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Disruptive Proposal to Fill One Gap in Waste Collection in Hungary Regarding Plastic Recycling

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Plastic waste is one of the biggest problems facing our planet. From mountains to oceans, it pollutes our environment, can affect human health, and destroy ecosystems. While global plastic production was 1.5 Mt in 1950, by 2021, it will have risen to 390 Mt. Plastic products have an average lifespan of 10 y but can take up to 500 y to degrade. Not all people can be persuaded to do an activity immediately, even if the activity is genuinely beneficial or useful to society. An example is the case of plastic waste that the public can collect in the plastic waste recovery process. This is a critical point in the process, which needs to be taken in several directions to facilitate. The aim of this research is to develop a disruptive proposal for an innovative solution for the mandatory packaging return in Hungary with domestically developed recycle vending machines. This study outlines several possible solutions, such as multifunctional recycle vending machines, their placement at strategic locations, the use of innovative technologies, and the implementation of environmentally friendly operations at the design stage. The proposals set out the user requirements for the whole system and the steps needed to implement it in society.

1. Introduction

The distribution of plastic production and consumption in the European Union in 2023 (European Union, 2023), according to Eurostat data for 2018 (European Union, 2018), can be seen in seven areas. These are packaging (39.9 %), construction (19.8 %), automotive (9.9 %), electrical and electronic equipment (6.2 %), agriculture (3.4 %), household, leisure and sports (4.1 %) and other categories (16.7 %) such as medical devices (due to COVID, these figures first fell in 2020 but have since recovered to this level). However, only 46 % of the plastic waste generated is recycled, compared to 32 % under the Packaging and Packaging Waste Directive (PPWD) (Directive (EU) 2018/852). This amount is managed in three areas: energy recovery 42.6 %, landfill 24.9 %, and recycling 32.5 %. In recent years, the Netherlands (65 %), Germany (55 %) and the Czech Republic (55 %) have achieved the best results in plastics recycling. The domestic result of 26 % calls for more effective solutions. These figures also show that traditional environmental policy measures will not bring significant progress in the future. Long-term results can be achieved through education in primary schools, but it will take two generations. Remarkable data in 2019: plastic collected for recycling accounted for only 15 % of all plastic waste (Statista, 2023). At the other extreme, physical enforcement of the law (e.g., Singapore's ban on chewing gum imports) is less viable in Europe. The most common practice is to put out collection bins and local media communication about it. However, this has not yet brought a quick and effective solution because Hungary has the lowest plastic collection rate in Europe. This is due to the fact that disruptive technologies are less well-known and less widespread in the country. In 2020, Hungary was ranked last out of 27 EU (+3 European) countries; only 26 % of plastics were recovered, and EU figures are not encouraging (Plastic Europe, 2022). Therefore, we have developed a proposal that could allow immediate and effective intervention at the level of small communities using a disruptive approach. Due to labour market processes, greater use of human resources does not work, so the basic technology of the solution will be high-tech automation. There has been a strong process of 'making the economy more transparent' in the operation of recycling vending machines, which will be a good basis for the regulation of the operation of reverse recycling vending machines. Although regulation is in place at the EU and national level, it is worth reinforcing one of the EU's key principles of

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subsidiarity in this problem area: tackling the problem at the level closest to the citizen, where it arises. As the waste management and reduction of plastic litter becomes a major challenge worldwide, the importance of feasible solutions based on subsidiarity is growing. Disruptive waste management technologies can prove to be the most effective, and the application of related solutions can provide the answers. In our research, we seek to highlight that the exclusive use of disruptive technologies is preferable to traditional solutions rather than the use of traditional solutions. We intend to propose a methodology for doing so.
Our novel proposal goes beyond the old-fashioned daily routine of waste collection in Hungary. It breaks new ground for decision-makers and provides a complete package for achieving higher societal goals. In this paper, we start from the basic concepts of disruptive waste management and present its suitability and expected results. We will then formulate a proposal that is feasible, effective and immediately applicable in Hungary.

2. Disruptive plastic waste management

Plastic pollution problems require the creation of comprehensive global treaties (Tan et al., 2022), but it is important that the treaties not only specify what should or should not be done but also offer a clear framework for implementation. Disruptive plastic waste management technologies can provide a solution.
Disruptive plastic waste management refers to innovative approaches that use new ways to manage plastic waste to reduce its impact on the environment. These types of solutions are usually based on new technologies, processes, or business models that differ from traditional plastic waste management methods.
Four of the best-known disruptive methods are worth highlighting:

- Biodegradable plastics: Researchers and companies are developing plastics that are biodegradable, so they break down faster and in a more environmentally friendly way in nature. These plastics allow waste to be treated by composting or other biological processes.
- Plastic recycling: advanced recycling technologies allow plastic waste to be reused to make new products. For example, recycled plastics made from plastic bottles and packaging materials are reused to make bottles, packaging materials, or even other products.
- Bio Bio-degradative micro-organisms: research is underway into micro-organisms that can degrade plastics. These microorganisms produce enzymes, so this technology could offer the possibility of biodegrading plastic waste.
- Developing alternative materials: alternative materials can replace traditional plastics but are more environmentally friendly and more easily degradable. For example, biodegradable materials such as fungi-based materials or cellulose-based biopolymers are being developed.

These disruptive technologies can help reduce the problem of plastic waste in the future. Still, it is important to understand that change takes time and requires complex solutions in practical application. More sustainable consumption patterns and more stringent waste management systems are also essential to reduce and manage plastic waste. Therefore, we believe it is important to include in the disruptive regime the widespread dissemination of concrete technologies that can be applied immediately by the public to make the process more efficient. Plastic recycling can only be effective if the plastic collection itself is organised and efficient. However, reuse, recycling, and energy recovery require innovative approaches: better design, sustainable business models, and, not least, take-back schemes that support recycling and energy recovery systems (Xue, 2023). Smart city bin (Ravi et al., 2021) solutions are already available in many places. They are smart waste technologies that operate as an IoT network, collect Big Data, and improve the efficiency of waste collection and management.

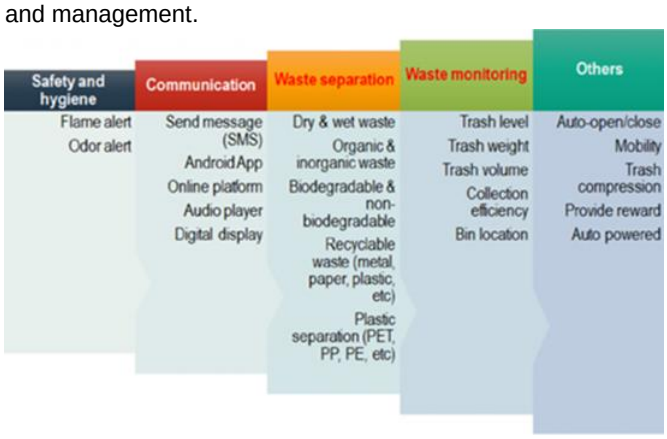

Figure 1: Key functions of smart trash bins adapted from Xue (2023)

The smart city bin provides hygienic and safe solutions, can be tracked online, and is suitable for waste control and sorting. The solutions are not just for plastic waste. Smart bins are equipped with sensors that detect the quantity and condition of waste. This data is transmitted in real time to the waste management system, allowing more efficient scheduling of waste collection and optimisation of logistics processes. For example, when a particular bin fills up, the smart system notifies waste collectors to empty only the bins that are full.
Automatic sorting systems can detect and sort different types of waste. Using optical sensors and machine learning, the smart system can distinguish between, for example, glass, plastic and paper. This enables more efficient recycling and reduces the amount of non-recyclable waste. The interactive waste bins provide a playful and interactive experience for users, encouraging them to collect waste correctly. For example, these systems give points or rewards to people who correctly place waste in the right bins. This method can have a motivating effect and increase the environmental awareness of the population. In smart cities, there are also mobile apps that allow people to track their own waste generation and get information on waste collection schemes and recycling opportunities. These waste-tracking apps can help promote more conscious consumption and waste reduction.

3. Circular economy and disruptive waste management

In a circular economy, resources are recycled, and products are improved and redesigned to extend their life cycle. This reduces the depletion of raw materials and waste. The circular economy aims to use materials and resources as efficiently as possible, minimising waste where possible. It is essential that the circular economy includes disruptive waste management as an essential element (Magnanelli et al., 2023).
The focus of the current study is on the urgent need to address plastic waste, but the authors are convinced that household collection can be effectively extended to other materials – such as paper, textiles, wood, metal liquids, etc.). The collection containers currently used for, e.g., textile waste, are blatantly inefficient. In many cases, municipal waste is thrown into bins or cracked open to remove the contents. With new and intelligent collectors, these cases could be avoided. Of course, both through truly efficient functions of the devices and through continuous and appropriate environmental education of the public. Public awareness of waste management is a measure of people's concern for the environment and sustainable development. This includes awareness of waste reduction, selective waste collection, recycling, and sustainable consumption habits. It is important that people become aware of these consumption habits and behaviours in more effective ways, as they have a direct impact on the amount and management of waste. It is not enough to create innovative technologies; they must be made available to the public in the right way.
Educational institutions, governmental bodies, and NGOs can play a role in raising people's awareness of waste management. Regular campaigns, workshops, and information materials can be organised to raise awareness of good waste collection and recycling practices. Responsible behaviour of individuals is not a given. Convenient options for the public need to be developed, and forms of motivation need to be found (see interactive collectors). In the current work, the aim is to make a real breakthrough proposal that stimulates social action, meaning people make a collective effort to achieve a change in direction to solving the problem.

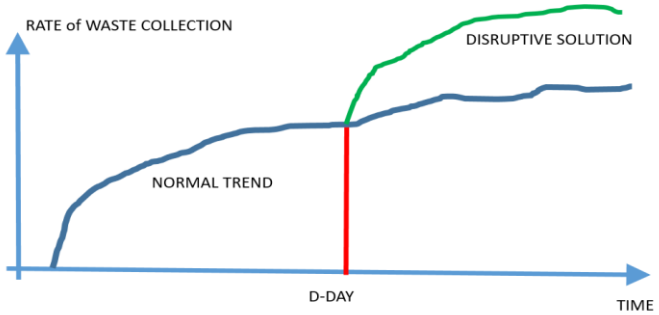

Figure 2: Possible positive change trend from D-day

As Figure 2 shows, by working together on taking collective action, more effective results and jump-like positive changes can be achieved.

4. Why is a disruptive solution necessary and possible?

The technical solution for the mandatory return of packaging materials cannot be solved with the current methods. Despite the waste management policies and practices of the past decades, the statistical indicators

show no improvement but a further slowdown. It can be concluded that the current and recent practices are not producing the expected results or improving trends. In fact, ‘the tree is not bearing good fruit’, and radically different solutions, not better ones, need to be developed. This is the necessary condition.
The options relevant to the Hungarian situation from all possible perspectives have been collected. From the 1960s onwards, there was a movement in Hungary where students collected newsprint from their households, usually trying to get some from the neighbourhood also. The motivation for this was a social competition, with every class in every school across the country wanting to be first in the quantity competition. The schools sold the waste paper to the public waste recycling company, for which the small community received a financial reward, which was spent on a common purpose, usually to finance a school trip. If people detach the political layer from this, there is a chance of revitalisation because of the high social awareness, i.e. a rethink of the 'school paper collection' as a continuous solution, taking place all year round, not only in (but also at) school (even the neighbour's packaging materials can be used). If 'everyone' knows what it is about, then the principle of individual benefit rather than small community benefit is likely to achieve a higher level of motivation and can work immediately.
The policy options, beyond the obvious global and local environmental and nature protection, can be expanded through communication activities. The issue of waste is both ‘hot’ and ‘cold’ in political communication and receives constant attention from a wide range of stakeholders. In the local field, it is a major focus of social attention, a great field for politicians, and can and should be exploited in decision-making at different levels to create new solutions. Domestic innovative entrepreneurs would do even more for technical implementation because they would like to have access to much more economic opportunities, such as grant funding. Resources were available in this area before EU accession and will continue to be available after accession, as it has always been a high priority in the EU. It may even be true that 'any amount' of funding can be obtained for projects in a very promising programme.
Due to labour market trends in Europe and at home, greater use of human resources is not working and is not expected to change in the near future. So high-tech automation will be the basic technology of the solution, which in the short term means unattended operation, which is already well established in industrial practice. This is an option that has already been proven in other areas and can be incorporated into the new solution. The development of direct-to-consumer vending machines is well underway in the world (e.g. gold bars, mobile phones, books, pancakes, pizza, French fries, etc.) and is also infiltrating Hungary (e.g. a vending machine combination of petrol station and cafeteria is under development).
The expansion of parcel vending machines in recent months also shows the proven technologies (e.g. contactless payment schemes, etc.). In Hungary, central electronic surveillance in the operation of retail vending machines has been a strong economic driver, and all social actors have learned from this that it is possible to implement economic policy processes quickly. This could also be a good element in the regulation of the operation of reverse vending machines. The use of plastic cards (bank or points cards, etc.) is popular and well known, used by all age groups at a very high level of proficiency, and the mobile phone version is also rapidly spreading. So this technology can be built into the new solution. It is possible to exploit a strong social pressure that can be derived from the consumer-trader relationship. The supermarket chains and mega-retailers that have made convenience (and rationally unnecessary) packaging a de facto consumer norm should also take their share of the return of 'convenience' packaging introduced according to their own requirements (e.g. mini yoghurts in two PET parts, including two tinfoil, cartons of milk in an extra carton, PET bottles in shrink wrap, etc.). This would certainly enjoy a high level of customer support, and the shops and supermarkets will recognise the additional benefits for them (e.g. another incentive to visit the retail unit in person).

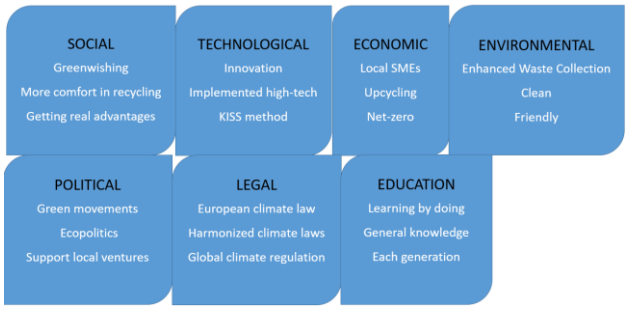

Figure 3: STEEPLE values of disruptive solution

All these possibilities need to be systematically integrated into the new solution, identifying and hitting the most useful application sites. A very strong alliance must be formed at the operational level to achieve any level of

goals in a very short time period. These goals form a list – a clean environment for people, a clean nature (minimal waste), an almost sustainable economy, people-friendly working processes in society, and happy politicians. This really shows our disruptive solution is necessary and possible.

5. Methodology

The process of disruptive problem-solving is usually implemented in two different forms, depending on which form the problem fits better. The most radical approach is to start from scratch, i.e. back to the lowest physical level of the problem, i.e. assuming only the most basic scientific principles and ignoring anything beyond that.
An example would be to start by measuring the size of microplastics in water, determining their type and finding a method to do this. But we make no assumptions about the history, the formation of the microplastics and the steps taken so far. This method is very good in some cases. However, it is not usually selected because it is very costly to possibly reinvent and implement activities that are already available on the market.
The preferred solution in practice is less radical, starting from the beginning, but carefully considering and selecting those proven technologies and solutions that are definitely part of the new thinking but do not retain their traditional embeddedness. A good example of this in waste recovery is the solution of sorting by material, the place of which in the process is always a big question mark. In this case, it is still worth using laser material identification, but not in the usual phases, but in the most promising part of the new process.
This research followed the latter approach, identifying those elements that are scientifically proven and proven in everyday practice, have industrial-grade solutions available, and have the necessary equipment available and fit for large-scale social socialisation. The problem was formulated as follows: a solution can be found for an innovative solution for domestic packaging return using domestically developed vending machines.

6. Designing the new solution

The following suggestions are made as a general basis for the solution. No imported solutions, because according to the priorities of economic development, this can be done competitively with domestic innovation and manufacturing capacity. This should be a purely political objective. Another economic policy objective is to encourage innovative initiatives among local SMEs and access EU money for innovation on the country level. In this area also needs disruptive thinking to really change the current practice of program and project management. A public, invitational innovation competition for domestic innovative enterprises is proposed, where stable and ‘scaleable’ SMEs can be put in place (e.g. EU funded R&D project successfully closed, min. one million EUR revenue for 2 y, min. 10 employees, etc.), e.g. with a tiered approach, with a narrowing down of the competition, eventually with 2-3 tested products to market for the winners. This could be done via co-financed EU money with strong publicity in up to 12 months. The timing and financing are really crucial for innovation today because Chinese production threats have spread to the entire European industry. The innovators should be faster and require more seals on IPRs, successful marketing campaigns, and Montecuccoli’s three things for this war-like situation in the fields of the global economy. The key would be to motivate everyone involved and to make them act, which in the medium term would become part of normal social behaviour, going from ‘don't litter’ to ‘recycle sensibly’. However, industrial giants nowadays try to steal the show from politicians with greenwashing activities (e.g., new attached caps).
As a new communication element, an innovative ‘show’ with weekly broadcasts could also be a great platform for environmental and nature protection using new interactive media. It can be helpful to increase social awareness about real user-oriented innovation. The operational level requirements for an innovative solution for domestic packaging recycling using domestically developed vending machines are set out below. Cash should not be used in any solution (e.g. security against tampering). The principle of crediting (bank or client) cards is recommended, as it is paperless (no printing of coupons), contactless and proven technology, mobile versions exist, and redemption can be made mandatory at card terminals. A national redeemable card (NVK) can be created at the national level, even in a student version (NVDK), with a very fast implementation time. An added advantage is the possibility of using data assets (e.g. spatial operational analysis). NVK and vending machine operation can be made economical (not likely separately), and operation is a great business opportunity for companies with large networks (e.g. Magyar Posta, MÁV-Volán, parcel delivery companies, etc.). A weekly or monthly lottery game could be developed for the NVK (a state-owned betting company that would draw e-mobility vehicles).
The following binding principles should apply to the technology of the vending machines:

- There should be both installed (shops, public areas, schools, institutions, office buildings etc.) and mobile versions (festivals, events, etc.)
- External energy is required, but can and should be ‘carbon footprint neutral’
- Five types of packaging material should be implemented (but possibly in several stages):

    - Cardboard (cut down to a given size)
    - Aluminium beverage cans (all sizes)
    - PET bottle (PET only would be fine, but it's not easy)
    - Glass (all sizes)
    - Plastic film (even harder to separate at the material level, but not necessary)
- Should be ‘sorted’ immediately after being thrown in the vending machine, this has many advantages:
    - Smaller volume
    - They do not take out the pieces already thrown in
    - Can be compacted (in the USA, the compactor seems to work)
    - Weight can be measured, allowing for more accurate counter-value calculations
    - Easier to process further, therefore more marketable
- Put the shreds in bags of their own material (but at least of the same processing ability), i.e. paper shreds in moisture-proof paper, aluminium shreds in aluminium bags, etc.
- Be very robust and very user-friendly (e.g. better than vending machines)

This specification directly supports decision-makers in establishing robust programs and well-designed projects with appropriate timing and financing on the national level, especially in Hungary.

7. Conclusion

This article presents a disruptive proposal to fill one gap in waste collection in Hungary regarding to plastic recycling. The problem space is described in detail, where traditional problem-solving does not seem to yield adequate results. The Hungarian situation is particularly disappointing compared to the EU average and even more so to the leading countries. The different possibilities of disruptive thinking and problem-solving in the field of waste treatment are analysed, and the chosen methodology is described. As a result of the research, a solution has been defined from a social, technological and political point of view, which is the specification of an innovative and quick-start programme. This multifaceted initiative aimed to harmonise these critical elements into a cohesive strategy that would not only protect our natural resources and biodiversity but also foster sustainable economic growth, spur technological innovation, promote community engagement, and ultimately elevate the overall well-being and prosperity of our citizens. This paved the way for an initiative at the national level, closely linked to both top-level environmental and nature conservation objectives, economic policy, the development of innovative industry, the involvement of society and the enhancement of the quality of life of individuals. It is important to note that while the initial costs of disruptive waste management can be high, such as technological investments, R&D, operational costs, logistics and infrastructure, regulation and permitting, in the long term, these disruptive innovative solutions have the potential to make waste management more efficient and economical, reduce environmental pressures and promote recycling.

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