



Enhancing Comprehensive Waste Management in Transition Economies Through Green Logistics: A Case Study of Bosnia and Herzegovina

Boris Novarlić^{1*}, Predrag Đurić²

¹ Waste Management Department, Communal Company Progres, 74000 Dobož, Bosnia and Herzegovina

² Military Academy Belgrade, 11042 Belgrade, Republic of Serbia

* Correspondence: Boris Novarlić (boris.novarlic11@gmail.com)

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Abstract: This study aims to elucidate the role of established public utility logistics in facilitating the integration of transition economies into the modern, developed world, with a particular focus on comprehensive waste management and the implementation of green logistics schemes. The research highlights the “green islands” waste collection system—networks of collection points that serve as separators for secondary raw materials from generated waste. It is demonstrated that such systems not only contribute to the optimization of public utility company costs and the selection of optimal transport routes but also play a crucial role in elevating public awareness regarding the importance of the 3R principle (Reduce, Reuse, Recycle). A significant contribution of this study lies in its demonstration of how academic knowledge can be transferred to the business sector through spin-offs, evidencing a theoretical model of green logistics schemes that can increase the total amount of secondary raw materials recovered from waste by 20% by 2030 in the City of Dobož. The research underscores the role of citizens, students, and businesses as primary waste producers in transition economies, emphasizing the effectiveness of a rewards system for conscientious waste selection at the source. Moreover, the establishment of an optimal transport route designed to support these green islands is shown to enhance the collection and recycling of valuable secondary raw materials, thereby preventing their disposal in landfills without value recovery. This innovative approach not only raises public awareness towards a more sustainable environment but also establishes a foundation for long-term environmental health. Through the lens of green logistics, this study presents a compelling model for comprehensive waste management in transition economies, advocating for practices that ensure the sustainable management of resources and contribute to environmental protection and public health.

Keywords: Waste collection systems; Green islands; Green logistics schemes; Optimization of transport routes; Comprehensive waste management; Transition economies; Raw materials produced from waste; 3R principle (Reduce, Reuse, Recycle)

1 Introduction

In a situation of comprehensive global changes, innovations, and improvements in innovation and communication, transition economies must use their superhuman potential to keep up with the rest of the modern and developed world [1]. To conclude, if transition economies do not follow scientific achievements and those of technology in all spheres of life, they would have a problem being competitive with developed countries in terms of the economy. Transfer of knowledge from university to real businesses by means of university spin-off contributes to improvement of business-to-business relations and enforcement of economic competitiveness [2]. It is exactly that scientific-business transfer that is the starting point of this introductory article, and considering the fact that the domain that this paper deals with is extremely extensive, we would use a funnel approach method to narrow it as well as the issue this paper deals with. So, our activities would be focused on the sustainability of the environment and people’s health through the optimization of the management of green logistic schemes and the system of comprehensive waste management in a way to establish a connection between useful theoretical knowledge and practice or reality. The topic that this paper talks about is very up-to-date and comprehensive and is an issue of everyday research, so we intend to present the most significant segment of it through the case study in Bosnia and Herzegovina.

Namely, the waste management issue in Bosnia and Herzegovina is a priority and is at the top of the needs list, which is developing day by day. Landfills are a burning issue in cities, as well as a lack of awareness among people that waste is a raw material that can be reused in a new cycle instead of being transported to a landfill. Consequently, particular secondary raw materials from waste (plastics and PET, foil above 50 microns, cardboard packaging, glass, etc.) have their own use value, which may be reused by means of recycling instead of being transported to a landfill, losing their use value [3, 4].

A characteristic feature of the system of comprehensive waste management in transition economies is a poor middle treatment (incinerators and reuse of raw materials and then waste recycling), a lack of modern waste collection vehicles of the latest generation, and the absence of systemic management of transport routes [5, 6]. Therefore, we would pay special attention in this paper to the optimization of waste management through the reduction of operational costs of the utility company as well as the proposal of a strategy for improving systematic waste collection in the City of Dobož (one of the 10 biggest cities in Bosnia and Herzegovina), which should be of general benefit for all other cities in Bosnia and Herzegovina as well as for the countries of our region, but especially for the citizens of the aforementioned cities and municipalities.

Structure of this paper comprises of literature review of relevant researches as well as of the representation of a practical solution which is widely accepted for a comprehensive waste management and these are green logistic schemes, as well as discussions, that is, comparison of our research results with other similar researches, through a scientific contribution of this paper to the academics as well as to a wider public, that is, to all target groups interested in the domain of a comprehensive waste management, based on a concept of an optimization of green logistic schemes and is a result of a theory model which would be of a general benefit for the following researches in this domain. Besides, we are going to present a theory model of the optimization of green logistics schemes, which would be a bond between academic work and reality, with the final goal of setting new grounds for successful practice in developed economies whose positive practices would be adopted in transition economies too, adequately adapted to them.

2 Literature Review

The European Union (EU) comprises 27 member states whose primary goal is the cohesion of a general social and economic operation as a whole, viewed from the angle of economic developments, demographics, and culture too, but with a special emphasis on the protection of the environment and health of its entire population. Circular economy, that is, 3R (reuse, reduce, and recycle), takes primary place in the EU [7]. In the long term, the EU intends to reduce mistakes that occurred years ago, such as insufficient care for secondary raw materials from waste and recycling policies, because of the lack of devotion to useful waste from total municipal waste, that is, waste that has a calorific value [8]. We are witnesses to the fact that in modern economies, due to a lack of adequate strategy in the domain of waste management, the same mistakes are repeated, namely that mixed municipal waste, to a large extent, ends up in public landfills, together with waste that has a calorific value. Therefore, it is necessary to put all material and non-material efforts into using all useful secondary raw materials from waste that would, in the next phase of the circular economy, be reused instead of ending up in public landfills or in incinerators with low calorific value. On the other hand, the primary EU goal is the adequate storage of useful secondary raw materials from waste, following the waste separation cycle at the place of its origin, collection, transport, and storage [9]. All previously defined have one of the most urgent tasks: the creation of optimal transport routes that would help to avoid waste of time at transport and collection of waste with adequate storage. So, waste management policy in the EU should serve as a standard for transition economies, such as Bosnia and Herzegovina, because it borders with an EU country and with its immediate surroundings, so the adoption of positive regulations in terms of protection of the environment in the EU is a primary goal of developing economies bordering with EU countries or economies.

Numerous authors have researched the role and significance of the circular economy in terms of waste management and the selection of optimal transport routes, with the selection of an adequate waste collection vehicle for the collection of useful secondary raw materials from waste that would be reused in the next reproduction cycle [10–12]. The leaders in comprehensive waste management and logistic management solutions for utility companies in Japan are the prefectures of Osaka and Tokyo, which have developed a special waste management model with significant success and whose idea is well used in the developed world and in developing countries alike [13]. By minimizing a useful waste at the place of its origin through a constant time interval of its collection and transport, with adequate medium treatment, they have reached the maximum success of a 3R strategy [14]. Selection of waste as per categories and place of its origin, selection of adequate waste disposal containers of a standard size, selection of adequate vehicles for their transport, and optimal transport routes are the success of the developed economies and the most developed economies of the world [15, 16]. Many case studies have been done on the topic of the selection of an optimal waste collection vehicle and a public utility route that minimizes the operational costs of the public utility company using a genetic algorithm that monitors and tracks down the route of the waste collection vehicle with a particular capacity for waste collection [17]. The growth of population in urban parts of the world brings an increase in all waste categories: mixed waste, secondary raw materials, and solid municipal waste, which causes potential problems in the selection

of an adequate method of its collection [18, 19]. It is known that low-income economies have bigger budgets for the service of waste collection and transport due to the absence of a clear written strategy for waste management, inadequate waste collection vehicles, and unstandardized waste disposal containers, the expenditure of which for this service is up to 45% of the total income [20].

There is no unique strategy of municipal waste management that can be applied as such in every city or municipality as well as in their local communities [21]. Analysis of the business environment and of a local community, people's habits, and their conduct affect the selection of an adequate strategy in relation to comprehensive waste management, projected to transition economies [22]. Research has demonstrated that unless there are no conditions for setting up a comprehensive system of waste management in the way that all waste is disposed of in containers without separation of useful from unuseful, the population of the observed area would not be interested and would not support it, even when a common and obligatory waste management system is established [23]. Many studies have demonstrated that organic waste should be composted, plastics and PET packaging should be used for recycling, and special attention should be paid to mixed municipal waste that would end up in an open landfill and not produce flammable methane due to landfill gases [24].

There are various mathematical models used for the calculation of the optimal time for the collection and transport of municipal waste, with a decrease in waste of time on the utility route, which are generally accepted in a developed world [25]. Undeveloped countries and developing countries have an issue with the willingness of their population to take part in a process of solid waste management and adequate separation of the same because they are not financially rewarded for their contribution to the environment as is the case in developed countries due to the absence of penalties for reckless citizens. Inadequate legal framework, negligence of citizens and their contribution to adequate waste treatment, lack of a rewarding system for the individuals obeying the rules, etc. are features of a solid waste management system in developing countries [26]. Developing countries need to move from a spot that they have stood on for years, which simply means putting waste disposal in a container, a method of its transport and disposal to the landfill, instead of advancing medium treatment and enhancing the 3R strategy [27]. Lack of legal framework and political will and failure to penalize all those committing an offense in terms of collection, separation, and recycling, that is, waste disposal, make undeveloped countries and transition economies more challenging for an additional study [28].

3 Green Logistics Schemes

Transition countries face a high level of flammable landfill gases, which are directly linked to negligent waste management and disposal and the absence of a conscious legal framework and its accompanying regulations. The biggest problem is a lack of citizens' education, especially those of the youngest age (pre-school institutions, primary and secondary education). Waste is a raw material that has its own value in the next reproduction phase and is not garbage. The essence of green logistics is the protection of the environment and a comprehensive benefit to the people living and working in it, as well as to the wildlife around it.

3.1 Awakening Consciousness of the Public

It was in the introductory part of this part where we reiterated that it is focused on a case study in the City of Doboj, which is one of the 10 biggest cities in Bosnia and Herzegovina, so the study results will be of general benefit to the whole country of Bosnia and Herzegovina, that is, to its near surroundings. So, the positive practice that the authors of this paper created, together with the representatives of a local utility company called "Progres" from the City of Doboj (Bosnia and Herzegovina), will create a generally accepted starting point for other local communities in BiH too when it comes to comprehensive waste management through the establishment of green logistic schemes. This paper represents an upgrade to the practice started in 2017 and contributes to the enhancement of the business community viewed from the angle of comprehensive waste management [29].

Establishment of a sustainable waste management system in Bosnia and Herzegovina and in other transition economies is not possible without an adequate attitude from the public and a high level of environmental awareness in society. Without accepting and understanding, taking interest, consciousness, and recognition of the benefits and responsibilities of various participants and the public in general, there is no possibility to implement a policy of adequate waste management nor a sustainable development of a waste management system. The efficiency of the implementation of the waste management plan and the sustainability of the results expected to be achieved by its implementation will, in the end, depend on the level of environmental awareness of the citizens. Without an upgrade in the level of environmental awareness of the citizens, it is believed that infrastructure, economics, and institutional aspects of the enhancement of a waste management system will not yield the expected results, especially when it comes to their long-term effects. Raising the consciousness of the public means adopting an adequate form of behavior on the level of an individual, which brings about a reduction in waste creation, stimulates a repeated use of waste, the purchase of products made of recycled materials, the separation of waste for recycling, and, at the bottom line, adequate and conscious waste disposal. Taking into consideration the great significance that a level of environmental

awareness of the citizens has for the efficient implementation and establishment of a sustainable waste management system, it is necessary to timely create development programs of public awareness and implement them continuously.

It is very important that citizens have verified, reliable, and timely information related to the status of a waste management system in the city or town they come from and to get it continuously by using various means and channels of communication, such as the preparation and printing of various informative leaflets that can be communicated to citizens with garbage collection bills, then printing informative posters, etc., but also the organization of informative gatherings aimed at continuous education of the population and others. On the other hand, an informative-educational campaign, beside the dispatch of information, has as its goal education of various target groups in the waste management chain. So, by sending information and messages, they educate citizens and the public generally, or members of specific target groups such as rural households and businessmen, but we reiterate, especially children and the youngest population, because they are a key bond between success and failure in the field of comprehensive waste management in the long term. Messages that are sent to citizens or individuals in this respect, at the bottom line, have as their goal the awakening of the consciousness of society and the change of existing behavioral rules. On the individual level, they may deal with waste management (collection, reuse, recycling in the end, etc.) or they may stimulate the regular management of various types of waste (recycled, hazardous waste, etc.).

A special place in the informative part should be given to waste prevention. Prevention represents the most important part of a waste management system, and it is necessary to take measures directed at a set of activities and processes during production itself, as well as places of waste origin in the cycle of use. Information sent to citizens should provide descriptions of measures for waste prevention from food (promotion of home composting, avoidance of the use of plastic bags, prevention of other special waste streams, etc.).

In order to have the education of citizens achieve a desired effect (adequate waste disposal at the place of its origin and its regular disposal in garbage containers), it is necessary to encompass all target groups and beside citizens (youngest population, pre-school and school age, and all others). These are representatives of the local community, the local economy, utility companies, the state, as well as all others that form this chain in waste management. Education must be continuous, at least aggressive, and with a strong note—a healthy living environment, a happy population, and a will for life. As a conclusion, the first and most important step in comprehensive waste management is the population and their willingness to obey rules and regulations.

3.1.1 Green islands and significance of waste sorting at the place of its origin

Accelerated globalization and growth of population in urban areas contributed to greater pollution of the environment and the citizens [30]. Waste is being dumped out of inertia, in garbage containers predicted for waste disposal and placed on public surfaces, and out of predicted locations for waste disposal too, creating landfills that jeopardize the health of the Bosnia and Herzegovina population as well as the whole environment. A bigger problem is created by the fact that, due to the insufficient education of the population, all waste is disposed of in the same container instead of those depending on the category they belong to (separately unusable, mixed waste from waste that has a useful calorific value, such as cardboard and paper, glass, plastics, etc.), and that way, all the aforementioned waste, unfortunately, ends up in a public landfill without medium treatment. Here we need to reiterate that Bosnia and Herzegovina, unfortunately, has no waste incinerator, the reason being a lack of finances and different legal regulations at the level of entities. Bosnia and Herzegovina consists of two entities, Republic Srpska and the Federation of Bosnia and Herzegovina, and three constitutive peoples, Serbs, Muslims, and Croats, which do not share common attitudes when it comes to comprehensive waste management. At the level of the whole BiH, they have various legal regulations, and the biggest issue is that because of that, they cannot apply for donor funds and grants for waste registration.

However, the City of Doboj has installed, in cooperation with the utility company and the academic community and with the advisory support of the author of this paper, 46 green islands in a narrow city center for the disposal of non-hazardous municipal waste, whereas until 2030, we designed a total of 100 green islands, which depends on the income of the utility company, which is a donor and implementer of the installation of green islands. The green island represents an enclosed space with a shed made of polycarbonate accommodating garbage containers of 1100 l volume for mixed waste and secondary raw materials (plastics, foil above 50 microns, cardboard, and paper), as well as a bin of 240 liters for PET bottles.

It may be seen in Figure 1 that, besides being esthetic, the green island has functional value as well. A shed made of polycarbonate that has a permanent guarantee, except for physical damage, is extremely useful during autumn and winter when waste is exposed to rain. That way, we keep the waste dry and save on disposal costs because we pay less for dry mixed municipal waste disposal than the one that is wet from rain and that gains weight. The black garbage container is for mixed municipal waste, that is, all that non-hazardous municipal waste that does not have use value, whereas in the green one, we dispose of plastic and nylon; in the yellow garbage container, we dispose of cardboard and paper; and the bin with a 240-liter volume serves only for PET bottle disposal. One may notice that garbage containers have no lids except the bin. The reason is an order issued by the authorized Department of Housing and Public Utilities of the City of Doboj so that the population has easier access to waste disposal, which in the long

term may be an extremely big issue (bad odor and potential viruses during hot summer days spreading around from garbage containers with open lids or covers, although regularly disinfected).

On the other hand, green islands are the second most important step or phase in waste sorting at the place of its origin and a key element in comprehensive waste management. The point is that the waste should be sorted at the door top adequately and disposed of after that into adequate waste disposal containers. This would make 50% of the success only for the utility company in charge of waste management, which would transport the sorted waste by an adequate waste collection vehicle to the sorting center and, with manual and automatic work, prepare the waste for recycling so to obtain a new use value at the end of the cycle.



Figure 1. Green island in a narrow city center of the City of Doboj

Note: Author's documentation

3.1.2 The issue of negligent waste disposal

It was in 2018 when we advised the management of the City of Doboj and that of the utility company that they should put maximum efforts into the education of the proposition, with a special accent on an electronic campaign intended for the younger population, who are key stakeholders in comprehensive waste management, in order to raise public awareness on the significance of waste management and its benefits to a higher level. However, still, we have not succeeded in raising public awareness about waste management through continuous education, and that is why we need to act progressively today. So, it has been 6 years since the red alarm was activated, indicating that we need to act urgently in order to prevent the continuation of negligent behavior by the population in terms of negligent or improper waste disposal. Figure 2 gives us the best example of negligent or improper waste disposal, especially solid and bulky waste, which is disposed of inadequately and represents a special waste category.



Figure 2. Improper disposal of bulky waste as well as hot smoldering waste

Note: Author's documentation

Legal regulations in Bosnia and Herzegovina, in both entities, clearly define that all waste categories, except a mixed one, which by its structure may fit in the mentioned container, must be disposed of separately to the landfill or incinerator with a fee, and that it is strictly forbidden to dispose of it in a garbage container or in any other way. However, negligent or improper conduct exercised by an individual continuously, by night most often, by transporting the aforementioned waste to the container and leaving it by it, as can be best seen in the figure illustrated above, is marked with a red color, and in that manner, they pollute the environment and people's health, especially for the reason that landfills are created that way, staying in locations that are not predicted for that, ruining the aesthetics and the beauty of cities and municipalities. It is also important to stress that during a study we conducted related to the City of Doboj and green islands in 2020, we suggested to a local utility company, whose co-author of this paper is a deputy general manager, that it was necessary to install metal garbage containers in green islands being built in the vicinity of households that do not have a central heating system installed exactly because of improper disposal of hot ash (formed during wood firing in stoves used for households' heating) into garbage containers, often causing fires, creating the biggest problem for waste collection vehicles during the collection and transport of waste from containers. To our delight, our suggestion has been accepted, and the tin roof has been replaced with one made of polycarbonate due to the defined reason. It is important to stress the positions of those green islands we named "black spots for collection of municipal waste" without containers for sorting secondary raw materials, for earlier depicted reasons.

3.2 Mapping of Transport Route on the Position of Green Islands

The authors of this paper have dedicated a special place to the local community of the City of Doboj and to this region too, which may be replicated as a useful practice throughout the whole of Bosnia and Herzegovina in the draft of an optimal transport route for the collection and transport of waste as per categories in the City of Doboj. The scientific contribution in this paper is reflected in the selection of a transport route as a basis for waste management in the City of Doboj and in a suggestion for the installation of green islands in the narrow city center (46 green islands have been installed from 2018-2024, and the plan is 100 until 2030).

As a conclusion, the utility company of the City of Doboj had a huge problem in selecting the optimal method of collection and transport of waste due to unstandardized waste disposal containers and a lack of a written strategy that would cover standardized transport and disposal.

Our proposal was that green islands should be installed in a narrow city center in the manner depicted in Figure 1, starting from the nearest starting point from a garage that the waste collection vehicles start from and that would be concentrated close to one another, and they would serve as a pilot project for a successful system of comprehensive waste management in this local community. The essence of this strategy is to avoid waste of time and to ensure that all waste (secondary raw materials and mixed ones) is collected with minimum fuel costs and with optimal transport and collection times. It is important to mention that useful secondary raw materials from waste are collected three times a week and mixed waste every day, continuously. However, we suggested that a special vehicle should be provided for the collection of secondary raw materials from green islands, of a smaller dimension that would easily access each green island, and with a reduction in fuel costs, so that secondary raw materials can be collected continuously in order to prevent illegal collectors from stealing them.

From Figure 3, we see that the first green island has been built in the vicinity of a garage, from which waste collection vehicles start when collecting waste on a transport route (the yellow arrow leads from a garage to the first green island). The vehicle is specially designed for the collection of only secondary raw materials, as per the categories illustrated in Figure 1.

From Figure 4, we see that waste is collected from green islands in an order, as per the drawn green islands on a map, going from one to the next closest spot. If a truck fills a sufficient amount of secondary raw materials, for example, on the 9. green island, it stops there and returns to a start point (a garbage place where the trucks are parked and a Waste Sorting Center with a capacity of 5 t/h) where collected raw materials are disposed of, and they are further processed manually and automatically. After their finalization, they are sent to recycling centers for processing, and only that waste that does not have a use value is collected with another waste collection vehicle with the assistance of a human factor and additional machinery and is transported further to the landfill. The truck that served the green islands on a transport route continues to collect secondary raw materials from the islands all the way to the last one on a transport route.

We created a successful strategy of utilization of useful secondary raw materials from waste, depicted above, that we are going to deliver to recycling centers with a charge that we shall use for the reconstruction of public utility infrastructure in the City of Doboj (purchase of waste collection bins and containers and other necessary equipment).

According to the research conducted by this group of authors in the period from 2018 to 2022, a key issue in solving problems in the domain of comprehensive waste management lies in insufficient education of the population as well as insufficient incentives (there is no defined compensation for the sorting of useful raw materials from waste, for example, paper and cardboard, PET bottles, and others, which citizens would collect and dispose of two green islands or in any other way). The aim of the circular economy is that all stakeholders are included in the process of

waste management and that they are compensated or rewarded for their work (population for proper waste disposal as per categories, utility companies for proper collection, transport, and sorting of the waste as per categories, and recycling centers for their contribution to the creation of new value from waste). The conclusion of the previous analysis is in shortened form; look at Figure 5.

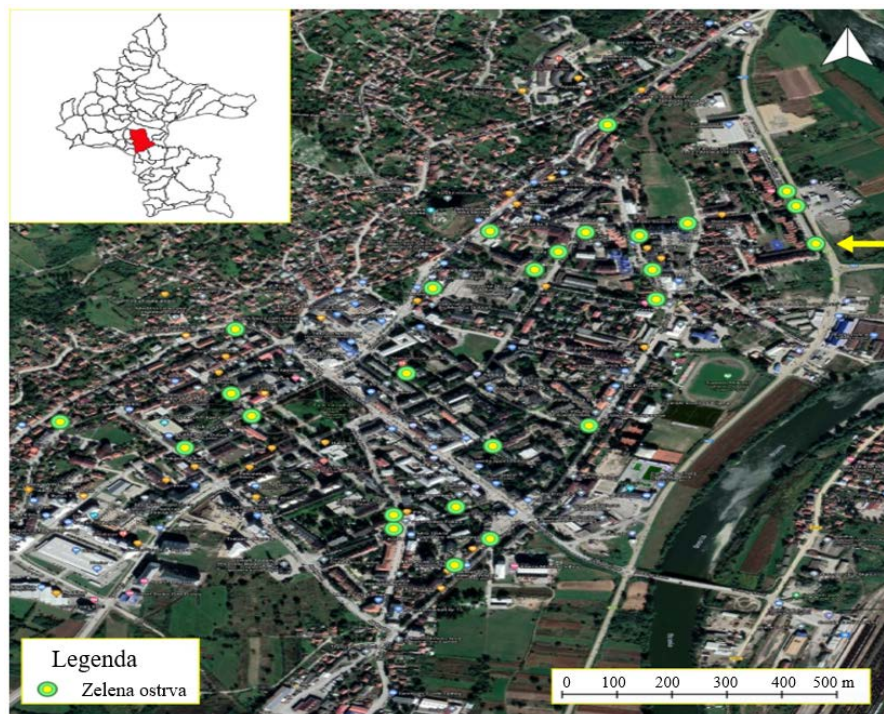


Figure 3. Green islands in the City of Doboj - initial phase
Note: Author's documentation

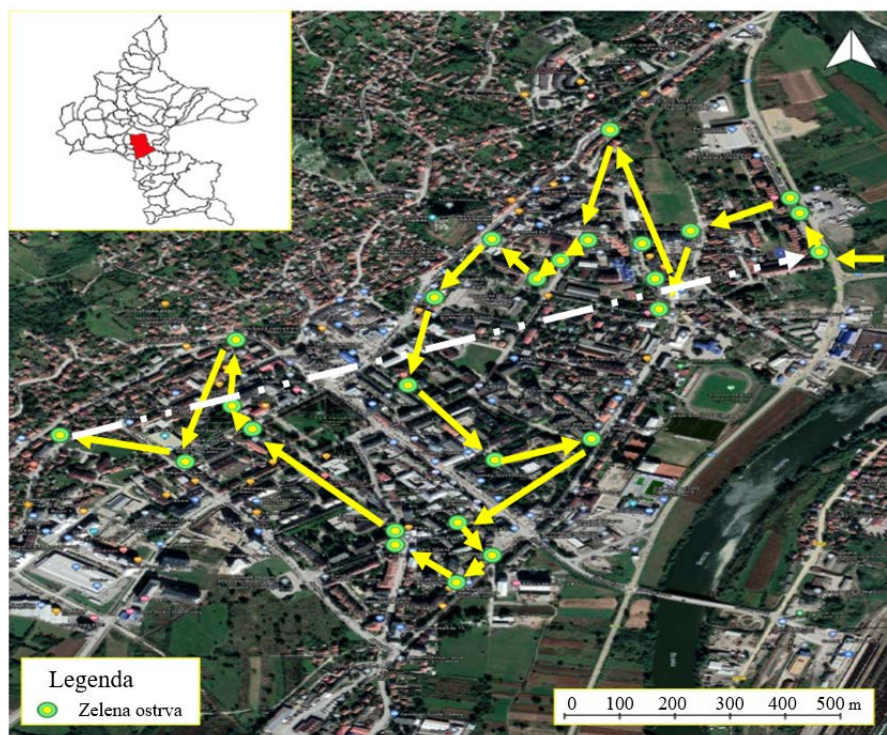


Figure 4. Optimization of a proces of management of useful secondary raw materials from waste
Note: Author's documentation



Figure 5. Shortened illustration of resolution of main problem

Note: This figure was prepared by the authors

According to Figure 3, a red alarm has been activated ever since 2018, and still, we see no move forward in terms of waste sorting at the doorstep. It is only when that practice is in place and when all stakeholders stick to this rule that we will move forward and resolve the issue of comprehensive waste management in the City of Dobož, Bosnia and Herzegovina, as well as in the rest of the developing countries in our close vicinity. As it is seen in the same figure, a circular approach to waste management means that after its collection, it is transported to a sorting center, where it is manually and automatically sorted, and after that, it is sent to recycling by a special vehicle. All waste that does not have a use value is transported by another vehicle to the landfill and disposed of there instead of ending up in an illegal landfill. It is only in this way that we maintain a healthy living environment.

4 Theory Model of Management of Green Logistic Schemes

The contribution of this paper is reflected in a theory model of green logistic schemes, applied to the City of Dobož, Bosnia and Herzegovina, and is a combination of academic and technical knowledge that we pass on to a business sector through spin-off.

Bad practices that we have had so far in terms of waste management should, with the method of an inverted funnel, filter all current and potential problems in such a way that all threats and opportunities are used as a chance and to use a 3R strategy to the maximum as its own successful strategy. On Figure 6, we present our proposal for improving the waste management system in transition economies, with a special focus on Bosnia and Herzegovina.

According to the results of the research conducted in 2022 by a group of authors, a red alarm is activated (subgraph (a) of Figure 6) in terms of the amount of disposed waste in Bosnia and Herzegovina, where around 90% is disposed to landfills in comparison to the poor medium treatment in the form of reuse and recycling (10%). The desired vision of the author of this paper (subgraph (b) of Figure 6) is to achieve a maximization of waste disposal in the next 20 years, where the primary task for local communities should be prevention (education of the youngest population of primary and secondary schools), which is narrowing with the method of an inverted funnel. The next important step is the utilization of existing usable raw materials from the waste and their exploitation instead of being directly dumped in landfills. The last step should be the recycling of raw materials and the disposal of unusable substances after their

recycling to the landfill, which is inversely proportional to disposal to the landfill compared to the left triangle.

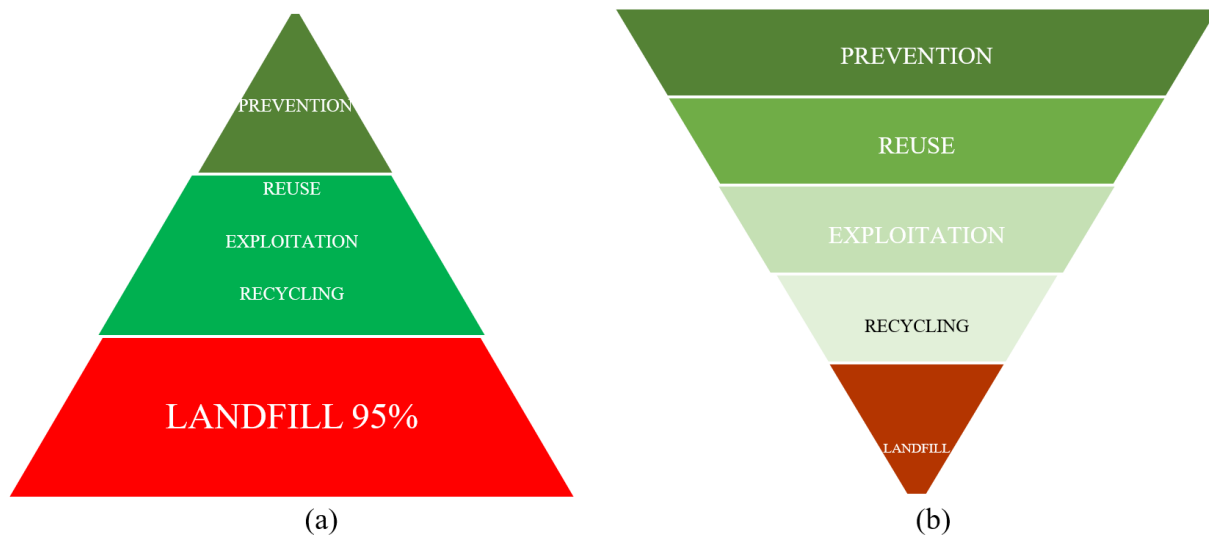


Figure 6. (a) Hierarchy of waste management - current situation; (b) Vision of waste management (until 2030)

Note: This figure was prepared by the authors

As per research conducted in Croatia in 2022, countries in southwestern Europe dispose of negligibly small amounts of waste in landfills due to an organized system of waste management and the existence of waste incinerators, whereas countries surrounding Croatia are in a somewhat better position than developing countries but insufficiently compared to the average of the EU [31]. For a better understanding of a previous quotation, refer to Table 1.

Table 1. Deposited waste in B&H in relation to the closer environment of EU countries

	Bosnia and Herzegovina	Romania	Bulgaria	Croatia
Deposited waste at a registered landfill (2022)	90%	76%	61%	59%

Bosnia and Herzegovina falls into a group of developing countries on the European continent, with a low level of accumulation of funds intended for protection of the environment and citizens' health. There are small investments in the installation of capacities and the creation of preconditions for comprehensive waste management following the model of the developed countries of the EU. Due to the aforementioned reasons, BiH lags behind not only Europe but also the poorest EU member states, being still far away from the aforementioned.

In order to be able to understand problems that are burning in terms of waste management, look below at a proposal of a theory model for comprehensive waste management, with a special emphasis on green logistics schemes.

With two-headed green arrows on Figure 7, we reiterated the importance of key stakeholders in the procedure of comprehensive waste management, projected for the City of Dobož as well as for developing economies. Key stakeholders in the creation of a positive environment in the domain of waste management are households, the economy, and schools, as the biggest generators of waste production on a daily basis. Since 2018 up to now, the aforementioned key stakeholders have not been involved enough in the process of comprehensive waste management. The red alarm is on, and if the situation remains the same, there will be a total collapse of the system as well as a situation in which we would not be able to join the EU and the rest of the developed world in the domain of comprehensive waste management.

The lack of public consciousness, standardized waste bins and containers for waste disposal, and inadequate public utility infrastructure are the main problems of systematic waste management in developing countries, such as BiH. The biggest issue is poor medium treatment, which means there is no waste incinerator and the waste is collected with a simple method, then symbolically sorted and, at the end, deposited in landfills. Unfortunately, although there is a center for manual and automatic waste sorting with a capacity of 5 t/h in the City of Dobož, it is not adequately affirmed due to the lack of raw materials (paper and cardboard, plastics, PET bottles, and others), which is the result of a lack of public consciousness for the population to dispose of all waste together in the same container; they do not sort it at their doorstep, and that is why we have the aforementioned problem: more than 90% of waste ends up at the landfill instead of sorting all useful waste from the mixed one and forwarding it to further processing and recycling.

Comprehensive waste management in the city of Dobož with emphasis on green logistics schemes

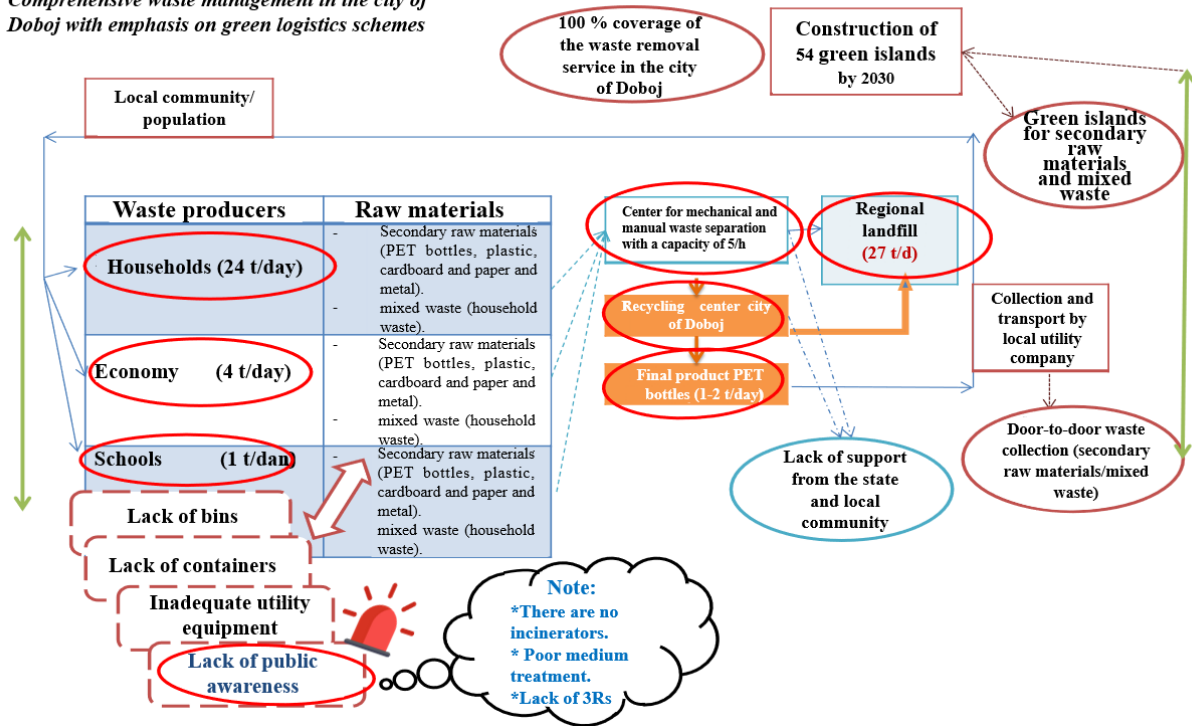


Figure 7. Proposal for comprehensive waste management in the City of Dobož with special emphasis on green logistics schemes

Note: This figure was prepared by the authors

As a conclusion, affirmation, and involvement of all stakeholders in the process of comprehensive waste management would contribute to a positive environment and the provision of 100% of the service of transport and sorting of waste in BiH until 2030, with an installed network of green islands, which is a constituent part of green logistics schemes.

5 Discussion

The aim of the EU is to recycle at least 55% of municipal waste until 2025, which includes an increase to 60% until 2030 and to 65% until 2035, with the especially important and most desirable option being raising public awareness, that is, prevention, followed by reuse and recycling, whereas waste disposal to landfills represents the least desirable option [32]. Bosnia and Herzegovina follows the legal regulations of the EU in terms of the collection, transport, and processing of waste, with its disposal and disposition, and although it has no legal obligation to follow the rules on comprehensive waste management in the EU, it must adopt its own courses of action as a consequence of the aforementioned if BiH wants to acquire the status of candidate in the EU and join the modern world, and protection of the environment is priority 1 [33]. There is no medium treatment for waste management in the Republic of Srpska (one of the two entities that form Bosnia and Herzegovina) or in the neighboring Republic of Serbia. They have poor existing public utility logistics and infrastructure for waste management; there is no penalty system for disobeying citizens; and there is an extremely high number of landfills, as well as a lack of arranged space for waste sorting—green islands [34].

In Macedonia, there is a need to install public utility infrastructure, with a special emphasis on collection points for secondary raw materials, for which numerous authors say to make a group of collection points for disposed waste, which is green logistics [35]. Often mistakes in developing countries are due to a lack of knowledge of legal regulations and minimizing the useful amount of waste from a total amount. However, the solution is in regulated logistics schemes, that is, proposals for the utilization of useful secondary raw materials from total mixed waste [36]. The creation of an optimal transport network, that is, a mapped route on which waste disposal containers are placed, would contribute to a greater utilization of secondary raw materials from total waste that is intended for recycling instead of simple disposal to landfills [37].

Reverse logistics and a model of transport routes based on genetic algorithms contribute to the improvement of the total performance of a waste collection vehicle (which reduces waste of time on a transport route with clearly

positioned waste disposal bins and containers for solid and other waste categories) as well as that of companies, resulting in a reduction of operational costs. The collection of the aforementioned waste in concentrated green spots contributes to CO₂ reduction and raises public awareness about the usefulness of waste and its general significance for a local community [38].

Undeveloped countries, as well as developing ones, lag extremely behind developed countries in terms of waste management and green logistics, but they are willing to adopt the model from developed countries and use it adequately in their countries. Classical waste disposal to temporary landfills, transshipment by special trucks, tipper trucks, and garbage/dump trucks to the final waste dumps won't adequately manage the waste with efficient medium treatment, which refers to secondary raw materials [39].

Dry dump, that is, waste that may be recycled, should be collected twice a week with exactly defined conditions, that is, locations that the special category waste collection bins are placed on, that is, secondary raw materials. It is essential that one vehicle serve or travel a complete route, from a starting point to a final point, where the bins for the aforementioned waste are placed, by which they would maximize total operational costs of fuel when it comes to a waste collection vehicle, which directly affects utility company business too [40].

Numerous models of municipal and solid waste management have been tested, but a common conclusion is that there should be the involvement of all stakeholders at the state level, from individuals to authorities, and that without them, there is neither progress nor prosperity in waste management nor in the utilization of useful secondary raw materials from waste [41].

Developing countries must adopt a solid waste management policy, which refers to waste sorting at the doorstep and the installation of green logistics spots for waste disposal with a higher fee from households and businesses, with special bins for the collection of this type of waste provided to them. They should also follow national regulations and international directives for comprehensive waste management [36, 42–45].

6 Conclusions

The introduction of new information-communication technologies and monitoring of new trends in terms of comprehensive waste management not only improve the organization of business operations of the utility company but also reduce their operational costs, which are reflected in savings in fuel and lubricants.

Developed countries of the world, with a focus on the EU, are incomparably more advanced in systemic protection of the environment and people's health than countries in transition, through their clear legal regulations and directives that need to be strictly obeyed, whereas transition countries lack legal regulations and enforcement of penalties, especially strict ones for all citizens not obeying clear rules nor contributing to the protection of the green economy. Bosnia and Herzegovina dumps 90% of its waste directly to landfills, with a poor or absence of medium treatment, whereas our neighbor, Croatia, an EU member state, dumps 59% of the aforementioned waste to landfills, with a further decrease tendency, thanks to the introduction of modern technologies, grants, and EU financial support.

The first conclusion of the author of this paper is related to an urgent amendment of the legal regulation in waste management (a common law in both BiH entities) referring to raising public awareness in terms of waste sorting at the doorstep and regular waste disposal into waste collection bins, with strict penalties for those not obeying the instructions of the local community and authorized utility companies, but with previously ensured conditions for the implementation of the aforementioned measures.

High involvement of all stakeholders in a waste management chain, with clear individual assignments clearly defining the role and significance of every individual stakeholder in relation to local community representatives and the state.

Significant funds invested in the renewal of utility equipment and the supply of new waste collection vehicles (hybrid or electric) for the installation of green islands used for mixed waste disposal and secondary raw materials would contribute to the decrease in the total amount of waste disposed of at landfills, with the sorting, utilization, and recycling of secondary raw materials and the creation of new value. The state, that is, a local community, must provide funds, or co-funding, to a maximum of 70% of its finances in order to supply the aforementioned equipment and mechanization, which would adequately manage the waste in every local community in Bosnia and Herzegovina.

Further, it is necessary to motivate the biggest waste producers, which are primary and secondary schools, local businesses, and the local population, who will be provided with the needed utility equipment for waste disposal, but the reward will also be for properly collected and disposed waste. Every local community in BiH should do this and would design its own reward system for the proper utilization of a utility service and penalties for those not obeying the law and who will be publicly promoted as an example of a bad practice. This would be good marketing for all other citizens to awaken and give their contribution to the protection of the environment and the area they live in.

With the installation of utility infrastructure in the City of Doboj that covers rural areas that are currently not covered with a service of waste collection and which should be 100% by 2030, there will be preconditions created for a systematic collection of waste in this local community, with a special emphasis on sorting of secondary raw materials and reduction of total amount of deposited dump for an additional 20%. Income generated from the sale of

secondary raw materials will be directed toward the renewal of utility bins and the need for mechanization for the operation of the utility company.

Limiting factors in Bosnia and Herzegovina in the field of comprehensive waste management are unclear legal regulations and guidelines on waste management because every BiH entity has its own policy in this domain, so it is urgent to have a dialogue and adopt a common law for both entities and for all target groups in that country.

Green logistics schemes represent the perfect tool for the collection of useful secondary raw materials from waste, which is primarily seen in the awakening of the public consciousness that waste is a raw material and not a dump. On the other hand, the pressure on the public landfill is getting smaller because these raw materials are being reused in the form of cardboard packaging, PET bottles, etc. The installation of green islands in the City of Doboj helps positively in the adoption of world directives in the field of comprehensive waste management, 3R (reuse, reduce, and recycle), and primarily in public awakening, which has implacably slept ever since 2018. The red alarm was activated a long time ago, and if we do not react promptly, it is already tomorrow, which may be late.

Will Bosnia and Herzegovina be successful in the implementation of a common strategy in the protection of the environment? Will it meet conditions set in the field of green economy, which are directly linked to the accession to the EU? Do green logistics schemes in theory represent a positive practice in the management of all categories of raw materials from waste, and what will be a realistic and final deadline to raise public awareness on this issue to a higher level?

Data Availability

The data used to support the research findings are available from the corresponding author upon.

Conflicts of Interest

The authors declare no conflict of interest.

References

- [1] G. Mićunović, N. Novaković, and G. Stefanović, "Globalizacija i njen negativni uticaj na zemlje u razvoju," in *Synthesis 2015 - International Scientific Conference of IT and Business-Related Research*, Singidunum University, Serbia, 2015, pp. 345–348. <https://doi.org/10.15308/Synthesis-2015-345-348>
- [2] S. Petković and B. Novarić, "Conditions and limitations on investments of small and medium enterprises in intangible assets as a response to the crises of the real sector," *Acta Econ.*, vol. 10, no. 17, pp. 53–82, 2012. <https://doi.org/10.7251/ACE1217053P>
- [3] P. Hill, "Waste," in *Environmental Protection*. Oxford University Press, 2017. <https://doi.org/10.1093/wentk/9780190223069.003.0009>
- [4] A. Morrissey and J. Browne, "Waste management models and their application to sustainable waste management," *Waste Manag.*, vol. 24, no. 3, pp. 297–308, 2004. <https://doi.org/10.1016/j.wasman.2003.09.005>
- [5] S. Das and B. K. Bhattacharyya, "Optimization of municipal solid waste collection and transportation routes," *Waste Manag.*, vol. 43, pp. 9–18, 2015. <https://doi.org/10.1016/j.wasman.2015.06.033>
- [6] A. Mihajlov, A. Mladenovic, and F. Jovanovic, "Country in transition (Serbia) case: Circular economy starts from waste management," *Environ. Res. Technol.*, vol. 4, no. 1, pp. 83–88, 2021. <https://doi.org/10.35208/ert.853792>
- [7] M. Agovino and G. Musella, "The integrated waste cycle in Italy and EU countries," in *EU Waste Regulation in a Linear-Circular Economy Transition*. Springer, Cham, 2023, pp. 63–70. https://doi.org/10.1007/978-3-031-28103-7_4
- [8] M. Saita and M. V. Franceschelli, "The role of waste management in the green economy: An empirical analysis of economic data of the business," in *Sustainable Entrepreneurship and Investments in the Green Economy*. IGI Global, 2017, pp. 169–199. <https://doi.org/10.4018/978-1-5225-2075-7.ch006>
- [9] A. M. Troschinetz and J. R. Mihelcic, "Sustainable recycling of municipal solid waste in developing countries," *Waste Manag.*, vol. 29, no. 2, pp. 915–923, 2009. <https://doi.org/10.1016/j.wasman.2008.04.016>
- [10] J. T. Powell, T. G. Townsend, and J. B. Zimmerman, "Estimates of solid waste disposal rates and reduction targets for landfill gas emissions," *Nat. Clim. Chang.*, vol. 6, no. 2, pp. 162–165, 2015. <https://doi.org/10.1038/nclimate2804>
- [11] M. S. Andersen, "An introductory note on the environmental economics of the circular economy," *Sustain. Sci.*, vol. 2, no. 1, pp. 133–140, 2006. <https://doi.org/10.1007/s11625-006-0013-6>
- [12] P. Morsetto, "Environmental principles for modern sustainable economic frameworks including the circular economy," *Sustain. Sci.*, vol. 17, no. 5, pp. 2165–2171, 2022. <https://doi.org/10.1007/s11625-022-01208-w>
- [13] S. Sakai, "Municipal solid waste management in Japan," *Waste Manag.*, vol. 16, no. 5-6, pp. 395–405, 1996. [https://doi.org/10.1016/s0956-053x\(96\)00107-9](https://doi.org/10.1016/s0956-053x(96)00107-9)

- [14] Y. Nabeshima, "Summary of research on waste minimization studies by Japan waste research foundation (JWRF)," *Waste Manag.*, vol. 16, no. 5-6, pp. 407–415, 1996. [https://doi.org/10.1016/s0956-053x\(96\)00086-4](https://doi.org/10.1016/s0956-053x(96)00086-4)
- [15] H. Yuda, "Regarding the establishment of the containers and packaging recycling law," *Jpn. Soc. Waste Manag. J.*, vol. 6, no. 6, pp. 417–421, 1995. <https://doi.org/10.3985/wmr.6.417>
- [16] Y. Ishimura, "The effects of the containers and packaging recycling law on the domestic recycling of plastic waste: Evidence from Japan," *Ecol. Econ.*, vol. 201, p. 107535, 2022. <https://doi.org/10.1016/j.ecolecon.2022.107535>
- [17] M. Misic, A. Dordevic, and A. K. Arsic, "The optimization of vehicle routing of communal waste in an urban environment using a nearest neighbors' algorithm and genetic algorithm: Communal waste vehicle routing optimization in urban areas," in *Ninth International Conference on Advanced Computational Intelligence (ICACI)*, Doha, Qatar, 2017. <https://doi.org/10.1109/icaci.2017.7974519>
- [18] B. I. Kim, S. Kim, and S. Sahoo, "Waste collection vehicle routing problem with time windows," *Comput. Oper. Res.*, vol. 33, no. 12, pp. 3624–3642, 2006. <https://doi.org/10.1016/j.cor.2005.02.045>
- [19] N. Labadi, C. Prins, and M. Reghioui, "A memetic algorithm for the vehicle routing problem with time windows," *RAIRO Oper. Res.*, vol. 42, no. 3, pp. 415–431, 2008. <https://doi.org/10.1051/ro:2008021>
- [20] E. C. Rada, M. Ragazzi, and P. Fedrizzi, "Web-GIS oriented systems viability for municipal solid waste selective collection optimization in developed and transient economies," *Waste Manag.*, vol. 33, no. 4, pp. 785–792, 2013. <https://doi.org/10.1016/j.wasman.2013.01.002>
- [21] X. Zhang, C. Liu, Y. Chen, G. Zheng, and Y. Chen, "Source separation, transportation, pretreatment, and valorization of municipal solid waste: A critical review," *Environ. Dev. Sustain.*, vol. 24, no. 10, pp. 11 471–11 513, 2021. <https://doi.org/10.1007/s10668-021-01932-w>
- [22] G. Tavares, Z. Zsigraiova, V. Semiao, and M. D. G. Carvalho, "A case study of fuel savings through optimisation of MSW transportation routes," *Manag. Environ. Qual.*, vol. 19, no. 4, pp. 444–454, 2008. <https://doi.org/10.1108/14777830810878632>
- [23] J. Hu, K. Tang, X. Qian, F. Sun, and W. Zhou, "Behavioral change in waste separation at source in an international community: An application of the theory of planned behavior," *Waste Manag.*, vol. 135, pp. 397–408, 2021. <https://doi.org/10.1016/j.wasman.2021.09.028>
- [24] L. De Medina-Salas, E. Castillo-González, M. Giraldi-Díaz, and V. Guzmán-González, "Analysis of economical and environmental costs for the selection of municipal solid waste treatment and disposal scenarios through multicriteria analysis (ELECTRE method)," *Sustainability*, vol. 9, no. 11, p. 1758, 2017. <https://doi.org/10.3390/su9111758>
- [25] A. Singh, "Solid waste management through the applications of mathematical models," *Resour. Conserv. Recycl.*, vol. 151, p. 104503, 2019. <https://doi.org/10.1016/j.resconrec.2019.104503>
- [26] I. Onungwe, D. V. L. Hunt, and I. Jefferson, "Transition and implementation of circular economy in municipal solid waste management system in Nigeria: A systematic review of the literature," *Sustainability*, vol. 15, no. 16, p. 12602, 2023. <https://doi.org/10.3390/su151612602>
- [27] A. Batlles-de-la Fuente, L. J. Belmonte-Ureña, J. A. Plaza-Úbeda, and E. Abad-Segura, "Research trends of the management of solid waste in the context of circular economy," in *Handbook of Solid Waste Management*. Springer, Singapore, 2021. https://doi.org/10.1007/978-981-15-7525-9_2-1
- [28] D. M. Simatele, S. Dlamini, and N. S. Kubanza, "From informality to formality: Perspectives on the challenges of integrating solid waste management into the urban development and planning policy in Johannesburg, South Africa," *Habitat Int.*, vol. 63, pp. 122–130, 2017. <https://doi.org/10.1016/j.habitatint.2017.03.018>
- [29] B. Novarlić, Ž. Stević, P. Đurić, and M. Vasiljević, "Efficiency in organizing transport routes as a part of the city waste management: Proposal for an innovative way of transport," *Int. J. Qual. Res.*, vol. 11, no. 3, pp. 507–524, 2017. <https://doi.org/10.18421/IJQR11.03-02>
- [30] T. Litman, "Transportation and public health," *Annu. Rev. Public Health*, vol. 34, no. 1, pp. 217–233, 2013. <https://doi.org/10.1146/annurev-publhealth-031912-114502>
- [31] "Izvješće o obavljenoj reviziji učinkovitosti gospodarnje komunalnim otpadom u Republici Hrvatskoj," 2022. https://www.revizija.hr/UserDocsImages/izvjesci-novo/Revizije%20-%202022/IZVJESCA%20_O%20_OBAVLJENIM_REVIZIJAMA/REVIZIJE_U%C4%8CINKOVITOSTI/GOSPODARENJE_KOMUNALNI_OTPADOM/POJEDINA%C4%8CNA_IZVJE%C5%A0%C4%86A/GOSPODARENJE%20KOMUNALNIM%20OTPADOM%20U%20REPUBLICI%20HRVATSKOJ.pdf
- [32] "Directive (EU) 2018/852 of the European parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste," OJEU, 2018. <https://eur-lex.europa.eu/eli/dir/2018/852/oj>
- [33] D. Pešević, "Upravljanje otpadom," 2022. https://www.researchgate.net/profile/Dusica-Pesevic/publication/366839679_UPRAVLJANJE_OTPADOM_knjiga/links/63b47920097c7832ca89747b/UPRAVLJANJE-OTPADOM-knjiga.pdf
- [34] M. Jović Delić and O. Kalamanda, "Analiza upravljanja otpadom u republici srpskoj i srbiji sa osvrtom na neke

- evropske zemlje,” *Časopis Poslov. Stud.*, vol. 15, no. 16, 2016. <http://doi.org/10.7251/POS1616197D>
- [35] I. Dukoski and N. Talevski, “Implementation of a sustainable logistic system model for the communal waste collection in the municipality of Bitola (Macedonia),” *Transylv. Rev. Syst. Ecol. Res.*, vol. 16, no. 1, pp. 155–160, 2014. <http://doi.org/10.1515/trser-2015-0010>
- [36] B. S. Agustinus and T. S. Imaroh, “Waste minimization efforts towards green logistic at PT Nardevchem Kemindo,” *Eur. J. Bus. Manag. Res.*, vol. 6, no. 4, pp. 277–281, 2021. <https://doi.org/10.24018/ejbmr.2021.6.4.992>
- [37] D. V. Tung and A. Pinnoi, “Vehicle routing-scheduling for waste collection in Hanoi,” *Eur. J. Oper. Res.*, vol. 125, no. 3, pp. 449–468, 2000. [https://doi.org/10.1016/s0377-2217\(99\)00408-7](https://doi.org/10.1016/s0377-2217(99)00408-7)
- [38] J. Rodriguez-Melquiades and L. R. Cerna, “Reverse logistics based on green open vehicle routing for waste collection in the urban context,” *Pesqui. Oper.*, vol. 43, pp. 1–33, 2023. <https://doi.org/10.1590/0101-7438.2023.043.00269174>
- [39] R. J. Kuo, F. E. Zulvia, and K. Suryadi, “Hybrid particle swarm optimization with genetic algorithm for solving capacitated vehicle routing problem with fuzzy demand – A case study on garbage collection system,” *Appl. Math. Comput.*, vol. 219, no. 5, pp. 2574–2588, 2012. <https://doi.org/10.1016/j.amc.2012.08.092>
- [40] F. McLeod and T. Cherrett, “Quantifying the transport impacts of domestic waste collection strategies,” *Waste Manag.*, vol. 28, no. 11, pp. 2271–2278, 2008. <https://doi.org/10.1016/j.wasman.2007.09.041>
- [41] T. Nuortio, J. Kytojoki, H. Niska, and O. Braysy, “Improved route planning and scheduling of waste collection and transport,” *Expert Syst. Appl.*, vol. 30, no. 2, pp. 223–232, 2006. <https://doi.org/10.1016/j.eswa.2005.07.009>
- [42] P. P. Kamugisha and S. F. Mhanga, “Sustainable solid waste management in developing countries: Tanzania Outlook,” in *Sustainable Waste Management Challenges in Developing Countries*. IGI Global, 2020, pp. 382–408. <https://doi.org/10.4018/978-1-7998-0198-6.ch016>
- [43] G. Vujić and B. Tot, “Solid waste management in the Republic of Serbia,” in *Sustainable Waste Management Challenges in Developing Countries*. IGI Global, 2020, pp. 306–326. <https://doi.org/10.4018/978-1-7998-0198-6.ch013>
- [44] A. Demir, A. Basturk, B. Ozkaya, and M. S. Bilgili, “Municipal waste management in Turkey,” in *Sustainable Waste Management Challenges in Developing Countries*. IGI Global, 2020, pp. 441–465. <https://doi.org/10.4018/978-1-7998-0198-6.ch018>
- [45] M. Manzoor, I. Gul, I. Iqar, and M. Arshad, “Solid waste management practices in Pakistan,” in *Sustainable Waste Management Challenges in Developing Countries*. IGI Global, 2020, pp. 248–269. <https://doi.org/10.4018/978-1-7998-0198-6.ch010>