plastic waste by population does not reflect the actual situation. Typically, the amount of waste to be collected is not dependent on the number of round trips. A number of factors affect the amount of waste collected, including the type of TUK vehicle, human resources, traffic congestion, and other factors. Hence, the amount of plastic that should be collected at the point of interest should consider not only the size of the population, but also factors such as the density of the population in the area, the number and location of entities, and the size of the khoroo's territory.
5. Waste generated by Ulaanbaatar's city is disposed of at the CWDS. BGD and SKHD dispose of their waste at the Narang Enger CWDS, KHUD at the Moring Davaa CWDS, and ND at the Bayalag Khonkhor CWDS. Consequently, Ulaanbaatar's waste management system does not include steps for formally classifying waste generated

at the point of generation, reclassifying waste, or transferring waste. Plastic waste is collected by employees of TUK, by individuals, by AOAs, and by plastic waste collection organizations. The majority of plastic waste is collected by individuals and employees of TUK. The creation of a disposal, sorting, and transfer point based on this informal channel may be an option worth considering.