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# LOGISTICS PROCESSES OF DESTRUCTION WASTE

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**Abstract.** Ukraine currently has an imperfect system for the collection and transportation of municipal solid waste (MSW). This system needs to be improved and constantly adapted to the increasing volumes and types of household waste due to the growth of the urban population, improved welfare and changes in the residential, commercial and industrial sectors. The article identifies the peculiarities of Ukraine's environmental policy in the context of the European integration process. The main purpose of the article is to comprehensively cover the issues related to effective waste management, in particular, the logistical aspects of waste disposal, to develop a conceptual framework for the formation of a strategy for the implementation of environmental waste logistics in the context of sustainable and environmentally balanced development, and to determine the volume of accumulated waste. Practical experience of municipal solid waste management in Ukraine and developed countries are studied. The dependence of solid waste accumulation on the influence of key social, environmental and economic factors is identified, which makes it possible to predict its dynamics as a basis for making effective management decisions. The relevance of forming management decisions in the environmental logistics of solid waste to reduce the negative impact on the environment is demonstrated. The role of logistics in reducing waste and achieving economic, social and environmental goals is shown. The role of environmental information and environmental knowledge as a special resource in the innovation economy is highlighted.

**Keywords:** environment, ecological crisis, destruction waste, logistics, landfill, sustainable development.

## 1. Introduction

The adopted National Waste Management Strategy in Ukraine (Waste management, 2008) introduces a systematic approach to waste management at the state and regional levels and creates conditions for improving the living standards of the population by reducing waste generation and increasing the volume of its recycling and reuse. Local waste management plans have been developed accordingly. The implementation of the measures envisaged by these documents is carried out mainly at the local level by territorial communities (TCs) and at the municipal level by cities of regional or district significance. The market for waste management services is underdeveloped, and information on the potential for recycling solid waste (Kotsiuba et al., 2021) and construction waste is often scattered among different sources or is difficult to access. Waste sorting systems in amalgamated communities are underdeveloped due to insufficient demand for secondary resources and a lack of information on means and methods of waste disposal, especially military waste. The problem is that the amount of waste sorted by the population is small and of poor quality. The costs of collection and disposal are too high and do not bring the expected benefits to business.

A large proportion of resource-intensive components are often disposed of in landfills and dumps; recycling waste and construction waste and reusing them for commercial and industrial purposes will reduce the amount of waste in landfills. However, such measures require community involvement and support (Cosimato & Troisi, 2014), additional funding for waste management, especially for construction waste, and the introduction of systematic environmental education. An important element is the support of national and local authorities.

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Research issues in this area have always been of particular interest to S. Belyaeva, R. Berling, H. Vygovska, T. Halushkina, O. Hubanova, N. Zinovchuk, O. Kashenko, V. Kyslyy, L. Melnyk, O. Oksanych, Y. Stadnytskyi, Y. Stadnytskyi, S. Rybalka, V. Rudnytskyi, V. Rudnytskyi, and other domestic scholars. The works of Y. Stadnytskyi, S. Kharichkov and other national scholars have always been of particular interest. Issues related to the inclusion of environmental elements in logistics management systems were considered in the works of E. Krikavsky, N. Pakhomova, T. Skorobogatova, V. Meshalkin, and M. Nekrasova (Kotsiuba et al., 2018). However, the issues of improving waste management systems are mostly focused on one functional area of logistics, for example, resource conservation.

Waste management in communities is an important component of the economic system, but the current crisis in the provision of public services affects solid waste management (Kotsiuba et al., 2016). Waste management companies are unable to provide quality public services to residents of amalgamated communities. Their equipment is mostly outdated and worn out. Only a small proportion of household solid waste, construction waste, and waste from buildings destroyed as a result of military operations is collected separately and recycled. There are some successful enterprises in Ukraine, but their number is quite small.

Thus, the existing waste management system at the regional level does not ensure the economic and environmental security of the state. Solving this problem requires a new, modern approach to the formation of waste management systems at the community level.

## 2. Experimental part

An integral part of the logistics system for processing solid waste and construction waste is the process of sorting, processing or delivery to a storage facility, which ensures the organization of collection and transportation of solid waste and construction waste to a processing plant. Waste transportation is one of the most important factors that negatively affect the environment. Therefore, the choice of a business structure for the transportation of solid waste and construction waste is an important step in optimizing the logistics system of waste management.

Certain criteria should be used for a comprehensive assessment of the impact of the system of transportation, disposal and recycling of solid waste and demolition waste (Long et al., 2016). These criteria should include environmental impact criteria, cost-effectiveness criteria, and transportation and operational (logistical) criteria. There are several partial criteria for assessing the environmental and economic efficiency of transport and logistics systems as a component of the waste management system. The criteria of durability, availability of new equipment, service life of a new vehicle fleet or fleet of vehicles, and availability of own repair and treatment facilities are very important criteria for the normal functioning of the enterprise.

An important criterion for choosing a waste carrier is the availability of its own containers for separate collection (at least 30 % of the container fleet). Therefore, the number and availability of such containers is also considered an important indicator. The company's experience demonstrates its capacity and development prospects in this area. Obviously, the one that has been recognized in the market for many years and fully satisfies the users of its services will be chosen from the two companies. Therefore, it is advisable to choose practical experience as another criterion (Chun & Kim, 2012).

## 3. Results and Discussion

The concept of consumer waste is associated with the life cycle of products, which is a set of processes that are realized from the moment the needs in the product arise to the moment of their satisfaction and the disposal of the product as its consumer properties are exhausted. At the moment, the absolute majority of consumer waste is placed in landfills or incinerated. At the same time, it is known that consumer waste can be a valuable secondary material resource, which in the process of operation mainly do not change their original properties. Thus, recycling of consumer waste should have the character of targeted interaction aimed at solving both environmental and economic problems

In this study, it is advisable to use one that fully reflects the efficiency of the transportation process and its impact on the environment. When selecting criteria, attention should be paid to indicators that take into account the principles of sustainable development, consumption of natural resources (in the transport process, fuel is produced from oil, an exhaustible natural resource), the level of environmental impact of harmful components of exhaust gases emitted by vehicle engines, and minimization of environmental impact.

According to the $P_2M$ program management methodology (Khrutba et al., 2021), the most acceptable and effective way to form a system of program performance indicators is the 5 E's and 2 A's method The 5 E's and 2 A's method includes the following indicators: 5 E's – efficiency, effectiveness, earned value, ethics and environment ethics and environment, and two A's – accountability and acceptability.

Recycling logistics has borrowed many principles from the "traditional" areas of logistics and covers the planning, management, execution and control of all residual material flows as well as their associated information flows. Recycling logistics traces the entire path of waste movement from the place of generation to the place of disposal and recycling. Waste management is a typical example of solving a cross-sectoral system problem, where the following process steps should be developed in an integrated manner:

- forecasting the amount of waste generated;
- collection and accumulation of waste and its preliminary sorting;
- waste transportation;
- sorting of solid waste, sampling, baling and accumulation of waste types for sale and re-cycling;
- recycling of waste into secondary material re-sources;
- compacting and transporting "tailings" (residual solid waste after sorting) to a landfill.

This whole multi-stage system is constructed by calculating for each specific situation and each specific case. Predicting the amount of waste is the starting point for calculating the capacity of the entire recycling chain. An error in the prediction will lead to a geometric progression of errors in the calculation of the projected logistics chain, so a fairly wide range of complementary methods are used in predicting the amount of waste generated.

In the sphere of consumption finished products as a result of physical or moral wear and tear after some time become unusable, and due to the impact of physicochemical, mechanical and biological factors products can lose part of the original mass. Then the volume of consumption waste generation is determined by the following formula:

$$R^o=\sum_{i=1}^{n} V(t0-Ts)Ki(1-qi), \quad (1)$$

where $i$ is the type of consumed products (i=1, 2, 3, ..., n); (to is the year for which resources are calculated; $T_S$ is the service life of products; $V_i$ (to-$T_S$) is the volume of products distributed in the sphere of consumption, based on consumption in (to -TS )-th year; $K_i$ is the correction factor; $q_i$ is the coefficient characterizing mass losses of the i-th product during operation.

Due to the difficulties in obtaining reliable information on the volume of consumption by the population of the region of a particular type of product as a result of its migration from region to region, the volume of formation of the relevant types of waste can be determined by the formula:

$$R^o\sum_{i=1}^{n}\sum_{j=1}^{m} pHJ(1-qi), \quad (2)$$

where - average annual per capita consumption of products from the i-th type of raw materials; *Chj* is the population of the j-th region (j=1,2,3,...,m).

Due to the fact that of the total volume of consumption waste due to objective factors, some waste is currently unused, the volume of secondary material resources can be determined by the formula:

$$R^{B.c}=R^0(1\text{-}d), \quad (3)$$

where d is the coefficient that takes into account the volume of unused consumption waste.

In essence, secondary raw material resources calculated by this formula represent consumption waste to be collected for further utilization. In order to improve the accuracy of the forecast of generated consumption waste, it is advisable to apply regression analysis. Regression analysis is usually understood as a method of stochastic analysis of the dependence of a random variable $Y$ on variables ($j$ = 1, 2, ..., $k$), con-sidered as non-random variables, regardless of the true law of distribution. With the help of regression equation used for economic analysis, it is possible to measure the influence of individual factors on the dependent variable, which makes the analysis specific and significantly increases its cognitive value. This task is quite simply solved with the help of existing computer programs that analyze a variety of possible situations. A big problem in organizing a system for the disposal of consumer waste is the rational organization of its collection and delivery to the place of recycling. Therefore, the correct location of the recycling center is of utmost importance. When determining the capacity of the center, it is necessary to take into account the requirements for the conditions and terms of transportation, storage of materials, finished products, etc. When choosing the location of the waste recycling center from among the possible options, the optimal one is considered to be the one that provides a minimum of total costs for the construction and further operation of the center and transportation costs for delivery and dispatch of cargoes. Transportation costs include initial capital investments for the development of the transportation network (construction and reconstruction of access roads, purchase of rolling stock, construction of garages, repair facilities, etc.) and operational costs of cargo delivery and dispatch (costs associated with cargo transportation, maintenance and repair of vehicles, devices and facilities). Expenses for construction and operation of the center include, first of all, expenses for construction of the building (structure) and purchase of equipment, as well as expenses related to their further operation (maintenance and repair of the building and equipment, wages, electricity, etc.). When increasing the capacity and size of the center, specific capital costs per 1t of cargo turnover and storage reserves decrease, which speaks in favor of the construction of larger centers. However, on the other hand, this most often entails a reduction in the number of centers, and, consequently, an increase in transportation costs when delivering resources to the place of processing.

When using the principle of minimizing the cost of delivery of consumption waste, the approximate coordinates of the location of the center are calculated using the known coordinates of the places from where the deliveries will be made. Let (*xi; yi*) – coordinates of the places of "formation" of resources, *Гi* – capacities of the corresponding points (Fig. 1).

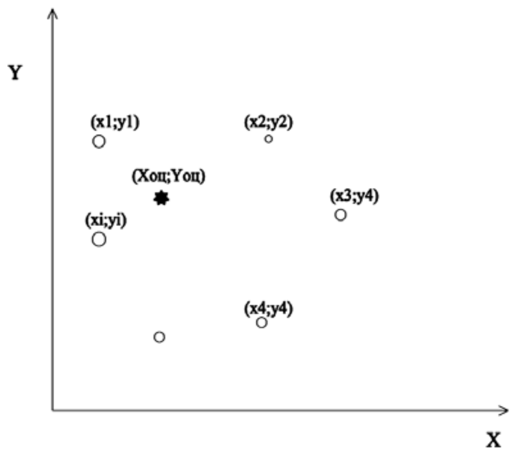


**Fig. 1.** Determination of the tentative location of the consumer waste recycling center

These coordinates are approximate, as they do not take into account the location of roads in the vicinity of the center. To determine the exact coordinates, the intersections of major roads (nodal points) in close proximity to the found indicative location should be considered (Fig. 2).

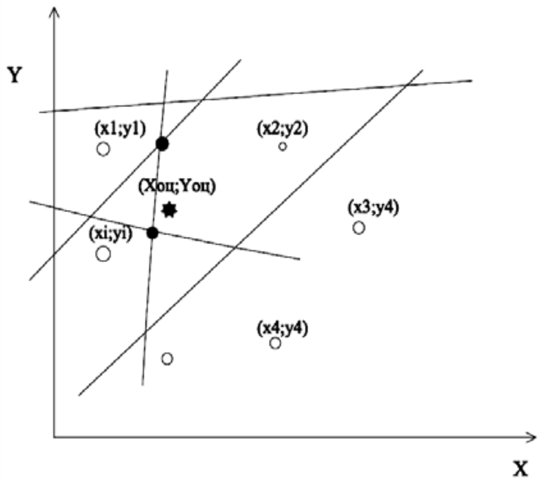


**Fig. 2.** Determination of the location of the consumer waste recycling center by the method of node point enumeration

The point, which corresponds to the minimum value of $K_j$, is the point of optimal location of the consumption waste center Difficulties in solving regional problems of consumption waste utilization are associated with both insufficient elaborations of the legislative base and territorial and economic peculiarities of the regions. In this regard, it is necessary to form a full-fledged regulatory system, a range of market and administrative tools that stimulate the collection and recycling of waste. This type of activity should be actively supported by the state and local authorities.

Thus, the solution to the problems of consumer waste utilization should represent a system of intersectoral interaction, starting from the stage of product design and ending with the stage of returning the recycled product to production. The participants of this system should be the state, local authorities, manufacturing companies, investors and ordinary citizens.

Whenever there is a disruption in the material flow, there is a high probability of financial losses. One of the main goals is to strive for a constant flow of materials, which ensures more reliable delivery and greater value for customers. That is why it is very important that internal logistics are clear and properly planned. The easiest way to eliminate supply shortages is to create a smooth flow of materials. Efforts are also made to reduce large production stocks and keep only the necessary amount of materials in stock. We can optimize all this thanks to the already existing systems. A method of managing the flow of materials and information to satisfy the customer by delivering the right product at the right time and in the required quality.

The cost minimization problem considers two variables: the shipment size and the reordering point (to reduce the amount of inventory costs), the ordering costs, and the storage costs. Transportation costs are assumed to be proportional to demand and therefore irrelevant to the problem as long as expected demand remains constant. However, a closer look at transportation costs reveals that not all of them are charged per unit. The picture is different for the stages at which shipment size can influence the choice of vehicle size (vehicle capacity), i. e., distribution and delivery. If there are upper and lower bounds on vehicle capacity, the cost of using the smallest available vehicle will be the cost per shipment or part of the order cost and is significant for the cost minimization problem. The cost of choosing a larger vehicle size will also be significant, implying that capacity should be included as a choice variable in the cost minimization problem.

Large-scale waste recycling is possible provided that the appropriate infrastructure is created, which includes a l ogistics scheme as a complete integrated economic system of collection, storage, sorting, certification and identification, sales, disposal and recycling with elements of the corresponding service: information, marketing, transport, comercial.

In accordance with the functional structure of waste logistics, the formation of a logistics scheme occurs in several stages.

The first stage – waste collection and storage – includes rationally built logistics chains of waste search (generation), transportation, collection and storage.

To ensure efficient operation at this stage, it is necessary to carry out procurement work, create specialized collection points, warehouses and a v ehicle fleet.

The creation of points for receiving waste from the population and organizations is complicated by the need to stimulate the waste sorting process. The solution to this problem can be the use of organizational, administrative and economic methods (fines for unsorted waste, partial compensation for waste removal fees when sorting it, organization of counter sales of high-demand goods in exchange for high-quality recyclable materials) with the active participation of city authorities, the media, and public organizations. The next stage is the stage of waste sorting, certification and identification. At this stage, the quantitative and qualitative composition of waste is determined, a database of existing waste is formed, and their ecological and economic assessment is carried out.

An integral part of the logistics system is distribution logistics, which is characterized by the features of warehouse management and inventory management. Evaluation of waste flows is important, the results of which are used to select transport, containers, as well as for the economic assessment of this resource. Economic assessment of waste involves determining the amount of costs for their storage and preparation for processing, assessing the economic result from their use in the production and business cycle, comparing the cost of placement and disposal of waste with the prices of the corresponding natural resources.

At the stage of promotion to the market and sale of secondary raw materials removed from household waste, it is necessary to form a specialized commercial intermediary network.

At the same time, the corresponding logistics functions are carried out: management of transport flows, flows of secondary raw materials, warehouse logistics operations in order to minimize costs. It should be noted that for the effective organization of the logistics scheme for the disposal of household waste, the management of the information flow, including data on the formation of waste, places of its accumulation, the need for certain types of secondary raw materials at enterprises, etc., is of particular importance.

When selecting the criteria, one should rely on the available quantitative and qualitative indicators of the enterprise's performance. The developed criteria make it possible to select enterprises that provide the relevant services. The set of local standards can be used by the enterprises themselves to implement specific measures.

Consider applying criteria to select more environmentally friendly vehicles for MSW and waste transportation.

From the proposed set of criteria, select the criteria that best characterize the environmental and economic efficiency of waste transportation.

Fuel costs affect the cost of waste transportation along with logistics costs, but this is an uncontrollable parameter, as fuel prices depend on the price of oil.

Environmental pollution and economic losses due to harmful pollutants emitted by internal combustion engines of vehicles mainly depend on the Euro class of the vehicle (Kotsiuba et al., 2023). In other words, the fewer pollutants an engine emits into the environment, the less environmental damage it causes, and, accordingly, the more environmentally friendly vehicles can be replaced, thereby minimizing the negative impact on the environment.

The environmental and economic damage cau-sed by environmental pollution by motor vehicles is calculated in accordance with the methodology for deter¬mining the level of environmental pollution by motor vehicles according to European standards set out in the guidelines “Assessment of Motor Vehicles as a Source of Hazardous Substances”.

Logistics costs for the transportation of solid waste and construction waste depend on the transport and operational characteristics of trucks. Fuel con¬sumption and emissions of harmful substances depend on the vehicle’s Euro class and, accordingly, determine the environmental and economic damage caused to the environment. An equally important criterion is the carrying capacity, which determines how many trips a vehicle must make to transport the required weight of cargo to a certain location (Demchuk & Nonik, 2024).

The environmental and economic efficiency of MSW and demolition waste management systems can be defined as the total environmental and economic damage caused to the environment; the less damage, the more efficient the waste management system (Co-simato, Troisi, 2014):

$$\sum EEZ \rightarrow min. \quad (4)$$

When determining the effectiveness of the C&D waste management system, the subsequent environ-mental damage (in the case of landfilling bottles) and the benefits derived from this activity should be taken into account.

## 4. Conclusions

As a result of the study, a conceptual model of an environmentally friendly innovative logistics syst¬em for community waste management has been for¬med. A schematic model of the logistics system of the regional waste management plan of the ATC is pro¬posed, which includes a waste management coor¬dinator who manages all logistics flows (monetary, material and information) of solid household and construction waste. A set of criteria is proposed for a comprehensive assessment of the impact of the system of transportation, utilization and recycling of solid waste, including material and technical criteria, criteria of professional requirements, financial and economic criteria, environmental criteria and social criteria. Each group of criteria is characterized by a set of local criteria that allow to choose the business structure of the carrier for the transportation of solid waste and demolition waste, while optimizing the logistics system of waste management.

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