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Circular Use of Resources

Theoretical and Practical Approaches of Sustainable Technologies, Business Models and Organizational Innovations

Edited by
Csaba Fogarassy, József Popp and David Christian Finger

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Cover image courtesy of Csaba Fogarassy.

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Csaba Fogarassy is an environmental management engineer, Director of the Climate Change Economics Research Center at Szent Istvan University, and founding member and secretary of the Interdepartmental Committee of the Circular Economy of the Hungarian Academy of Sciences. He obtained his PhD in 2000 on the study of energy crop cultivation and then, in 2014, in the field of business management, dealing with game theory modeling of sustainability in his second PhD dissertation. He is currently working on the design of material and energy-saving business models for the circular economy. He has carried out numerous sectoral surveys in recent years on linear circular transformation processes. He is committed to helping develop circular economic plans for developing countries. Csaba is obsessed with Rubik's cube and poetry, having so far published three volumes of his own poems. He also plays a significant role in charity programs, being the Vice Governor of Hungary's Lions Club in 2020/2021. Email: fogarassy.csaba@gtk.szie.hu.

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Preface to "Circular Use of Resources"

In circular economic theories, the primary goal is not to create cycles of material and energy flows (these are already known), but to transform business processes into sustainable, closed-loop resource systems. As long as the basic mechanisms of business models and business innovation planning do not support circular operating principles, material and energy flows cannot be operated in closed cycles. Unfortunately, the appropriate scientific foundations, relevant research background, necessary and credible databases, and connecting scientific analysis are not yet an active part of the linear–circular transformation processes. Typically, in circular economic models, economic actors and members of the supply chain integrate their resources with each other so that business ecosystems can constantly redesign themselves, i.e., operate dynamically and potentially in self-regulatory systems. In traditional supply chains, i.e., according to the linear business model, permanent roles are assigned, while in the cyclical model, we can talk about developing dynamic and potentially independent actors who work together to create circular value flows. The phenomenon can be visualized in a similar way as the form of the Archimedes spiral in which each circle always remains a circle but moves to an ever higher level on its scale of values. Thus, in the circular economy, we no longer talk about value chains, but circular value chains, because these value ranges cover the full spectrum of activities performed by different actors: a product or a service is not only delivered to the user, but its residues (material and energy) are also returned to the system. The different values and innovative elements are shared by the actors of each value group, so the existence of a wide-ranging system of relations and cooperation becomes especially important. Such a degree of cooperation requires digital decision support or the active use of data analysis technology systems.

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Editorial

Theoretical and Practical Approaches of Circular Economy for Business Models and Technological Solutions

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Abstract: Circular solutions are essential to tackle the imminent challenges of depleting resources and emerging environmental problems. The complex nature of material and energy systems and the changing economic and technological conditions depend on regional settings and accordingly result differently in developed and rapidly developing countries of the world. A wide variety of theoretical approaches can be used to facilitate a shift from the linear use of resources to circular systems, e.g., circular product planning, zero waste management, service-based repairing, refurbishing, and remanufacturing, to name just a few. The introduction and examination of circular solutions can be based on theoretical models in order to guarantee and ensure a successful application. The successful application of innovative technology approaches, business solutions, and organizational development can be facilitated through theoretical models and new scientific results that support innovation processes. The presented article focuses on sustainable and innovative methods that help and enable the proper use and recovery of resources.

Keywords: circular solution; environmental assessment; product lifecycle; sharing economy; short supply chain; biomass utilisation

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1. Introduction

The concept of the circular economy has become well known and researched through the European Union's Action Programs in recent years, but its scientific foundations and other system solutions have long been known. The context of the application of circular economic systems, i.e., the economic and technological environment of the introduction of new solutions, allows the development of very novel solutions [1]. The use of digital tools has opened up new opportunities and wide gates for businesses to follow consumer needs accurately, discover new market opportunities, explore new ways to connect with customers, and build fast and low-cost profiles in their sourcing and sales channels [2]. The change also means that it is not product development or organizational development that becomes the most important factor in corporate competitive processes, but the improvement of product marketing and sales mechanisms [3]. The basis of the circular economic concept is therefore not classical, Schumpeterian typology, product, technological, marketing or organizational innovation, but the re-dimensioning of business processes and models, i.e., business model innovation. Irrespective of the EU Circular Action Programs, the application of circular transformation and feedback system models has already started in business, the phenomenon can also be traced during the development of business models in different sectors (biotechnology, informatics, transport).

In circular economic theory, the primary goal is not to create cycles of material and energy flows (these are largely known), but to transform business processes into sustainable, closed-loop resource systems. As long as the basic mechanisms of business models and business innovation planning do not support circular operating principles, material and energy flows cannot be operated in closed cycles [4]. EU circular action programs can therefore provide good direction and financial resources for the introduction of sustainable business models, but unfortunately the scientific basis, the appropriate research background, the necessary and credible databases, and their thorough and scientific analysis, are not yet an active part of the current linear circular transformation processes [5]. Typically, in circular economic models, economic actors and members of the supply chain integrate their resources with each other, so that business ecosystems can constantly redesign themselves, i.e., operate dynamically and potentially in self-regulatory systems [6]. While in traditional supply chains, i.e., according to the linear business model, permanent roles are assigned, in the cyclical model we can talk about developing, dynamic and potentially independent actors who together create circular value flows in interaction with each other. The phenomenon can be visualized in a similar way to the form of the Archimedean spiral, in which the individual circles always remain circles but move to an ever-higher level on the scale of values.

Thus, according to the new business models, in the circular economy, we no longer talk about value chains, but circular value circle, because these value ranges contain the full spectrum of activities performed by different actors: a product or a service is not only delivered to the user, but its remnants (material and energy) are also transported back into the system. The different values and innovative elements are shared by the actors of each value group, so the existence of a wide-ranging system of relations and cooperation becomes especially important [7,8]. Such a degree of cooperation requires the use of digital decision support or data analysis technology systems, where the use of BigData systems, Internet of Things (IoT) or Artificial Intelligence (AI) systems becomes a basic criterion. Despite the fact that circular business model innovation is one of the development priorities of the European Union, currently interpreting the concept of circular economy and managing it in the right place is also a challenge, and market transformation research related to the field is an absolute novelty in the field. The key scientific challenge is to answer the following questions: how can business models of circular economic systems be successfully designed? What are the specific frameworks that can underpin sustainable business solutions in each sector? What sectoral and other specificities can be explored in the design and modeling of circular systems?

2. Theoretical and Practical Approaches

The popularity of the concept of the circular economy is different from any of the policies of the European Union, so it is worth treating it as a special phenomenon. The circular economic model presented in the action program is essentially an industrial service system that replaces the classic, one-way life cycle concept by offering to redesign material flows by helping to use renewable energy sources. Its main goal is to get rid of waste through the circular design of material use, product use and system applications, and this is achieved through the introduction of efficient business models [9,10].

An important detail in describing the models of the circular concept is that it further develops the usable indicators of the previous two ideas—the bioeconomy and the low-carbon economy—to describe biological and technological cycles. In all of his documents, he emphasizes the importance of developing the scientific basis and systemic relationships. Currently, the Ellen MacArthur Foundation's research community publishes the most professional publications on the topic in Europe. However, the majority of European university research teams and scientific research institutes are also interested in the scientific background for the development of the circular economy. The circular concept is the result of a shift from a simple mitigation model to an absolute value creation model that is socially, economically and environmentally positive.

Central to this is the decoupling of economic growth from increasing resource use and reducing adverse environmental impacts. A very important benefit of the decoupling economic approach is that business "sustainability" has become a comprehensive, social and economic necessity among governments, international organizations and businesses alike. Leaders in different sectors now understand that moving towards a more sustainable economy requires a global reduction in resource use, while human well-being requires an increase in economic activity and a local reduction in environmental impacts. The dilemma of expanding economic activities can be solved with this concept by reducing the rate of resource use while also reducing the environmental impacts of resource use [11].

In circular economic theory, unbundling means that we have to use fewer resources per economic emission unit on the input side, and from the resources used, the environmental impacts on the emission side also decrease exponentially [12,13]. The decoupling logic illustrates the two key aspects of decoupling sustainable development well, namely the separation of resources and environmental impacts. According to the resource-impact separation model, changes brought about on the input side result in a more efficient use of existing resources and technological assets and avoid the accumulation of means of production. On the output side of the production process, by recovering energy stored in secondary raw materials, we can reduce pollutant emissions and avoid external effect (harmful external, usually environmental, social costs).

Based on the professional concept established by the Ellen MacArthur Foundation in 2012, three important principles have been identified for the optimal design of circular economic systems [14].

2.1. Principle of Inputs

The first principle of the circular economic concept is to keep resource resources under control and to balance the material flow of renewable energy sources, to preserve and increase natural resource systems. In the case of inputs, the system is basically used to maintain the flow of renewable energy sources, so-called "flow or flow management", and aims to continuously circulate stocks instead of accumulating them, i.e., to stockpile them, while serving technological processes. Therefore, in terms of economic processes, they also focus on ensuring that renewable materials, resources and non-renewable raw materials are always available. In terms of systems that implement cycles (such as soil regeneration or the provision of secondary raw materials), this is achieved primarily by maintaining the flow of materials, most notably by continuously increasing the proportion of services. Therefore, the operation of the input side of circular economic systems requires, where possible, the provision of energy sources free from political and economic risks (production of renewable energy with local supply) and safe access to secondary raw materials by keeping material flow subsystems [15].

2.2. The Principle of Sustainable Cycles

The previously mentioned biological and technological cycles or cycle processes close the processes of the subsystems through loops of different lengths. As the functioning of the economy, but especially its growth, depends on the amount of resources available, these cyclical processes are able to ensure that production systems continue to function properly. In linear systems, if the resources (raw materials) essential for production cannot be obtained, the economy will be unable to grow or develop. Circular economic solutions offer directions for development that can ensure that these resources are always available at the highest possible level of material cycles (biological raw materials and raw materials) [14]. Its aim is to release the raw materials of the biological cycle processes into the environment through the shortest possible cycles, so-called cascades (e.g., circulation of soil nutrients, water cycle). The new product cycles of circular economic models are mainly generated in technological cycles, by re-acquiring resources or by modernizing and improving technological systems. It incorporates the requirement for circular design into the early stages of product design in order to reduce energy consumption throughout the product life cycle. Waste-free design principles that can be applied at this level therefore include reuse and recycling planning, remanufacturing, refurbishment, energy efficiency and flexibility of use. The essence of circular operation in sustainable cycles thus lies in the design of the product or service [15].

2.3. Principle of Outputs

Increasing the efficiency of the system must be achieved by accurately identifying the processes, adhering to the principles of the original circular design and providing the possibility of redesign, through which we can avoid negative and positive externalities with great certainty. This may include planned land use, avoid water and noise pollution, maintain good health, avoid the use and generation of toxic substances, avoid improper business solutions, and perform all of the interventions listed above using local resource utilization systems. In recent years, the principles of circular design have evolved the most in the direction of sustainability. In business innovation, environmental or economic problems are not solved through the development of technological systems or organizational innovation, but through a more efficient allocation and use of existing resources and means of production. As a result, far fewer new devices and equipment are introduced into production, and thus less pollution appears at the system level in connection with the production of these devices [15]. In business innovation, the process of value creation only supports systems that are viable on their own (also financially sustainable) [16]. With this, you can safely avoid harmful government interventions, negative externalities, and most of the external phenomena that were previously indispensable in business solutions referred to as sustainable. The development of closed-loop material flows, which may primarily be the responsibility of the circular service sector in the future, will significantly change the potential outputs of the consumption system. Zero waste systems can become an essential structure for economic systems thanks to proper regulation and the rapid development of a closed-loop material flow service system. This is illustrated, for example, by the announcement by British Prime Minister Boris Johnson in February 2020 of the UK's first post-Brexit climate action [17]: "Like several European countries, the UK has pledged to phase out petrol and diesel sales by 2040. However, the new plan is to bring this date forward five years and to add hybrids to the ban list".

This means that from 2035, only electric vehicles and electric vans will be available on the UK car markets.

3. Business Model Innovation

Irrespective of the EU Circular Action Programs, the application of linear-circular transformation, transition management, and system models based on feedback from cycles has already started in business [18]. There are economic sectors where this phenomenon is very spectacular (biotechnology, informatics, transport), the linear-circular transformations observed in these areas are actually the result of the natural development of business models. The resizing of business processes and models—that is, circular business model innovation—is therefore, if not necessarily conscious, an integral part of current business processes. In traditional value chains, these innovation processes can diverge, consumer chains break, economic and social change processes run side by side, changes actually evolve side by side (in each sector separately) and there is no relationship between the resources used. In this case, innovation in the traditional sense is not necessarily a useful element of system processes either (disruptive innovation effect). Nevertheless, development does not stop, but without the different levels of development (or values) building on each other, the loss of resources in the transformation process can be very significant, and the development/transformation phases lengthen. That is why it has a key role to play in consciously building the values that we want to see as an integral part of economic life for a long time to come. Sustainable business models are thus well-embedded systems, use resources efficiently and operate with less risk (mainly affecting risk factors stemming from global systems), permanently changing people's lives and the ways companies or society operate in a given circle. This position is in line with [5], who viewed environmental solutions as market expectations rather than complementary functions. The authors argued that the current benefits of business as usual (BAU) processes will soon pose a threat to companies in many ways. These include deficiencies in primary resources, including resource price volatility, declining supply chain efficiency, increasing bans on waste trading, declining costs of renewable energy sources, etc., and these unfavorable patterns can also be termed "linear risks". Recent studies [6,19] supported the above when they argued that the profitability of "mainstream" economic systems lies in outsourced external factors, i.e., it is cheaper to waste resources than to monitor and eventually regain them. However, this situation seems to be changing soon, as key global players (e.g., China, Kenya, Bangladesh) have exited from the waste markets.

It can therefore be assumed that the transformation from the "take-make-waste" approach and the creation of closed resource loops will be a basic requirement for companies and economic actors in general. This is one of the reasons why the European Commission has issued the Closing the Loop (An EU Action Plan for the Circular Economy) action plan, also mentioned in the introduction, which urges the transition to a circular economy [18]. The Circular Economy Action Plan is a concept that rejects the traditional features of economic growth (e.g., mass production, use of non-renewable resources, production of preserved goods, etc.) but offers innovative solutions to preserve natural capital and enhance social well-being. Achieving the best possible circular flow of materials and energy through economic processes and avoiding resource leaks is a top priority [20]. Contrary to previous sustainability efforts, these circular initiatives are receiving increased attention from the business sector. According to a recent study by the World Business Council for Sustainable Development (WBCSD), 80% of companies surveyed say that accelerating growth and increasing competitiveness depend on the use of circular strategies. The remaining 20% identified risk reduction as the main motivation for developing business models [21]. These results suggest that the application of circular strategies has reached the realm of business model research. In interpreting the concept of circular business models, Scott (2013) [22] argued that circular initiatives should use recyclable biological materials or use their technical raw materials continuously. Both activities are expected to be harmless to ecosystems and can be operated without waste. According to Mentink (2014) [23], circular businesses need to create value and capture material flows in a closed material cycle. However, he pointed out that a business model alone cannot be a circular system. Previous studies have not examined the business-level changes in circular progress, i.e., what circular elements and solutions the currently used business models use, and what phase of the linear-circular transformation they are in. Therefore, the main goal of our research in the future should be to evaluate the current business models and to analyze their fit with circular solutions. In characterizing business models, Segers (2015) [24] highlighted that each model variant is most often used in a consolidated manner by market participants, so a firm integrates the mechanisms of multiple models into one application when looking for the right solution for itself. In order for a small business to develop a proper business model, it must consider important design considerations [25]. One of the most popular types of sustainable business model design methods is the canvas design matrix, developed by Osterwalder and Pigneur (2010) [26] under the name "Business Model Canvas" (BMC), which has gained incredible popularity over the past decade. Lewandowski (2016) [27], who proposed the ReSOLVE criteria system for the circular evaluation of business models, considered BMC itself to be the best tool for developing and customizing business models. In a visual matrix, BMC demonstrates to the stakeholder how their business can create, deliver and capitalize on the value it offers. Of course, designed business models cannot consist of just circular attributes, as the operation of a business requires several additional activities that do not directly affect energy and material flows.

4. Technological Solutions

The sustainable engineering approach has represented the foundation that can be learned in environmental education, the importance of the three core competencies (reading, writing, arithmetic). Over time, environmentalists—symbolizing the priorities they represent—also created their own 3R trend by the second half of the twentieth century; it refers to the reduction in rapidly increasing amounts of waste (reduce), recycling (recycle), or prevention of their formation at all by reusing products (reuse). Thus, the theory of the circular economy [15], which is gaining more and more ground today, relies on these 200-year-old pillars. The concept was born in response to the linear economic approach that prevailed until the beginning of the 20th century, which favors production based on the use of new resources and then the disposal of products after their useful lives (end of life). In the cycle of natural ecosystems, the end product created by one life form always serves as a nutrient for another life form. It is inconceivable that any living thing in nature would create an 'output' that would not constitute an 'input' for another organization [28]. Another important aspect of natural life, in addition to the absence of waste generation, is that the phenomenon of overconsumption is also unknown. In the early stages of history, humanity, like animals, had to hunt, collect, and later produce for itself in order to obtain the food it needed. Today, however, these processes have been replaced by artificial care systems. Foods, which are thus becoming cheaper and more readily available, have induced the development of consumption, which is sometimes immoderate today [29]. In the last half century, however, our economy has begun to push for the overuse of people in other areas of life. The camp of representatives of alternative economic trends sees the foundations of today's consumer society in three main pillars. The first of these is the previously planned obsolescence.

The second such aspect is the issue of the use of credit. Although this tool has always been used to stimulate the economy, it was initially used with the aim of having its user invest the money earned in this way for later income. Later, however, it became common to use it to satisfy a constant consumption compulsion. Finally, marketing has emerged as another cornerstone of consumer society as one of the most effective ways of influencing consciousness to stimulate growing consumption. It is important to emphasize the processes that take place in nature, as this also contributes to the correct interpretation of the circular economic concept. This is because, in the light of experience to date, the name 'cycle' often gives rise to misinterpretations. This can be fatal in the sense that the scientific and practical foundations of the concept are still being laid. Based on what has been seen so far, the circular designation has repeatedly diverted researchers' attention towards increasing recycling. That is, most experts started from the question of how to recycle all the waste that humanity produces into production systems. This certainly proves to be a misinterpretation. Circularity actually refers to the environmental cycle as explained above. The idea is that the economy should replicate the functioning of natural ecosystems, where the functioning of systems in symbiosis with each other precludes the appearance of waste from the outset [30].

Furthermore, there is no overconsumption in this cycle. The theory itself cannot be said to be entirely new, as alternative trends (e.g., biomimicry, industrial ecology, natural capitalism, the cradle to cradle principle, the blue economy) have emerged continuously since the 1970s, placing production on systems with a natural basis. The circular economic theory sees all these theories as a breeding ground and its guiding principle is "The problem must be solved at the root!" view. This also emphasizes the need to work to avoid the appearance of waste instead of looking for waste management solutions [31]. The source of this can be seen in a much older context, the Jevons paradox, considered one of the foundations of environmental economics. In his 1865 book 'The Coal Question', William Stanley Jevons explained the long-term negative mechanism by which technological advances are aimed at increasing the efficiency of current systems. According to his example, although improving the efficiency of coal-based production has reduced industrial air pollution in the short term, more economical processes have ultimately led to the increased use of fossil fuel technology and higher CO_2 emissions [32]. Based on this, it is easy to imagine what would happen if circular solutions focused solely on recycling material flows back into production. The '3R' guideline presented at the outset is based on a similar logic, with only one of the three keywords focusing on recycling, the other two calling attention to curbing our consumption and maximizing the use of products we have already purchased. This is also based on Tom Szaky, director of the world-famous waste management company Terracycle. According to him, before declaring a product a waste, we need to focus on three things. The first is the function you loaded. If, in our opinion, it has not been used to such an extent that it is unable to fulfill its original purpose, we will continue to use it. In cases when it no longer meets our needs, we offer it to 'second hand' stores where others can still decide if they are willing to use it in its current form. The second important aspect is the shape of the product. In today's world, we have become accustomed to the fact that production systems assign different products to each function in order to increase consumption. As a result, we often do not even think about how many different purposes an object could be utilized for if we used our creativity. For example, instead of buying new pots, we can put our plants in used sour cream boxes. The series of examples could continue for a long time, as so-called 'further use' is now being built on several business models. Returning to Szaky's line of thought, the material of the worn-out object also appears as the last aspect. If we judge that a product no longer serves its original function for itself or for others and cannot be utilized for other purposes, we can think about recycling [29]. In developing circular theories, researchers use the 'R' -labeled methods presented earlier and follow a philosophy similar to that of Tom Szaky. The repository of waste management and prevention practices has now been expanded to '10R', which have been considered as priority levels in the circularity (refuse/reduce/renew/reuse/repair/refurbish/remanufacture/recycling/re-purpose/recovery).

In the circular concept, two priority aspects can be identified, along which we reinterpreted the order of methods and technological solutions. The application of the 'function before substance' principle aims to maintain the original purpose of the product for as long as possible. This ensures that the product used in the preferred function uses the least amount of material. The second priority is to minimize the energy used. That is, after the end of the useful life, convert the products for later use to use as little energy as possible.

5. Outlook and Conclusions

Further research is needed to clarify the theoretical details of the circular economy. A complete overview of resource systems needs to be set as a goal in order to extend the potential business innovations to the use of free resource elements with the greatest efficiency. A key goal in the future is for circular business models to focus not only on energy or material transport processes in scientific research, but also on the use of human resources or the circular operation of financial resources as a part of research. In order to eliminate existing or ongoing externalities for the sustainable operation of business models, it is necessary to know exactly which elements can be considered as the interventions needed to implement the circular economy, which are the parts and which are not. Linear-circular transformation processes are micro-, meso- and macro-level processes, the coordination, management and acceleration of which require information and data that can only be collected coherently from public and private data collection systems. In linear systems or in the traditional value chain, sectoral development processes may deviate from each other, there are no values, the processes of economic and social change do not or rarely meet each other, innovation processes do not support each other in the use of resources, but compete for available resources. Then, innovation is not a useful element of system processes either. Nevertheless, development does not stop, but without the different levels of development (or values) building on each other, the loss of resources in the transformation process can be very significant, and the development/transformation phases lengthen.

In circular business innovation, environmental or resource problems are not solved through the development of technological systems or organizational innovation, but through a service-based, more efficient allocation of existing resources and means of production. The presence of circular business solutions in the environmental sector is currently not common, because the tax system following the polluter pays principle in Pigou cannot deprive the state of its prominent role in the operation of the processes. Modification of this system property is essential to motivate circular mechanisms.

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Life Cycle Assessment of the Closed-Loop Recycling of Used Disposable Diapers

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Abstract: In Japan, approximately 23.5 billion paper diapers are produced annually (total of diapers for infants and adults produced in 2018). The majority of used paper diapers are disposed of through incineration; in certain regions, some paper diapers are recycled, mostly by open-loop recycling or thermal recycling. To date, several methods of recycling used paper diapers have been proposed and developed, but these methods are considered to have different types and amounts of recycled materials and different environmental performances. In this study, a new technology was developed for the closed-loop recycling of used paper diapers, and the use of the recycled pulp and superabsorbent polymer (SAP) as materials for paper diapers was evaluated via the environmental impact using the life cycle assessment (LCA) method, using data obtained from experimental facilities for recycling. The results between the comparison of the new method with the landfill and incineration processes demonstrate a greenhouse gas reduction of 47% and 39%, respectively. The results also show that such recycling is expected to reduce land-use occupation and water consumption, closely related to the pulp, main raw material of paper diapers.

Keywords: disposable paper diaper; material recycling; closed-loop recycling; life cycle assessment (LCA)

1. Introduction

Paper diapers are roughly divided into two types: those for infants and those for adults. Paper diapers for infants, which are highly convenient as they do not require laundering like cloth diapers, are essential for daily life in Japan. Paper diapers for adults have also become indispensable, given the increasing number of persons requiring nursing care and the shortage of caregivers, in line with the progressive aging of society. In 2018, in Japan, the annual production of paper diapers for infants was approximately 15.1 billion, equal to 480,000 tonnes, while that of diapers for adults mainly used in nursing care facilities and medical institutions stood at about 8.4 billion, equal to about 390,000 tonnes [1]. The production volume has been increasing for 10 years, since 2010: 1.7 times for diapers for adults and 1.9 times for those for infants. Paper diapers for adults, in particular, are expected to further increase in the future, due to the rise in the elderly population [2].

Paper diapers consist of pulp or superabsorbent polymer (SAP) used as a moisture absorber, exterior materials, waterproof materials, and plastic materials such as polyethylene or polypropylene used in internal nonwoven fabric material. Pulp, which accounts for the majority of the materials, is made of virgin materials for needle bleached kraft pulp (NBKP, or nadelholz bleached kraft pulp in German). The annual consumption of materials for NBKP, SAP, and plastics is estimated at approximately 330,000, 230,000, and 250,000 tonnes, respectively, based on the annual production [1] and the material composition of paper diapers (study by Unicharm Corp.).

The majority of used paper diapers from general households are collected and incinerated by local governments as combustible waste in the category of domestic general waste [3]. Paper diapers are considered to cover 6%–7% of the total volume of household combustible waste, and the high moisture content due to excreta included in used paper diapers leads to a low calorific value, inhibiting heat recovery efficiency during combustion [4]. Used paper diapers from business operators such as nursing care facilities and hospitals are not collected by local governments in principle but instead are entrusted to special disposal companies who collect and incinerate them as general waste from business activities or specially controlled waste [5].

As such, used paper diapers are mostly incinerated in Japan, but there are also some efforts and study cases on the recycling of paper diapers. Fujiyama et al. [6] conducted an analysis and a comparison with incineration processing of the material recycling of recovered recycled pulp to be used for fireproof plates, in addition to the manufacture of refuse paper and plastic fuel (RPF) from the thermal recycling of used paper diapers. They reported that greenhouse gas (GHG) emissions from recycling can be reduced by about 37% compared with incineration. A study related to the recycling of water absorptive sanitary products [7,8] also discussed thermal recycling treatment systems for processing used paper diapers recovered as they are, without separating or cleaning them, for conversion into solid fuel. Quantification of environmental loads adopting the life cycle assessment (LCA) is not confirmed, but reference was made to the possibility of reducing CO_2 emissions by using them as boiler fuel instead of fossil fuel. In the recycling of used paper diapers targeted for studies reported by Itsubo et al. [9], the preceding report of this paper revealed that recycled pulp has the same quality as NBKP, the virgin material that is the main component of paper diapers, which shows that pulp can be closed-loop recycled. It is also indicated that GHG emissions can be reduced by about 26% compared with incineration, as well as significant reductions in water consumption and land use occupation, areas where the pulp is considered to have high potential effects.

The present study introduces a new recycling technology that achieves the closed-loop recycling of SAP. This new recycling technology adopts a new crushing/cleaning/separating technology and improves the recycling rate for pulp, etc., and recycles SAP to the same quality as virgin materials, where SAP was thermally recycled with the preceding recycling technology. The environmental load over the entire life cycle of paper diapers from the acquisition of raw materials to the disposal/recycling phases is quantified.

There have been several reports on the recycling of used disposable diapers overseas [7,10–13]. An LCA report [12], which collected data from an experimental-scale recycling plant, stated that plastics could be recycled and pulp containing SAP could be used to generate the steam needed for the sterilization process, which indicates that the environmental impact is reduced compared to landfill disposal.

Many previous studies have focused on climate change. Disposable diapers use paper as the main material, and the supply of chips, the main raw material for paper, requires a lot of land use and water consumption. Recycling of disposable diapers is expected to contribute to reducing the burden on water consumption and land use but has not been evaluated in previous studies. In this study, in addition to climate change, water consumption and land use are evaluated.

2. Materials and Methods

2.1. Objective

This study assesses the life cycle of paper diapers, including the closed-loop recycling that recycles pulp and SAP from used paper diapers into a quality product to be used as the raw material for paper diapers. The quantified environmental impacts are discussed and compared with those for incineration and landfill. In performing the LCA, an inventory analysis and impact assessment were conducted for the production, transportation, recovery, recycling, and disposal of disposable diapers in accordance with the international standard for ISO 14040 [14].

2.2. Scope of This Study

2.2.1. Overview of Key New Technologies for Closed-Loop Recycling

1. Crushing, Washing, and Separation Technologies

Used paper diapers are required to be degraded into composition materials such as pulp, SAP, and plastics for recycling. The crushing process is characterized by dissolving the diapers in an organic acid solution of pH 2.5 or less, which prevents a reduction in treatment efficiency as there is no loss of liquidity in the treatment tank caused by the swollen highly water absorptive polymer [15]. It also has the effect of continuously securing hygiene in the facility, using a safe organic acid to enable safe treatment and to prevent odor and contamination. In conventional techniques using a water solution for the basic cleaning/separating process [9], SAP absorbs a large amount of moisture to become gel-like, losing its liquidity. This, in turn, greatly reduces the performance of the treatment equipment, making it necessary to use a large amount of lime to inactivate the SAP. Moreover, the use of hypochlorite as a disinfectant generates a highly alkaline environment in the treatment tank, which degrades the pulp fibers and lowers the pulp recovery rate and quality. Conventional techniques also require lengthy agitation and heating for separation, making it difficult to improve treatment efficiency. The process in this study, that is, applying the new technology, improved the recycling rate of SAP to about 80% and that of pulp also to about 80% compared to around 40% with conventional techniques [9].

2. Ozone Treatment Technology

Reusing the pulp recovered from the crushing/cleaning/separating process as raw materials for paper diapers requires that the pulp be recycled to a sufficient quality usable for sanitary materials. Ozone treatment uses ozone water to dissolve and solubilize SAP contained in the recovered pulp as residue, then discharges the ozone water to remove the SAP from the pulp, thereby extracting pulp ingredients only [16]. Ozone treatment also thoroughly sterilizes the pulp, eliminating the need for disinfectant. Moreover, ozone is returned to oxygen after use, without generating resistant bacteria, which improves the safety of recycled pulp.

3. SAP Reactivation Technology

As the SAP recovered from the crushing/cleaning/separating process is inactivated, it is necessary to recover the water absorption performance so that it can be used instead of virgin SAP [17]. Conventional techniques [9] use acid or alkaline treatment, which leaves the possibility of acid or alkaline residue in recycled SAP if not completely neutralized. Using such recycled SAP as raw materials for paper diapers may cause skin irritation, making it difficult to reuse as sanitary materials. However, the process targeted in this study makes it possible to recover the water absorption performance of SAP by neutralizing the SAP that has been inactivated by the organic acid solution.

4. Verification of the Quality and Safety of Recycled Products

The present study targeted closed-loop recycling, where pulp and SAP are recycled to a quality equal to that of virgin materials, and thus are usable as raw materials for paper diapers. The quality of the pulp was confirmed by consigning inspections about the standards stipulated by the Ministry of Health, Labour, and Welfare (MHLW) [18] to a third-party inspection organization. Inspection items and results are summarized in Table 1. The recycled SAP was also confirmed to have a water absorption performance equal to that of SAP in virgin materials, and thus can be used as raw materials for paper diapers.

Table 1. Quality inspection results of recycled pulp.

Quality Inspection Items		Criteria	Inspection Results
Purity	Appearance and Properties	Color is white, no odor, no foreign substances	conform
	Color elution	No color is exhibited when observing the eluate from above and from the side	conform
	pH	4.5~8	conform
	Fluorescence	No fluorescence	conform
	Ash content	0.65% or less	conform
	Kjeldahl nitrogen	50 mg/kg or less	conform
Cleanliness	Bacteria	Not more than 1000 per 1 gram	conform
	Escherichia coli	Not detected	conform

2.2.2. Functional Unit

The functional unit is assumed as the "provision of one paper diaper and its disposal." Paper diapers have different material compositions and composition ratios depending on the manufacturer and the shape. The individual material composition ratios for paper diapers for adults and infants (study by Unicharm Corp.) were calculated by weighing them with the individual production volumes [1] to determine the average material composition ratio (see Table 2). In this study, 40.5 g per paper diaper was adopted for the average weight of all paper diapers, including those for adults (except underwear liners or pads), based on diaper production statistics (2019) [1] (see Table 3). Furthermore, the composition of excreta included in used paper diapers is based on studies by Unicharm Corp. and literature values [19] (see Table 4).

Table 2. Material composition ratio of paper diapers. SAP, superabsorbent polymer.

Materials		Composition Ratio (%)		
		Average	for Adult	for Infant
Pulp		40.9	52.2	33.3
SAP		27.9	19.8	33.3
Plastics	Polyethylene	6.2	5.6	6.7
	Polypropylene	18.7	16.8	20.0
	Polystyrene	6.2	5.6	6.7
Total		100.0	100.0	100.0

Table 3. Average weight of paper diapers.

Type	Production Weight (tonne)	Production Quantity (1000 pieces)	Average Weight (g)
for Adult	365,804	5,864,108	62.4
for Infant	484,079	15,094,904	32.1
Total	849,883	20,959,012	40.5

Table 4. Composition of 1 tonne of used paper diapers.

Composition		Weight (kg)	Composition Ratio (%)
Paper diaper		383	38.3
Collection bag made of polyethylene		4	0.4
Human excreta	Moisture content	598	61.3
	Solid content	15	
Total		1000	100.0

2.2.3. System Boundary

The scope from the acquisition of raw materials to the production, distribution, and disposal/recycling of paper diapers was selected as the system boundary. For the use phase, non-use of electric power, fuel, and other utilities were assumed, thus these processes were excluded from the scope of the assessment. Figure 1 illustrates the life cycle flow. As comparable systems, two models using incineration and landfill to treat waste in the disposal/recycling phase were set. For incineration, the combustible general domestic waste treatment currently used in Japan was assumed. For waste power generation, the power generated was assumed to substitute the average purchased power in Japan. For landfill, general waste landfilling was assumed. In this paper, the systems for recycling, landfilling, and incinerating waste in the disposal/recycling phase are called RE, LF, and IN, respectively (see Table 5). Table 6 shows the recycled products and alternative products.

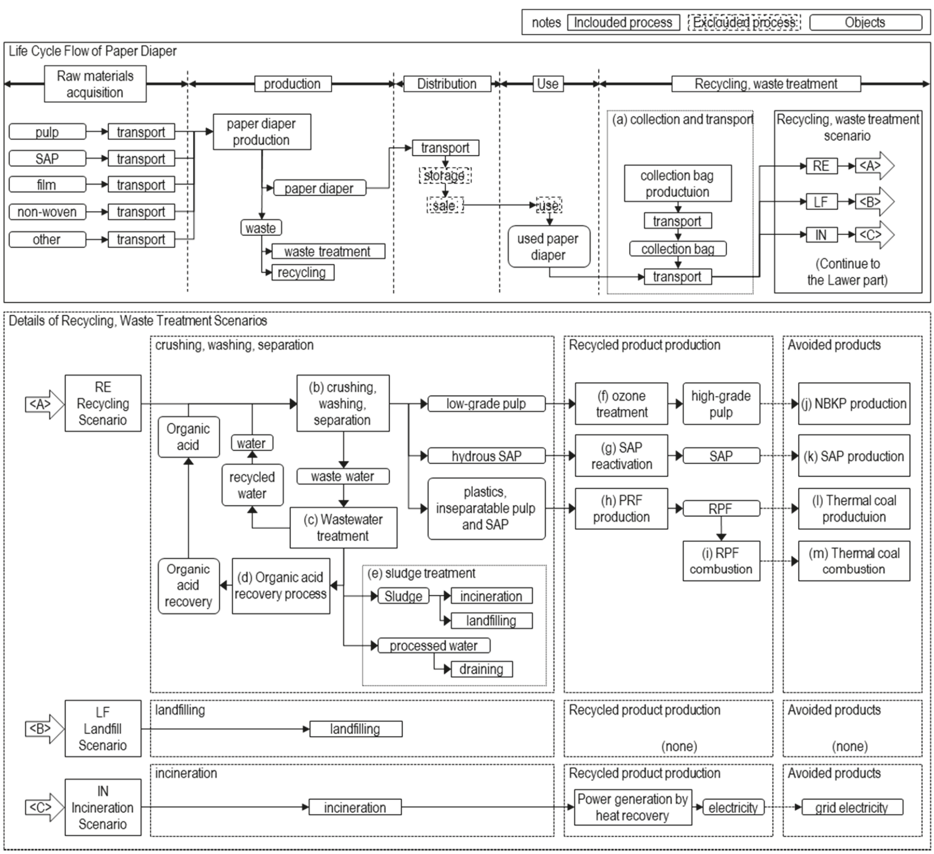

Figure 1. Life cycle flow chart. The upper part shows the life cycle of paper diapers, and the lower part shows details of recycling, waste treatment scenarios. The system boundary is from raw material production, disposable diaper production, transportation, disposal/recycling, production of recycled products, and production of alternative products (excluding storage, sales and use of disposable diapers). RE, recycling; LF, landfill; IN, incineration; RPF, refuse paper and plastic fuel; NBKP, needle bleached kraft pulp.

Table 5. Scenarios in this study and their differences.

Scenario	Abbreviations in This Study	Life Cycle Stage	
		Raw Materials Acquisition ~ Production ~ Distribution ~ Use	**Recycling, Waste Treatment**
Recycling	RE	Common for all scenarios	Recycling
Landfill	LF		Landfilling
Incineration	IN		Incineration

Table 6. Recycled products and alternative products.

Scenario	Recycled Products	Alternative Criteria	Alternative Products
RE	Pulp	Mass equivalent	NBKP
	SAP	Mass equivalent	SAP
	RPF	Heat value equivalent	Thermal coal
LF	(none)	-	-
IN	Electricity	Electric power equivalent	Public power

2.2.4. Impact Categories

Table 7 shows the impact categories and evaluation methods for the targets. In addition to global warming, land use occupation (maintaining) and water consumption were also included as impact categories closely related to pulp, the main raw material of paper diapers. Furthermore, blue water was considered as the target for water consumption.

Table 7. Environment impact categories and methods in this study.

Impact Category	Unit	Evaluation Method
Global warming	kg-CO_2e	IPCC 2013 GWP 100a
Land use occupation	m^2a	LIME2 [20]
Water consumption (blue water)	m^3	water consumption inventory

2.3. Inventory Analysis

2.3.1. Data Collection

1. Raw materials acquisition stage

The input amount of each raw material was determined by multiplying the average material composition ratio for paper diapers for adults and for infants, calculated from their respective composition ratios, by the average weight of paper diapers (see Table 8). For transport, the scenario of importing NBKP from North America via marine transport, and procuring other materials in Japan via land transport using trucks (see Table 9), was used.

2. Production stage

For energy input related to paper diaper production, primary data were collected from the paper diaper plants of Unicharm Corp. Raw material residue generated in the production processes was used as raw materials for pet goods and other products within the same plant; thus, it was assumed that no material loss occurs (see Table 8).

Table 8. Main collected data and collection methods.

Life Cycle Stage	Data Item	Data Type	Collected Data	Data Collection Method
Raw materials acquisition	Input amount of various raw materials	foreground	Pulp, SAP, Film, Non-woven fabric, others	Collected from Unicharm's paper diaper factory
Production	Energy consumption Waste amount	foreground foreground	Electricity Residue material	
Recycling, waste treatment	Input amount of Energy, utilities and auxiliary materials Pulp recycling rate SAP recycling rate Plastics recycling rate RPF heat value	foreground foreground foreground foreground foreground	Electricity, LPG, Industrial water, Organic acid, others 80% 80% 100% 36.3 MJ/kg	Demonstration experiment data

Table 9. Transport scenarios.

Life Cycle Stage	Transport Object	Transport Route	Distance	Mode of Transportation
Raw materials acquisition	Raw materials and auxiliary for paper diapers	Domestic land transportation	500 km	10 t truck, loading ratio of 50%
		Ocean freight (From North America to Japan)	18,707 km	Container transport ship, >4000 TEU
Distribution	Product (paper diaper)	Domestic land transportation	555 km	10 t truck, loading ratio of 50%
Recycling, waste treatment	Used paper diaper Auxiliary materials Waste	Domestic land transportation	100 km 200 km 100 km	2 t truck, loading ratio of 50%

3. Distribution stage

Paper diapers are generally distributed from the manufacturers to the stores, nursing care facilities, etc., through many distribution channels, which makes it difficult to determine the actual distribution amounts and distribution routes in detail. Therefore, in this study, it was assumed that the diapers are distributed from the paper diaper plants of Unicharm Corp to all 47 prefectures nationwide, with the distribution amounts proportional to the population of individual prefectures. The transport distances for individual prefectures were determined using Google Maps and were then weighed by the transport amount for individual prefectures. For the vehicle class and loading ratio, general domestic transport was assumed (see Table 9).

4. Use stage

In this stage, no additional energy was used, so it was excluded from the assessment of environmental impact.

5. Recycling, waste treatment stage

For RE or recycling processing, primary data were collected from simulated demonstration experiments at a recycling plant being developed by Unicharm Corp. in Shibushi City, Kagoshima Prefecture that processes about 500 tonnes of waste annually (see Table 8). Eighty percent of the SAP and pulp included in the used paper diapers is recycled, and part of the unrecycled content is mixed with plastics to produce RPF. The plastics are completely recovered and then mixed with part of the unseparated pulp and SAP to produce RPF. For LF and IN, it was assumed that one tonne of used paper diapers with the same composition as in RE is processed. Since waste is separately recovered in a polyethylene collection bag of 20 g per 5 kg of used paper diapers in RE, it was assumed that the same bags are used in LF and IN and that the scenarios for transport related to waste materials and collection are common to RE, LF, and IN (see Table 9).

2.3.2. Background Data and Software

Background data from the Life Cycle Inventory (LCI) database IDEAv2 [21] were mainly used, with missing data complemented by the GHG Emissions Accounting and Reporting Manual [22], and SimaPro 8.5 was used for the calculation.

3. Results

3.1. LCA Results and Comparison between the Three Scenarios

The LCA results of the system targeted in this study, which assumes the disposal/recycling phase as "recycling processing" in the life cycle, as well as the results for landfill and incineration are shown in Figure 2 and Table 10. The system boundary is the life cycle, including the individual phases from the acquisition of raw materials to the production, use, and disposal/recycling of paper diapers, and the functional unit is the provision of one paper diaper (40.5 g).

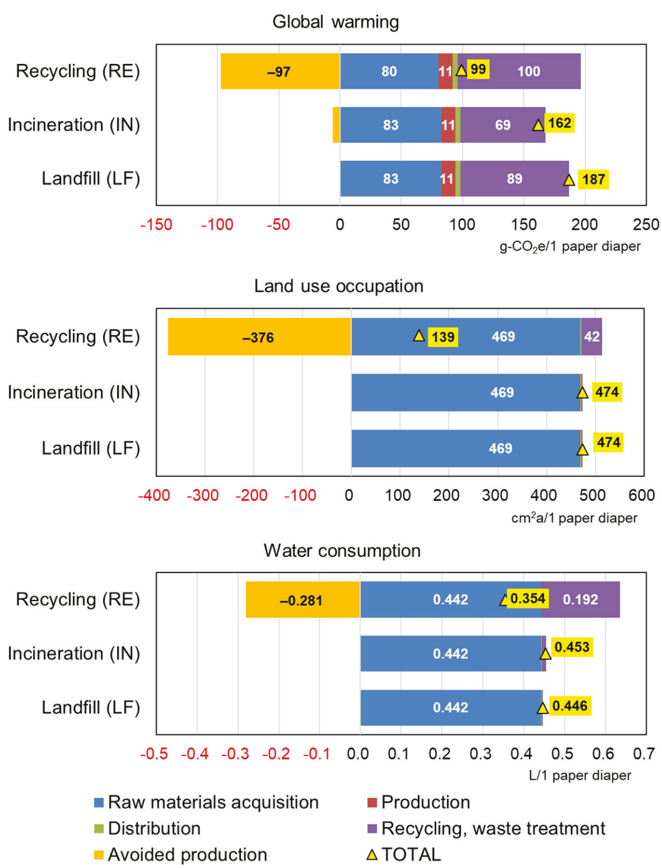

Figure 2. Life cycle assessment (LCA) results and comparison between the three scenarios.

Table 10. LCA results for each scenario and reduction effect rate.

Scenario			Global Warming (g-CO_2e)	Land Use Occupation (cm^2a)	Water Consumption (L)
RE	Recycling		99	139	0.354
	Reduction rate	IN Δ	39%	71%	22%
		LF Δ	47%	71%	21%
IN	Incineration		162	474	0.453
LF	Landfill		187	474	0.446

3.1.1. Global Warming

GHG emissions of IN and LF were calculated as 162 and 187 g-CO_2e, respectively, while that of RE was estimated at 99 g-CO_2e, a reduction of 39% and 47% compared with IN and LF, respectively. In RE, the amount in the disposal/recycling phase was 100 g-CO_2e, larger by 11%–45% compared with IN and LF. However, a significant reduction effect compared with IN and LF is expected in the entire life cycle, with the contribution of the total deduction at 97 g-CO_2e due to the substitution effect of recycled pulp, SAP, and RPF.

3.1.2. Land Use Occupation

The land use occupation values for IN and LF were almost the same at 474 cm^2a, while that for RE was estimated at 139 cm^2a, a reduction of 71% compared with IN and LF. About 99% of the loads from IN or LF are due to pulp production included in the raw materials acquisition phase, while RE has a lower value in this phase due to the substitution effect of recycled pulp. Thus, for RE, the load is expected to be reduced in the life cycle.

3.1.3. Water Consumption

Water consumption values for IN and LF were calculated at 0.453 and 0.446 L, respectively, about 97% of which is the contribution from the raw materials acquisition phase, and about 75% in this phase is the contribution from pulp production and SAP production. The value for RE was 0.354 L, although the ratio in the disposal/recycling phase for RE was 0.19 L, accounting for 53% of the total compared to 2%–3% for IN and LF, due to the contribution of 0.069 L of cleaning water and 0.10 L related to the production of organic acid for cleaning chemicals. Meanwhile, the value for RE in the entire life cycle was estimated to be 21% and 22% lower than that for IN and LF, respectively, with the contribution from the substitution effects of recycled pulp and SAP.

3.2. Detailed LCA Results at Recycling, Waste Treatment Stage of the Recycling Model

The treatment scenarios targeted in this study are characterized by recycling in the disposal/recycling phase, so the LCA results for disposal/recycling, ranging from collection/transport to production of the recycled products and using the substitution effect (deduction) with the recycled products as the system boundary, are presented in detail (see Table 11). The process IDs in the table correspond to the symbols in (a) to (m) described in the individual processes in Figure 1. The functional unit was the disposal/recycling of one used paper diaper.

3.2.1. Global Warming

GHG emissions were calculated at 3.18 g-CO_2e. Emissions related to the phases from the collection/transport of used paper diapers to the production of recycled products were 100 g-CO_2e (subtotal-1), due to a significant contribution of 97.2 g-CO_2e (subtotal-2) from the deduction total as a result of NBKP production (j), SAP production (k), as well as thermal coal production and combustion (l), (m), substituted by recycled pulp, SAP, and RPF. Details of the recycling are as follows: 7.8% for collection/transport (a); 22.7% for crushing/cleaning/separating (b, c, d, e); and 69.5% for recycled products production (f, g, h, i). The substitution effects for NBKP production and SAP production were

19.3% and 20.2%, respectively, while that for thermal coal production/combustion was the highest at 60.4%, due to a significant contribution from CO_2 direct emissions caused by combustion.

Table 11. Detailed life cycle assessment (LCA) results at the recycling, waste treatment stage.

	Process	Process ID	Global Warming (g-CO_2e)	Land Use Occupation (cm^2a)	Water Consumption (L)
Collection and transport	Collection and transport	(a)	7.83	1.48	0.00282
Crushing, washing, and separation	Crushing, washing, and separation	(b)	9.63	39.7	0.182
	Waste water and sludge treatment	(c, e)	9.53	0.320	0.00143
	Organic acid recovery	(d)	3.68	0.0628	0.000298
Recycled product production	Ozone treatment	(f)	5.55	0.104	0.00100
	SAP reactivation	(g)	17.0	0.307	0.00243
	RPF production and combustion	(h, i)	47.2	0.233	0.00252
	Subtotal-1, (a)~(i)		100	42.2	0.192
Avoided products	NBKP production	(j)	–18.8	–375	–0.100
	SAP production	(k)	–19.7	–0.324	–0.180
	Thermal coal production and combustion	(l, m)	–58.7	–0.00654	–0.000690
	Subtotal-2, (j)~(m)		–97.2	–376	–0.281
	Total		3.18	333	–0.0886

3.2.2. Land Use Occupation

The land use occupation was −333 cm^2a, considered as a negative load in the entire process, due to the contribution from the deduction by the substitution effect. Details are as follows: the total of the recycling, from collection/transport to recycled products production (subtotal-1), was 42.2 cm^2a; and the total of the deduction from the substitution effect by recycled products (subtotal-2) was 376 cm^2a. In recycling, the crushing/cleaning/separating phase (b) accounted for the majority at about 94%, which was largely due to the contribution from land use in the plant culturing phase, as the organic acid used was plant-based. Meanwhile, the substitution effect of NBKP production (j) was 375 cm^2a, accounting for almost 100% of the total at 376 cm^2a, which was due to the significant contribution from land use related to the production of forest resources (softwood) used as materials for virgin pulp, which was avoided by using recycled pulp.

3.2.3. Water Consumption

The water consumption per paper diaper was −0.0886 L as a whole, a negative value calculated by deducting the substitution effect. Details are as follows: the total of the recycling, from collection/ transport to recycled products production (subtotal-1), was 0.192 L; and the total of the deduction from the substitution effect of recycled products (subtotal-2) was 0.281 L. In recycling, the crushing/cleaning/separating phase (b) accounted for the majority at about 94.5%, among which about 40% was due to directly consumed water in the cleaning tank, while about 60% was due to production of the plant-based cleaning agent.

4. Discussion

4.1. Comparison with Previous Studies

The results of previous studies related to the recycling of used paper diapers were reviewed and compared with this study. As previous studies assess only the disposal/recycling phase in the life cycle of paper diapers, the disposal/recycling process from the results of this study were extracted and the system boundary was set to cover "disposal/recycling of one tonne of used paper diapers" only (see Table 12).

Table 12. Comparison with previous studies. The functional unit is recycling, waste treatment of 1 tonne of used paper diapers.

Comparative Studies	GHG Emissions (kg-CO_2e)				Recycled Products
	Collection and Transport	Recycling, Waste Treatment	Recycling Effect	Total	
This study					
Recycling	74	875	–919	30	Pulp (127 kg) SAP (91 kg) RPF (155 kg)
Incineration	74	579	–55	598	Electricity (91 kWh)
Landfill	74	764	0	838	(None)
Comparative studies					
Itsubo et al. [8]					
Recycling	55	1132	–821	366	Pulp (89 kg) RPF (306 kg)
Incineration	55	523	–85	493	Electricity (137 kWh)
Fujiyama et al. [6]					
Recycling	(out of boundary)	530	–240	290	Pulp (159 kg) Fermented fertilizer
Incineration	(out of boundary)	432	(none)	432	(None)

Among the domestic studies, Itsubo et al. [9] discuss closed-loop recycling. The paper targeted the closed-loop recycling of recycling pulp as fine pulp usable as raw materials for paper diapers, where plastics and SAP were converted to RPF for thermal recycling. Compared with the present study, this system as characterized by a lower pulp recycling amount by about 30%, but a higher RPF recycling amount of about two-fold. The calorific value for RPF as lower by about 34%, making the total of the substitution effect (deduction) smaller by about 10%. The total GHG emissions related to recycling was about 1.3 times that of the present study, which resulted in a total—including the deduction—at 366 kg-CO_2e, which was about 12 times the value in this study at 30 kg-CO_2e. Compared with the study by Itsubo et al., GHG emissions related to recycling in this study were reduced by 23%, while the recycling ratio of pulp was about 80%. For RPF, the contamination rate of pulp and SAP residues other than plastics was low, resulting in a higher calorific value, and the deduction was higher due to SAP recycling, significantly reducing GHG emissions as a whole.

In the study by Fujiyama et al. [6], the GHG emissions related to recycling were about 60% of the value obtained in the present study, but the substitution effect (deduction) in their study was about a quarter of the value obtained in the present study at 240 kg-CO_2e. This is presumably caused by a lower deduction range per unit of weight of recycled products compared to the present study as Fujiyama et al. used downgrade recycling.

The study report on the processing equipment for thermal recycling of used paper diapers as solid fuel [7] indicates the possible reduction of CO_2 emissions by using such fuel as a substitute for fossil fuel, but that effect was excluded from the comparison as the effect was not quantified.

Note that the values in the present study cannot be directly compared with those in previous studies as the prerequisites differ in the following points.

1. The system boundaries are not always the same in studies, such as the inclusion of the collection/transport process.
2. Individual studies may use different background databases, resulting in different environmental loads, even with the same inventory.
3. The composition of used paper diapers (material composition of used paper diapers, the ratio of excretion in paper diapers, etc.) differs by study, which results in, for example, a different yield in recycled products, even with the same recycling ratio.
4. The suitability of recycled products is not sufficiently assessed. If recycled products substitute virgin materials in equal amounts, the quality of the former should be sufficiently verified. It is also necessary to assess the market demand. Sufficient information on these matters cannot be obtained from a comparison with previous studies.
5. Values not provided in the report by Fujiyama et al. were directly measured using a chart, which may have errors.

4.2. Estimation of the Potential for Environmental Load Reduction

The potential for environmental load reduction by recycling used paper diapers in Japan and the world was estimated from reduction amounts obtained in this study and by applying them to the incineration and landfill baselines of Japan and the world (see Table 13). The annual production volume of paper diapers for adults and infants in Japan was 878,000 tonnes. The waste weight was estimated at 2.294 million tonnes, assuming that the disposal weight increase factor was 2.6; this is due to the increased weight from excretion. Based on this waste amount and the ratio of 98:2 for incineration vs. landfill, the reduction potential nationwide was estimated at about 1.314 million t-CO_2e for GHG emissions, 726 km^{2}a for land use occupation, and 2.149 million m^3 for water consumption.

Table 13. Estimation of the potential for environmental load reduction.

	Unit	Incineration		Landfill		Total Amount of Reduction per Year
		Current Estimates	Apply Recycling	Current Estimates	Apply Recycling	
Japan						
Paper diaper production	Mt/year	0.878				-
Disposal volume	Mt/year	2.294				-
Ratio of disposal method	%	98%		2%		-
Amount by disposal method	Mt/year	2.248		0.046		-
Environmental load per year						-
Global warming	Mt-CO_2e	1.344	0.068	0.038	0.001	1.314
Land use occupation	km^{2}a	4	–708	0.1	14	726
Water consumption	Mm^3	0.222	–1.881	0.006	–0.038	2.149
Global						
Paper diaper production	Mt/year	4.866				-
Disposal volume	Mt/year	12.720				-
Ratio of disposal method	%	37%		63%		-
Amount by disposal method	Mt/year	4.706		8.014		-
Environmental load per year						-
Global warming	Mt-CO_2e	2.814	0.142	6.712	0.241	9.143
Land use occupation	km^{2}a	8	–1482	13	–2524	4027
Water consumption	Mm^3	0.466	–3.938	1.111	–6.706	12.221

Overseas, the annual production volume of paper diapers was estimated at 120 billion [23], but the weight per diaper is unknown. Thus, the production volume for the world was estimated at 4.866 million using the average weight of 40.5 g for diapers for adults and infants produced in Japan. The weight increase factor for disposal was set at the same value as in Japan, or 2.6, and the waste weight was estimated at 12.720 million tonnes. The ratios of the processing methods were set at 63% for landfill and 37% for incineration [24]. Using these prerequisites, it was estimated that the GHG emissions reduction potential was 9.143 million tonnes-CO_2e, land use occupation was 4027 km^2a, and water consumption was 12.221 million m^3 when applying recycling throughout the world (see Table 13).

The estimates were based on the assumption that all used paper diapers produced in Japan and the world are recycled, which requires the following cautions.

- No comparative study on costs has been conducted, so it is uncertain if economic rationality is achieved in all regions.
- It is uncertain if a system to recover used paper diapers for recycling facilities can be established, as the disposal methods for used paper diapers differ by nation or region.
- It is uncertain if the destinations for using recycled products can be established in all regions.

5. Conclusions

As the production of paper diapers is expected to increase in the future, there is a strong need for an appropriate recycling technology in terms of waste treatment after use and for sustainable use of resources. While previous studies and cases are limited to open-loop recycling, the present study achieved closed-loop recycling of pulp and SAP from "paper diapers to paper diapers" thanks to a new technology, thus clarifying that the environmental load can be further reduced compared to that in the preceding report [9] in the assessment of GHG emissions, water consumption, and land use occupation for the life cycle of recycling used paper diapers (see Table 14). The recycling technology in this study demonstrated a high recycling effect by enabling the recycling of high-quality pulp and SAP. In the future, further reductions in environmental impact are expected through the efficiency of SAP regeneration and the improvement of the recycling rate. On the other hand, in this study, it was considered that uncertainties were included from the following points, but even if these factors are taken into consideration, a significant reduction in environmental load was confirmed.

Table 14. Reduction of environmental load by the recycling technology of this study and other recycling technologies.

This Study				Other Recycling Technologies
		Reduction Rate		
System Boundary	**Impact Category**	**Compared with Incineration**	**Compared with Landfill**	
Full life cycle *	Global warming Land use occupation Water consumption	39% 71% 22%	47% 71% 21%	Previous studies in Japan have not evaluated the full life cycle.
Recycling, waste treatment stage	Global warming	95%	96%	Itsubo et al. [9] reported a 26% reduction, and Fujiyama et al. [6] reported a 33% reduction in GHG emissions.

* Full life cycle includes all life cycle stages of the paper diaper, from the acquisition of the raw materials to the recycling, waste treatment stage, except for the use stage.

The recycling facility from which the data were collected is a prototype, so its representativeness may be low.

- Japanese data were used for LCA calculations.
- Thermal coal and electricity were set as alternative products for the recycling effect. However, if these are changed to other products, the recycling effect may change.

In addition, it is expected that the recycling process of this study will have great social and economic benefits. Analyses focused on social and economic aspects were also assumed, but were not included in this study due to the difficulty in obtaining data, etc., and the immature evaluation method.

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Environmental Assessment of Innovative Paper Recycling Technology Using Product Lifecycle Perspectives

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Abstract: Paper can be reused to efficiently manage biomass consumption, meaning that it has potential as an environmentally friendly material. On the other hand, because of high energy usage during the recycling process and transportation inefficiencies, there is a call for the development of technologies that can mitigate this environmental burden. This study evaluated, from a lifecycle perspective, a new technology that can collect and recycle paper within the office. This technology can reduce by over 90% the amount of water used compared with the conventional recycled paper that is pulped and bleached once by the dry process. It also eliminates transportation from paper collection facilities to recycling factories, reducing greenhouse gas emissions. This new technology is already in use in Japan, and analyses by user data indicate that evaluation results differ greatly depending on the utilization rate of the machine. In the future, environmental information should be shared by both users and manufacturers, so that users could increase their utilization rate, and manufacturers could develop alternative bonding agents in order to further reduce the total environmental burden.

Keywords: LCA; paper production; CO_2 emission; water consumption; water footprint; Japan; recycle

1. Introduction

Forests mitigate climate change, conserve biodiversity, lessen the risk of natural disasters, and conserve soil, thus providing diverse functionality and value. These roles that forests play are essential assets and services to living things, and thus international efforts are underway to promote sustainable forest management as well as to prevent global warming. According to the Food and Agriculture Organization of the United Nations (FAO) [1], forests covered a total of 4 billion hectares worldwide in 2015, approximately 31% of the world's land area. In the five years from 2010 to 2015, the area of forested land has increased significantly through planting in China, Australia, and other countries; however, countries, such as Brazil and Indonesia, have seen a decrease in areas covered by tropical forests—this has given a net annual reduction of 3.31 million hectares [2]. This decrease is attributable to problems, such as felling of forests to make farmland, illegal logging, and forest fires. Focusing on forest fires in particular, a total of approximately 19,900 forest fires were confirmed in Brazil's tropical rainforest along the Amazon River basin as of September 2019 with serious damage, including the loss of 43,500 km^2 of forest between January and August [3]. Despite the situation of global deforestation, issues with marine plastic pollution in recent years mean we have seen a focus on using paper as a replacement, with an attendant increase in demand. Many companies in Japan are using slogans that urge reductions in the usage of plastics, thus promoting the development and usage of paper-based products. However, from the perspective of ever-decreasing forested areas, the effective usage, reuse, and recycling of paper are also important points of consideration.

Paper has a long history as a medium for transmitting information, and with printers becoming widespread, offices are using increasingly large quantities of paper. At present, Japan produces around 7.87 million tons of paper for printing and for communication paper, and around 800,000 tons of PPC (plain paper copier) paper [4]. A characteristic of paper is that as a medium, it is easier to read, understand, and find errors in information than with electronic media. Even in recent years, these characteristics have resulted in a minimal change in the amount of PPC paper production in spite of the prevalence of electronic media and the move towards a paperless society [5]. Paper used in the marketplace is actively recycled so that it can be used more effectively. The paper collection rate in Japan is around 81.6% [6], which is high when compared to other countries, but this high collection rate is primarily due to the recycling of cardboard, magazines, and newspaper, and the collection rate for shredded paper and office paper is low, at under 60% [6]. The reason for this is that office paper often has confidential information printed on it, which needs to be securely disposed of. Additionally, shredding paper reduces its transportation efficiency, and if it is shredded too finely, reuse of the paper itself becomes difficult. Recent years have seen an increase in the use of processing of paper by dissolving, after which this material is mainly reused as cardboard, with only a low proportion of it reused as paper for printing. However, in terms of energy usage, the pulp and paper industry is focusing on energy reductions, and is investing in the development of manufacturing processes that are efficient over the long term, triggered by increasing energy prices, as well as to maintain competitiveness [7,8]. In addition to the above, achieving efficiencies in energy usage is also considered to be the most cost-effective way to reduce CO_2 emissions [9]. However, it is important that we recognize not only the impact of the paper manufacturing process but also that of the overall lifecycle, from the procurement of materials through to their disposal. In view of this, up until now, we have actively been using an LCA (lifecycle assessment) for paper [10–21].

LCA is a methodological tool for assessing the environmental impact associated with a process, product, or services by identifying and quantifying the energy and materials used, as well as the waste products released into the environment. Many academic papers in the early 2000s discussed energy usage during the production stage while many recent studies tend to focus on waste processes and technical innovations. Furthermore, China had not formerly carried out proper LCA until this point, but given the increased paper consumption there, we are seeing an increase in paper-related academic papers [17]. When focusing on evaluation targets, there are a range of types of evaluations, not just for paper products but also for printing paper, newsprint, and for the paper industry as a whole. Similarly, some evaluation scopes cover only the paper production stage, but there are also articles covering everything from raw materials, production, and transport, through to sales and disposal [10–12,14,17,18]. While the majority of these academic papers used the literature to determine activity data, there are some [10] that also conducted interviews with multiple factories, and have highly reliable data. Most of the annual activity data comes from the late 1990s to early 2000s. There is some variance in the results from these academic papers, but this is due to differences in the evaluation scope and selections of energy source at the manufacturing stage, as well as in the disposal methods. In addition, there are academic papers that focus not only on greenhouse gas substances but also on water consumption [22], indicating that there is a large increase in paper-related water consumption. However, simply utilizing recycled paper will not in itself necessarily reduce greenhouse gas emissions. This is because the production stage of recycled paper uses large amounts of water, and other main causes include the energy required during drying processing, the high energy consumption of air blowing during the de-inking process, and greenhouse gas emissions during the collection process.

As mentioned above, research has been underway worldwide into the environmental burden of paper, and research and development is underway into reducing this environmental burden. However, the issue of the trade-off between greenhouse gas emissions and water consumption has not yet been resolved. Given this, Seiko Epson Corporation has developed a new dry-type paper recycling technology. This technology consists of three technologies, "defibration technology" for decomposing used paper into each one pulp fiber, "sheet forming technology" for forming fibers again into a uniform sheet, and "pressing and binding technology" for increasing the fiber density and bonding pulp fibers to each other to create new paper. As a specific aspect, it is possible to reduce CO_2 emission and water consumption by this technology. Using this technology not only eliminates the need for both water disposal and drying processing, but because the machine using this technology can produce paper within the office, it also reduces the environmental burden from thte transport required during collection. The aim of this study was to use an LCA to analyze the environmental performance of this paper recycling technology.

1.1. Innovative Paper Recycling Technology (Development of the Dry Paper Recycling Technology that Realizes a New Office Papermaking System)

This chapter describes this newly developed dry-type used paper recycling technology. Figure 1 shows a schematic of this technology. This technology can be broadly categorized into three processes.

(1) "Defibration processing" that degrades used paper into pulp fiber.
(Figure 1 (A) Paper feeding section, (B) shredding section, (C) defibration section, and (D) selection section)
(2) "Binding processing" that mixes a bonding agent to increase strength, and then forms sheets.
(Figure 1 (E) Mixing section, (F) binding section)
(3) "Forming processing" that uses pressure and heat to form sheets of paper.
(Figure 1 (G) Pressurization section, (H) heating section, (I) cutting section)

Furthermore, processes other than those detailed above are classified as "others."

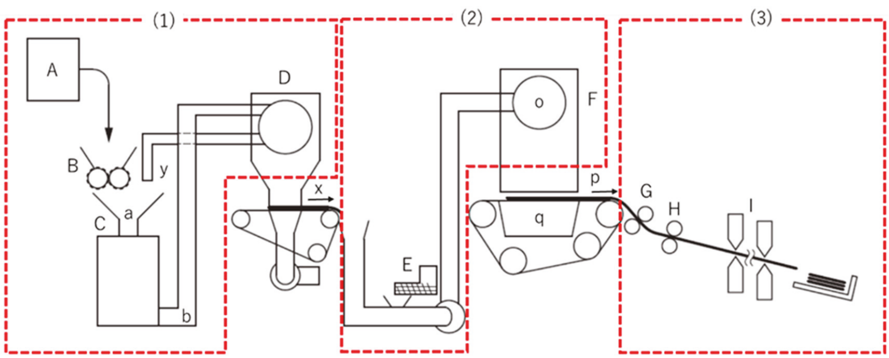


Figure 1. Dry-type used paper recycling technology process diagram ((1) Defibration process, (2) Binding process, (3) Forming process); (A) Paper feeding section, (B) Shredding section, (C) Defibration section, (D) Selection section, (E) Mixing section, (F) Binding section, (G) Pressurization section, (H) Heating section, (I) Cutting section, (a) Insertion section, (b) Discharge section, (o) Rotating sieve, (p) Mesh belt, (q) Suction mechanism, (x) Following process path, (y) Return path.

1.1.1. Defibration Processing

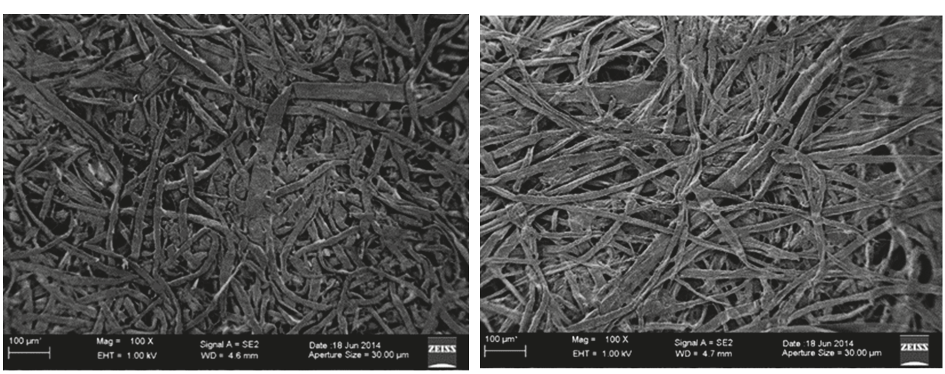
First, the used paper raw material is fed from the paper feeding section (A) to the shredding section (B). Next, in the shredding section (B), this is cut to a size of several millimeters to several centimeters, and then carried to the defibration section (C). In the defibration section, the cut paper is mechanically impacted to weaken the links between the fibers without shredding them. The aim of this procedure is to ensure the strength of the final paper product, and ensure it is uniform and free from unevenness. The defibration section (C) ensures that most of the fiber is evenly flocculated, but some remains uneven. Accordingly, there is a selection section (D) after the defibration section, and the fibers are selected by passing these through a sieve. The uneven fiber is returned to the defibration section (C) using the return path (y), and then is reprocessed to make it even. This minimizes fiber degradation, enabling continuous defibration and feeding to the binding processes.

1.1.2. Binding Processing

In the mixing section (E), material degraded into fiber in Section 1.1.1 is combined with fiber, and pneumatically fed to the binding section (F). In the binding section (F), the material is dispersed using a rotating sieve (o) comprising a cylindrical mesh, and the fiber is discharged at a constant speed and then deposited on a moving mesh belt (p), thus allowing the continuous formation of sheets. In order to continuously form sheets, it is important to ensure good dispersion of the fiber discharged from the rotating sieve (o) so that there is no difference in the density of the fibers on the belt. Additionally, reducing the size of the mesh in the rotating sieve (o) will make it is possible to prevent the discharge of fiber that is still clumped. However, a mesh size that is too small will make it difficult for the material to pass through the sieve, resulting in the sieve becoming clogged by the fiber. The machine was designed to set the selection section (D) sieve mesh size smaller than the rotating sieve (o) mesh size, enabling the continuous production of quality sheets of paper.

1.1.3. Forming Processing

Forming processing increases the density of materials formed into sheets in Section 1.1.2, forming sheets of paper with the fibers bound together. In wet process paper manufacturing, hydroxyls in the cellulose form hydrogen bonds in the process that squeezes out water and dries the paper, thus binding together the fibers in the paper. For this dry-type technology, a powdered bonding agent was developed. Before binding processing, the bonding agent is mixed with the fiber through the mixing section (E), with the fibers in the sheet formed in the binding process having bonding agent applied. This has 1 to 3 tons of pressure applied in the pressurization section (G), increasing its density. After this, the heating section (H) as a whole applies approximately 3600 J of heat, fusing the bonding agent, and bonding the fibers together. We can see that this pressure means that paper manufactured with this method (Figure 2a) has a higher density with the pulp fibers bonded together when compared with conventional wet-type paper (Figure 2b). This technology that uses the dry-type process is recognized as providing the functionality required of PPC paper. Furthermore, the strength of the paper differs depending on the amount of pressure applied. Tensile testing of paper produced using this method showed results of 12 to 15 MN/m^2 (density of 0.7 to $0.8/cm^3$), which has been confirmed as a sufficient strength performance required for PPC paper.



(**a**) (**b**)

Figure 2. Comparison image from scanning microscope. (**a**) Dry fiber paper (DFP) produced with this method (SEM), (**b**) Commercial plain paper copier (PPC) paper (SEM).

2. Materials and Methods

2.1. Scope of Evaluation and Functional Units

This study applied the fundamentals of the LCA methodology to evaluate the environmental impact of dry fiber paper (DFP) made by a dry-type office paper-making machine (Figure 3 and Table 1) in Japan. LCA can handle hundreds of inputs and outputs at different stages, "cradle-to-grave", and provides for a means of comparing the impact of different products. In LCA, it is important to define the system being studied, and to determine the system boundaries to aid in narrowing down the elements of the lifecycle inventory. The lifecycle inventory consists of flows into and out of the system boundary. This section describes the functional unit, system boundaries, and data collection method used in this project.

This study covers paper produced using this newly developed dry-type used paper recycling technology. Substances evaluated were CO_2 emissions and water consumption. The main reasons for this are that CO_2 has been well covered by research up until now, and large quantities of water are used as raw materials and in the production of paper. The functional unit in this study was 1 ton of DFP, and raw materials, energy, manufacture, transportation, and waste treatment were based on this functional unit. Although the ISO 14040 and ISO 14044 standards define the LCA methodology, some necessary flexibility is left to practitioners during implementation, especially regarding the allocation methods and definition of the system boundary.

Figure 3. Dry-type office paper-making machine's external view.

Table 1. Dry-type office paper-making machine's main specifications.

Main Unit Size	External dimensions	4500 (W) × 3500 (D) × 1820 (H) mm
Main Unit Weight Overall	Weight	1750 kg
	Product service life	7 years Corresponds to approximately 9.68 million sheets of paper produced (operation at 8 h/day, 22 days/month, for 7 years)
Productivity	Number of sheets processed	915 sheets/64 gsm A4 per hour
	Number of sheets produced	720 sheets/90 gsm A4 per hour
Paper Production	Size	A4/A3
	Paper thickness (basis weight)	Plain paper: 90 gsm and up Thick paper: User-configurable in 10 stages, corresponding to 150 to 240 g/m^2
Environmental Conditions	Operating environment	12 °C–28 °C, RH 30%–70%
Power	Power specifications	3-phase 200 V AC

2.2. System Boundary

Figure 4 shows the system boundary. This study includes in its evaluation scope the flow from raw materials' procurement and manufacturing through to disposal. Details for each flow are as follows. Raw materials' procurement and manufacturing includes parts, unit replacement parts, and cartridge parts required in order to manufacture the main unit. Transport includes transport of the main unit, cartridges, and replacement parts, and usage includes consumption of electricity and water during the paper-making process. Disposal includes the environmental burden incurred from disposal of the main unit, and of the waste generated during the paper production process. However, it does not include the environmental burden from transportation for sales locations and transportation to disposal units, PPC paper being used to feed into the unit, or DFP manufactured by this product being re-fed into the unit.

The system boundary considers the upstream processes associated with DFP production, transportation, and disposal. Figure 5 shows a schematic representation of the system boundary used in this analysis. DFP production requires chemicals, including polypropylene (PP), calcium carbonate, adhesion bond, liquefied, electricity, and water, at various stages in its production.

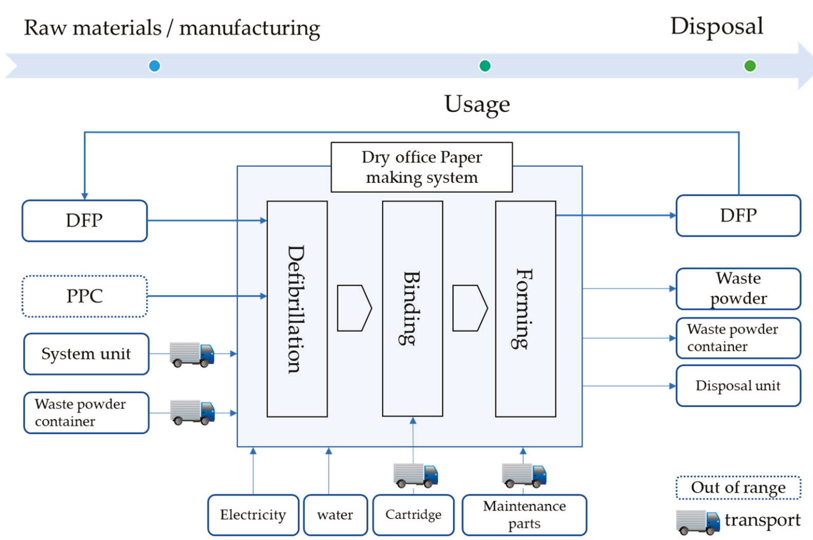


Figure 4. System boundary of the dry office paper making system. This system includes defibrillation, binding, and forming. Making the producing system, usage, and disposal of this system were considered in LCA.

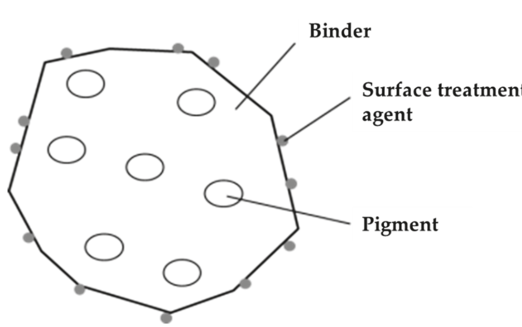


Figure 5. Bonding agent structure.

2.3. Database and Activity Data

CO_2 and water consumption were calculated using the following formula:

$$\text{Environmental burden} = \sum\left(\text{Activity}_i \times \text{Intensity}_{i,s}\right), \quad (1)$$

where "i" refers to articles, and "s" to substances that impact the environment (CO_2, water consumption).

In order to obtain the CO_2 emissions and water consumption results, we obtained basic units for the activity data and for the environmental burden.

The inventory analysis sums the emissions and calculates the consumption of energy, raw materials, water, chemicals, transport, wastewater, and solid waste treatment.

The inventory database used as the environmental burden basic units is as follows. CO_2 emissions by sectors were obtained from Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables (3EID) developed by National Institute for Environmental Studies (NIES) [23], CO_2 emissions by processes from Inventory Database for Environmental Analysis (IDEA) developed by the National Institute of Advanced Industrial Science and Technology [24], and finally the power generation inventory from the Agency for Natural Resources and Energy [25]. In the power generation results [25], the power company basic units and the amount of power generation are disclosed. This study used a weighted average of actual values from major power companies, creating and using power consumption basic units. Water consumption used the water consumption basic unit database developed by Ono et al. [26].

These databases were used to simulate the environmental burden. A generic database based on an input-output table was used to estimate the contributions of unavailable data. These databases were applied to the Japanese input-output table. 3EID covers the greenhouse gas emission intensity (CO_2, CH_4, N_2O, etc.) and the water footprint inventory database covers the water consumption intensity (total water consumption, rain, surface and ground water). Both databases have about 400 sectors. As the databases applied in input-output analysis are generally based on monetary data, we used the unit price list released by the Japanese government to convert these data into quantitative data for 3571 sectors.

The activity data for this study were provided by Seiko Epson Corporation, which is the largest DFP producer in Japan. The data year was 2018. Including components in the product body would increase the number of activity data items to several thousand, therefore these individual components are not listed individually. However, important items (power consumption for office paper-making machines, for the production of bonding agent, and for paper making) are listed below.

2.3.1. Office Paper-Making Machine

Information regarding the office paper-making machine main unit is categorized by the process (defibration, binding, forming), exterior, and common parts (Table 2). Furthermore, parts information for each unit is based upon that from the manufacturer of the office paper-making machine, with activity data obtained per part.

Table 2. Unit names and numbers of parts by process, exterior, and common parts.

Defibration		Binding		Forming		Exterior		Common Parts	
Unit Name	**No. of Parts**	**Unit Name**	**No. of Parts**	**Unit Name**	**No. of Parts**	**Unit Name**	**No. of Parts**	**Unit Name**	**No. of Parts**
Separator unit	103	Vaporizer	39	Cutter	1	Exterior	261	Shredding section	1
Defibration section	90	Bonding agent	126	Heating section	167			Main unit	651
Paper feeding unit	115	Mixing unit	39	Heater web CL	69				
Rectifying section	15	Sheet peeling unit	61	Tensioning unit	24				
Shredding section	42	Peeling and transferring unit	41	Paper ejection option	47				
Paper dust collection section	115	Sheet forming unit	185	Paper ejection (standard)	1				
Separation function	139	Former drum	120	Pressurization unit	212				
		Humidity control unit	96						
		Humidity control water supply section	83						
		Disposal collection section	136						

2.3.2. Bonding Agent

As detailed above, a bonding agent is used to bind paper fibers together, thus creating the paper. The bonding agent is a powder mainly consisting of a thermoplastic resin. For its structure, the binder contains pigments, with a surface treatment agent applied to the exterior surface of the powder (Figure 5). Its composition is shown in Table 3.

The manufacturing process for the bonding agent fully agitates and mixes together its raw materials, and then temporarily forms these into a mass. This mass is again pulverized, and then a functional surface treatment agent (for fluidity) as well as pigments (as necessary) are applied to the exterior surface. Figure 6 shows the bonding agent manufacturing process. Energy consumption and input/output data for all substances in all processes shown in Figure 6 were obtained from the primary supplier.

Table 3. Bonding agent composition.

Part Name	Material	Ratio by Weight
Binder	Thermoplastic resin	Approximately 90%
Others	Surface treatment agent, pigments, etc.	Approximately 10%

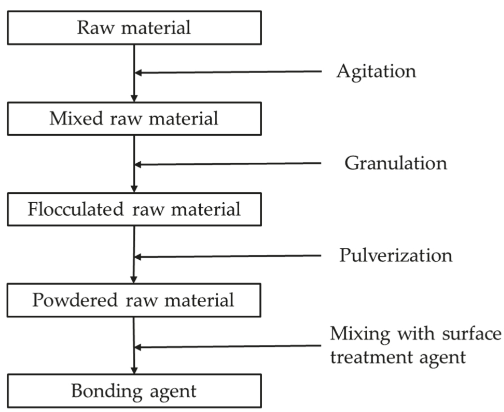


Figure 6. Bonding agent manufacturing flow.

2.3.3. Power Consumption at the Paper-Making Stage

This study measured the amount of power consumed as the basic unit for processes in the paper-making operation, from start-up and paper production through to shut-down, and applied these units for evaluation. As mentioned before, the electrical power consumption basic unit was calculated based upon data disclosed by the Agency for Natural Resources and Energy.

Figure 7 shows an example of the power consumption at the paper-making stage. Both start-up and shut-down take approximately 12 min, consuming a total of 0.74 kWh electricity. In total, 250 min of paper production produces 3040 sheets, consuming 21.75 kWh of electricity. As shown in Figure 7, variances in the power consumption in paper production are because of differences in the quantities of paper fed into the defibration section as well as in the quantities of materials returned from the selection section (separator drum unit) to the defibration section. From this, we can see that this series of processes consume a total of 22.49 kWh of electricity. Power consumption per sheet of paper is 7.40 Wh. Furthermore, these measurements were repeated three times, confirming their reproducibility (1st time: 22.50 kWh, 2nd time: 21.97 kWh, 3rd time: 22.62 kWh). The weight of DFP manufactured using this technology is 5.7 g per sheet, giving a power consumption of 1298.25 kWh (7.40 Wh/5.70 g × 1,000,000.00 g) per ton as the functional unit.

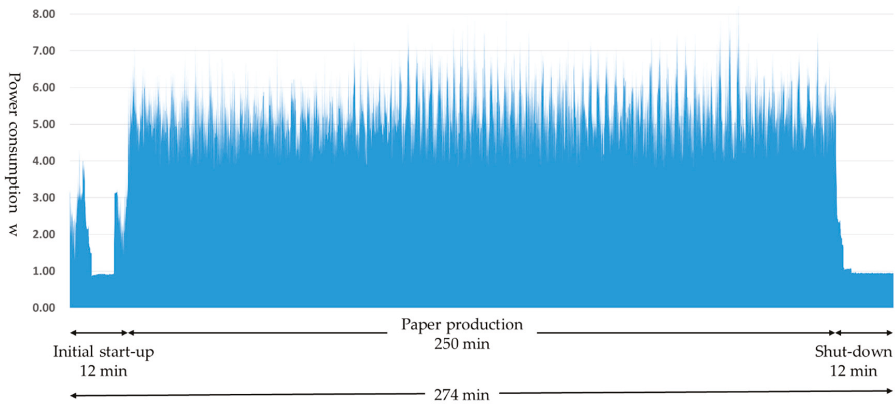


Figure 7. Example measurement results for power consumption.

3. Results

3.1. CO_2 Emissions

Figure 8a shows CO_2 emissions throughout the whole lifecycle. These results show 1449 kg-CO_2 per ton of paper. Looking at these emissions through each stage of the lifecycle, the discharge quantity in the usage stage had the largest influence on the results, comprising approximately 80% of the total. The next largest was the manufacturing of office paper-making machines, comprising approximately 10% of the total. In comparison to these, there was a low environmental burden for assembly and disposal, with each of these at below 5% of the total. CO_2 emissions for transportation were also relatively low, because the implementation of this technology means used paper within the office can be used to produce DFP, without the need to transport it to an external facility from the office. Focusing on the usage stage, there was a high environmental burden from the power consumption and the production of cartridges including adhesives, comprising 50% and 30% of the total, respectively.

Accordingly, Figure 8b shows a breakdown of the CO_2 emissions in the usage stage. Among the defibration, binding, and forming processes, the defibration process had the highest emissions, taking up approximately half of the total, because this process requires time to break down paper into fiber, and thus takes longer than the other processes. Additionally, binding processing and forming processing each comprise under 20% of the total, with a large impact from the binding section heater and from the heater used during forming. This study assumes usage within Japan, and therefore uses CO_2 emissions basic units corresponding to Japanese power generation. Accordingly, power structures and generation efficiency differ between countries and regions in which the product is used, meaning that CO_2 emissions will also differ widely depending on these parameters.

Next, Figure 8c shows a breakdown of the CO_2 emissions from the bonding agent cartridge. These results show a large proportion of CO_2 emissions from the production of polyester, a major component in the bonding agent. Accordingly, when looking towards further future reductions in the environmental burden, the important parameters are the efficiency of the defibration section and the reduction of the bonding agent quantity used.

Finally, Figure 8d shows a breakdown of the CO_2 emissions in the production stage. By process, this is defibration (9.7%), binding (25.7%), and forming (36.7%), with forming comprising the largest proportion. The reason that the forming process has the highest ratio is the large sizes of the pressurization and heating units used during manufacturing, with a corresponding large environmental burden from the procurement of these materials.

Next, the results from this study were compared with the case of recycled paper (Figure 9). To calculate the CO_2 emissions for recycled paper, CO_2 emissions until production used data from the Japan Paper Association [27], and emissions from transport and sales used data from Environmental

Hotspot Analysis (EHSA) [28]. It was shown that utilization of the dry-type paper recycling technology enabled a total reduction of 500 kg, or 26% in CO_2 emissions. In particular, this technology produced reductions in the environmental burden up until the procurement of pulp, and in the delivery and sales of the product. However, CO_2 emissions through the use of this technology in the production stage of DFP were comparatively high. Therefore, as shown previously, further study is required in how to reduce the environmental burden by reducing power consumption and the amount of bonding agent used.

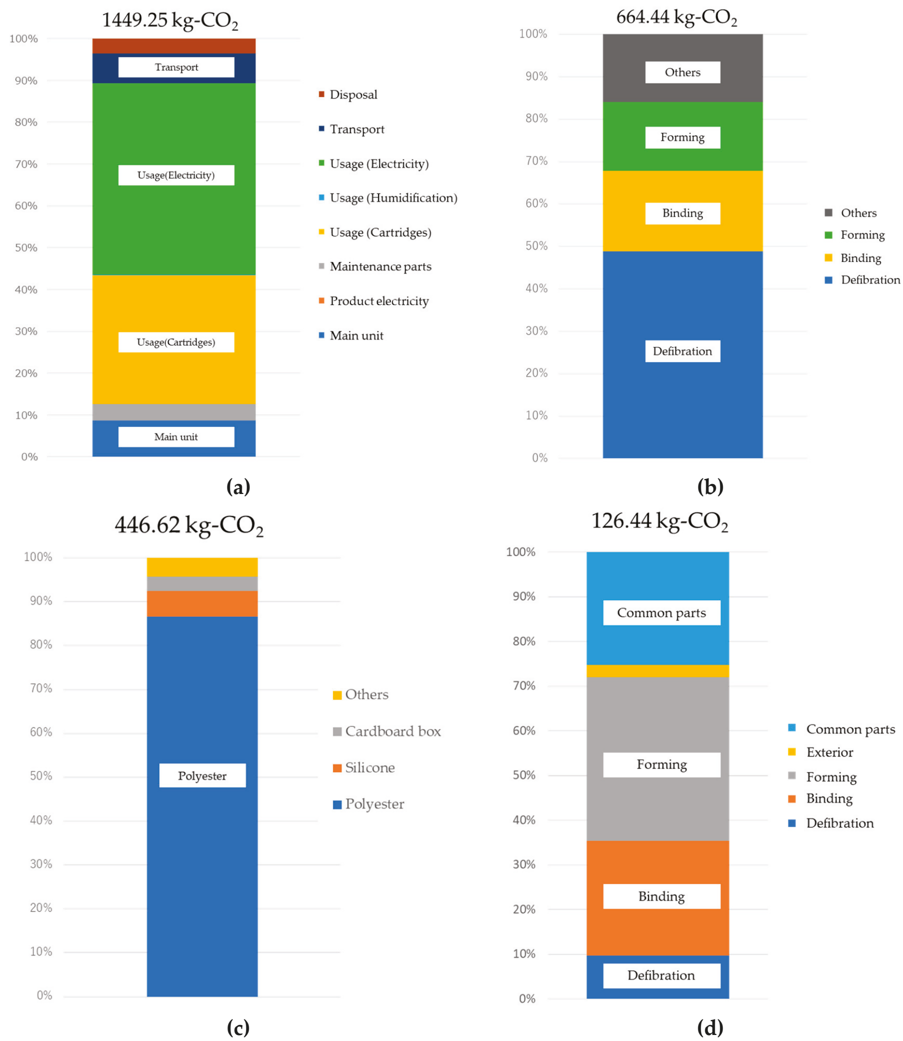


Figure 8. Office paper-making machine's CO_2 emissions calculation results: (**a**) Whole lifecycle CO_2 emissions and breakdown, (**b**) Power consumption breakdown at the usage stage, (**c**) CO_2 emissions breakdown with a focus on cartridges, (**d**) CO_2 emissions breakdown during the production stage.

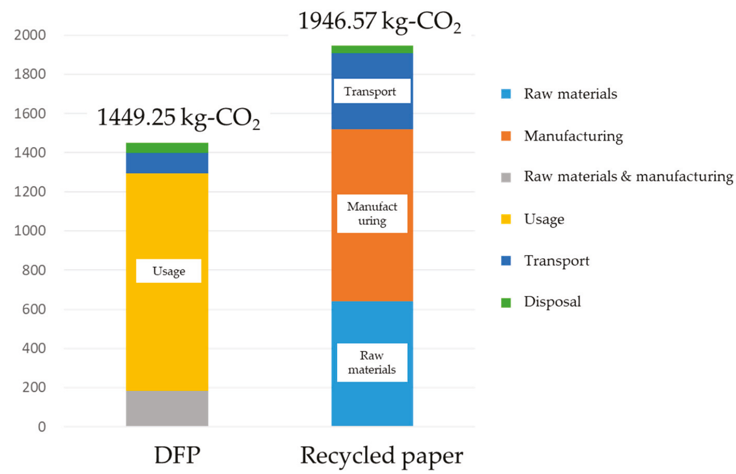


Figure 9. Comparative results in CO_2 emissions between the office paper-making machine (left) and recycled paper (right).

3.2. Water Consumption

In addition to CO_2 emissions, this study also focused on water consumption. Figure 10a shows the water consumption results when using this technology. Water consumption per ton of product is approximately 9 m^3, and as with CO_2 emissions, the usage stage was responsible for more than half of the total. However, the production of cartridges had high water consumption, rather than power consumption. Figure 10b shows a breakdown of the water consumption focusing on cartridges. As with CO_2 emissions, there was high water consumption (approximately 75%) until the production of materials with polyester as a main ingredient, with packaging and external additives around 10% each.

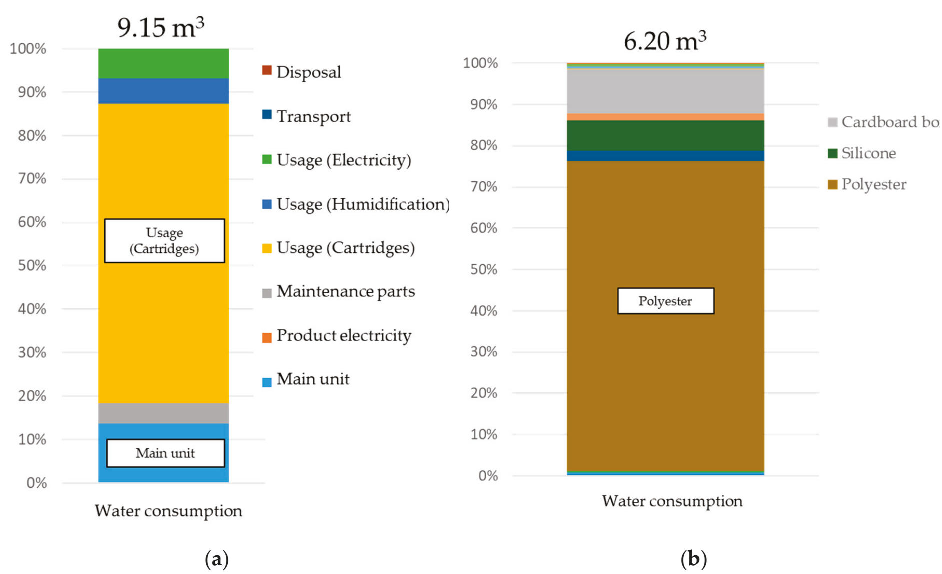


Figure 10. Water consumption for office paper-making machines (**a**) and with a focus on cartridges (**b**).

We compared the results above with existing studies (Figure 11). This comparison used data from the Japan Paper Association [27] and the Water Footprint Network (WFN) [22]. The WFN [22] has results for three types of printing paper (broadleaf, softwood, and eucalyptus), but as Japan mainly uses domestic and imported broadleaf, this study used the figures for broadleaf. Water consumption for the production of 1 ton of paper comes to 965 m^3. The water consumption from the distribution of PPC paper from Ono et al. [24] was added to this, giving a total of 983 m^3. Compared to the water consumption for PPC paper, that for producing 1 ton of DFP was approximately 9.15 m^3, roughly 1% of that for PPC paper. The reason for this is that printing paper requires large amounts of rainwater in order to grow wood and to produce pulp, whereas DFP reduces the consumption of virgin pulp. Furthermore, because it uses a dry-type production process, the water used during the production process is also significantly reduced. There is high water consumption during the production stage of wood and pulp, which comprise the raw materials used to make paper as well as during the paper-making stage, but this technology obviates the need for this production, thus limiting water consumption during the paper-making stage.

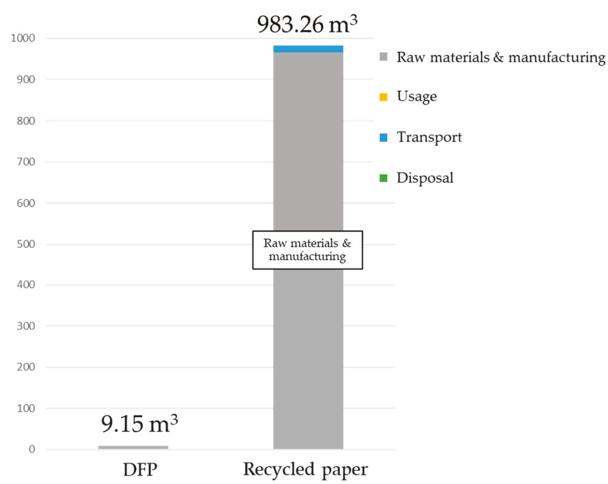


Figure 11. Comparative results in water consumption between the office paper-making machine and recycled paper.

4. Discussion

This study used the production of 1 ton of paper as its functional unit. Note that the environmental burden per unit will differ depending on the utilization rate of the office paper-making machines. Fundamentally, evaluations based on actual specification data are desirable; however, since this system has only just entered the market, there is insufficient data to set usage scenarios. Therefore, this evaluation was based on 8 h of operation per day.

This section evaluates the sensitivity of CO_2 emissions to variances in the product utilization rate. With 100% utilization set at 8 h per day, we ran simulations at between 10% to 100%, with results of the comparisons of CO_2 emissions for the manufacture of recycled paper (Japan Paper Association) shown in Figure 12. The lowest CO_2 emissions were obtained for the 100% utilization rate scenario, at 1449 kg-CO_2, whereas emissions for the 10% scenario were 2.8 times higher, at 3975 kg-CO_2. A breakdown of CO_2 emissions shows the environmental burden from cartridges as 31% and that of electrical power usage as 46% in the 100% utilization rate scenario, comprising approximately 80% of the total emissions in the usage stage. On the other hand, in the 10% utilization rate scenario, the manufacture of the main unit comprised 32%, transport 26%, and disposal 13%, with emissions in other than the usage stage comprising more than half of the total.

The reason for this is while the per-unit environmental burden for the production of paper at the usage stage is unchanged, that for manufacturing and transport changes, and becomes relatively higher as the utilization rate lowers. From the above, it is clear that effective reduction strategies will differ depending on how this technology is utilized by users. Usage of the office paper-making machine at the 100% utilization rate is expected to provide a reduction in CO_2 emissions of roughly 500 kg. However, lower utilization rates have a corresponding increase in per-unit CO_2 emissions, giving less of a reduction in the environmental burden than with recycled paper. The environmental burdens intersect at a utilization rate of 36%. Results showed that with a utilization rate above this, the office paper-making machine has a lower environmental burden, but with a utilization rate below 36%, the environmental burden increases. A utilization rate of 36% corresponds to approximately 3 h of usage daily. This should act as a guide for users who are anticipating using this product to reduce their environmental burden.

The study above clarified the following. Firstly, increasing the utilization rate can increase the per-unit environmental burden reduction effect. Therefore, it is important to promote usage of this technology as an alternative. There is a need to visualize environmental information and convey this to a wide range of stakeholders, including manufacturers, users of paper-making machines, and users of paper, and to strive towards increasing the collection rate for used paper. We need to communicate to not only manufacturers but also users of the office paper-making machines and of paper the fact that the utilization rate has a large impact on the overall results, and to increase the collection rate for used paper. Next, given that environmental burden reduction measures differ depending on the utilization rate, it is absolutely necessary that we fully understand the usage conditions of users. If there is a high utilization rate, there will also be high power consumption and burden from the usage of the bonding agent. Therefore, there is a need to make further energy savings and increase usage efficiency for the bonding agent, as well as to prioritize the usage of renewable energy. On the other hand, a low utilization rate means that the environmental burden from the manufacture of paper-making machines and from transport becomes relatively higher; therefore, this becomes an issue of reviewing raw materials, costs, and parts, as well as achieving efficiencies in delivery.

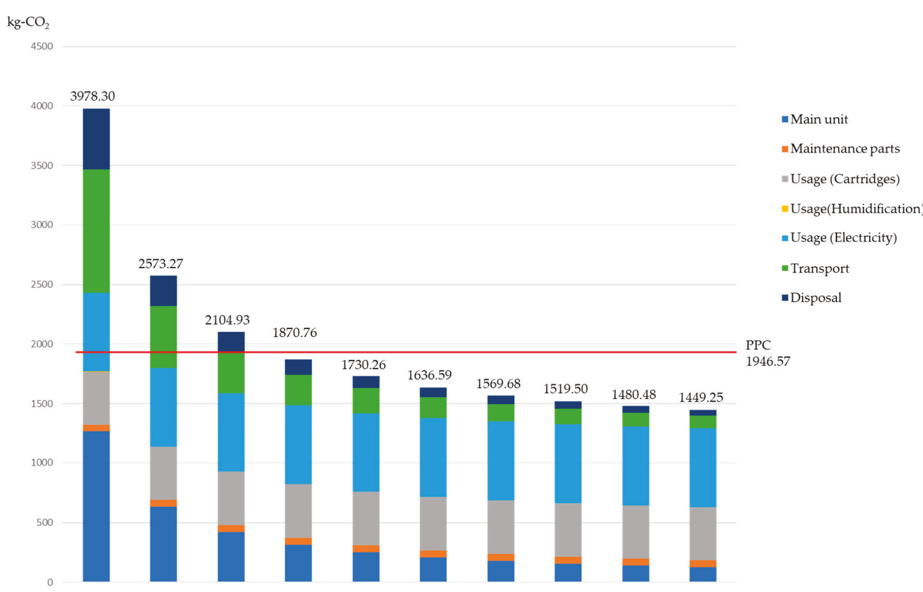


Figure 12. Sensitivity analysis and comparison when changing the utilization rate of the office paper-making machine.

5. Conclusions

Recycled paper has been widely used to reduce the land usage required for forestry; however, substantial consumption of energy and water is still required in the production of recycled paper, and this requires the development of further measures in order to reduce the environmental burden. This study focused on an innovative technology for the dry-type production of paper as developed by Seiko Epson Corporation. Using this technology not only eliminates the need for both water disposal and drying processing, but also by producing paper within the office, reduces the environmental burden from transport required for paper collection. The aim of this study was to analyze from an LCA perspective the environmental performance of this innovative paper recycling technology.

The study showed that the use of this technology enables a reduction of 26% in CO_2 emissions, and a 99% reduction in water consumption over similar general PPC paper. Focusing on CO_2 emissions, when compared to PPC paper, this shows a large contribution in reductions in the production and transport stages, and a large contribution to decreased water consumption attributable to reduced usage of raw materials. The CO_2 emissions results show that there is a high environmental burden from power consumption in the production and usage of cartridges. Therefore, further studies will need to look at making this technology more environmentally friendly, including considerations of the used quantities of and materials selection for the bonding agent used within the cartridge, as well as energy savings during usage. Additionally, evaluation results differ significantly depending on users' utilization rates. Therefore, it is necessary to convey information to the users of office paper-making machines and paper, and to improve the collection rate of paper. As a limitation of this study, this study was evaluated assuming that all processes were performed in Japan. Therefore, it is not right to compare with other countries' PPC paper. In case of comparisons, it is necessary to make evaluations using primary data, usage conditions, and an environmental load database in specific countries and regions.

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Dominant Consumer Attitudes in the Sharing Economy—A Representative Study in Hungary

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Abstract: As a result of the digital revolution, new business models are emerging, and one of the most dynamic is the sharing economy. In many cases, the strategic communication of sharing economy firms is linked to current socio-economic trends, such as digital innovation, consumers' empowerment, experience gaining (instead of stock), environmental awareness, and community building. In our research (a nationwide representative sample of 3520), we aimed to determine how open the Hungarian population is toward sharing economy services. Furthermore, we explored the relationship between openness and consumers' socio-demographic factors, attitudes related to the current consumer trends and Internet usage habits. As a result, we found that 38.4% of the Hungarian population is open toward sharing economy services. From a socio-demographic point of view, wealthy, metropolitan, family-oriented, educated, and younger people are more open toward sharing activities. In terms of consumer attitudes, people who take risks, like having a social life, are environmentally and health conscious, spend their leisure time actively, enjoy quality things, and have a positive attitude toward digitalization are more open to using the sharing economy services. As a final result of the regression modeling, we found that the examined consumer attitudes and Internet usage habits determine openness, but socio-demographic factors largely lose their significant effect, except for generation and wealth, in the case of the integrated model. Our results show that a well-defined and relatively large segment is open to the sharing economy, and sharing economy companies could target them directly to achieve a more sustainable environment.

Keywords: sharing economy; consumer behavior; consumer attitudes; sustainability

1. Introduction

The sharing economy is playing an increasingly important role in our daily lives, and there is a blurring of lines between the personal and commercial assets, consumers and producers [1]. Centuries ago, sharing activities could be found in society [2], and the question now is why this phenomenon began to grow dynamically. Many factors are contributing to this growth, but the development of digital technologies must be emphasized [3,4]. As a result of the digital revolution, people in the online space can find, pay for, and value each other's activities easily and quickly.

The sharing economy is present in every part of our lives, be it work or leisure. About a decade ago, sharing activities emerged that were later classified by the literature as part of new business activity. The best-known examples are Airbnb [5], which appears in the accommodation market, Uber in the passenger transport market [6], crowd-funding in the financing area [7], and TaskRabbit in the labor hire sector [8]. The phenomenon of the sharing economy or collaborative consumption can support sustainable consumption [8–12] which could have also long-term impacts. One of the benefits of sustainable consumption is the reduction of waste, and this is one way of effectively feeding back to consumers the direct relationship between consumption and waste production [13].

Many factors must contribute to the success of a new business model. In this study, we are looking for the reasons why consumers are increasingly choosing these types of services, and the factors that influence the consumers' openness to these new, alternative business models. Consumer behavior is most influenced by external impacts. These are part of marketing origin and are determined by the company's strategy. On the other hand, the wider environment also influences consumer decisions, such as cultural and social factors, reference groups, and personal factors. Thirdly, there are socio-economic trends related to as sustainability, social networks, digitalization, and globalization that also influence consumer behavior [14–16].

In our research, we looked for the consumer segments that are open toward sharing-based services. We analyzed openness in socio-demographic terms, consumer attitudes, and Internet usage habits. We assumed that the more sensitive segments of the socio-demographic trends would be more open toward sharing economy services, and we aimed to prove this hypothesis.

2. Literature Background

A few years ago, the sharing economy was defined the following way: "In the sharing economy users share with each other their idle capacities and resources (e.g., fixed assets, services, money), on an on-demand basis (as and when the consumer need arises), usually via an IT platform, on the basis of trust, ascribing particular importance to personal interaction and the community experience, with an eye on sustainability" [17].

In recent years, new elements or expressions of the sharing economy have emerged, highlighting different dimensions or major features of the phenomenon. It was written about by Botsman and Rogers firstly in a widespread book in 2010 called 'Collaborative Consumption' [18]. They wrote about sharing and redistribution activities among individuals. In 2011, Gansky wrote about a new corporate model called the 'mesh economy', in which he encouraged companies to share instead of selling (for example, in the automotive industry) [19]. Bardhi and Ekhard [20] formulated the spread of 'access-based consumption', where consumers prefer access to goods and are willing to pay for the possibility of temporary access rather than buying and owning the good. The term 'sharing economy' was first used by Friedman in 2013 [21]. Curtis and Lehner concluded the following characteristics, or semantic properties, of the sharing economy for sustainability: "ICT-mediated, non-pecuniary motivation for ownership, temporary access, rivalrous and tangible goods" [22]. Since 2015, the concept of the circular economy has come to the attention of European Union policymakers, and one of the model solutions to achieving this could be the sharing economy. Models of western Europe and east-central Europe may differ in several factors, but the size of the EU provides an opportunity to revise circular processes [23]. The phenomenon is constantly evolving and changing and therefore different dimensions can be distinguished. The first dimension is the subject of sharing, which could be physical goods (car, apartment) or non-physical goods (time, knowledge, money). The second dimension: differentiate between C2C (or peer to peer), B2C, or C2B models. The third dimension states that from monetization's point of view, we can observe, barter, or use business models in financial exchange [8]. In various combinations of these dimensions, we can find businesses that place themselves under the auspices of the sharing economy.

The sharing economy can be analyzed from a variety of scientific perspectives. From an economics' point of view, the sharing economy has a stimulating effect on competition and can be seen as a form of economic innovation [24,25]. From a business economics' point of view, the phenomenon is mentioned as a new business model [26,27], which is a kind of competitor to the enterprises operating in the traditional business model. In the new business model, the value proposition of the company who is operating the platform is to effectively combine supply and demand (a peer-to-peer business model). The value proposition is one of the main elements of the business models, next to the partner network, resources, distribution network, market segment, and value configuration [28]. Further studies have referred to the sharing economy as a new innovative business model that could be used as a potential tool for corporate sustainability [11,29] or as a resource-saving potential that which can change consumer patterns [12]. Most of the criticisms of the sharing economy come from the tax and legal perspective. Most experts agree that new, innovative activities should also be regulated, but there are differences of opinion regarding the depth of regulation. Some experts favor unified regulation for companies in a similar industry [30], while others argue that regulation should distinguish between traditional and new models [31–33]. From a human resource management perspective, we are also seeing a new phenomenon that is increasingly being called the 'gig economy' [34]. Within the gig economy, employees are not employing full-time (or even part-time) employees in the traditional, long-term contracted way, but are engaging freelancers, typically through an online platform, occasionally. Freelancers typically share their knowledge and/or time (as a graphic designer, web-designer, etc.). The advantages include flexible working hours and the possibility of working from home. [35,36], while the disadvantages are a lack of advocacy and social networking [37]. Kallenberg and Dunn [38] make the points that the gig economy opens up new opportunities. It is thought that casual workers still make up only a small percentage of the total workforce, but the gig economy may have important implications for the future. In a knowledge-based economy, intellectual capital is one of the most important factors that can help a company grow and be a success [39], and the gig economy supports the free flow of intellectual capital. Additionally, many experts believe the basic elements of social security (minimum wage, health care, retirement, and unemployment insurance) should be also available to gig economy workers. In many countries, there are critical issues of human resource management in the central and non-central regions [40], and the gig economy can potentially solve at least one part of the problem. From a sociological point of view, the changing behavior of consumers can be analyzed [24], and there is already a proposal for transformation towards sustainable consumption, called the sustainable consumption and production (SCP) transformation model [41]. A further suggestion is to engage users in innovation to develop a user integrated sustainable product service system (PSS) [42]. One of the biggest challenges today is to convince society to change its habits, to achieve growth to be sustainable, from an economic, social, and environmental point of view. This is an interesting challenge from a marketing point of view as well. Several marketing studies have identified the preferences and motivation of consumers who participate in the sharing economy, which include, among others, economic gains, enjoyment of the activity, sustainability, utility, familiarity [43,44].

Schor's study summarizes the critiques areas of the sharing economy, including sustainability, building a social community, taxation, insurance, and labor conditions, but she also notes that critics are too cynical sometimes and there are many opportunities in this new business model that are gaining ground [45].

2.1. The Relationship between Consumer Behavior and the Sharing Economy

This study aimed to investigate the extent to which the sharing economy affects consumer behavior and/or how expectations arising from changing consumer behavior meet the perceived or real characteristics of the sharing economy. In several cases, companies in the sharing economy have used communication keywords that are in line with current socio-economic trends (local space, environmental protection, experience, community, sustainability, etc.). We assume that companies in the sharing economy can succeed, among other things, because related services support current consumer expectations that are driven by megatrends. We assume that those people who are more open to using sharing economy services are also more sensitive to megatrends. Megatrends are trends related to global phenomena that have a significant impact on our daily lives over a long time horizon of 10–15 years [46]. Trends could be related to social, technology, and economy changes. From the perspective of the research topic, the following trends can influence consumer behavior: ICT (Information and Communication Technology) trends (empowering consumers), well-being society (consuming experiences instead of materials, need for self-realization), the eco-paradigm and sustainability (environmental sensitivity), globalization and urbanization.

2.1.1. ICT Trends

The information revolution enabled the rapid flow of information and ideas. The number of digital platforms and devices is exponentially growing [17]. There is not only one-way communication between companies and consumers anymore, but also two-way communication (more interactivity from the consumers side), and furthermore, consumers can communicate with each other on social networking sites [47]. According to Prahalad and Ramaswamy [48], several aspects can be observed in terms of the spread of the Internet and these also influence consumer behavior, for example, wide access to information, global vision, networking, and experimentation (product development, knowledge sharing). The progression of the sharing economy is based on the existence of the digital platforms and, within that, both on the demand and supply side, consumers can easily interact with each other. Due to the digital revolution, people are operating both in real and virtual space: consumer participation is growing, and consumer collaboration is gaining ground [49,50]. The possibility of virtual connection leads to the creation of new communities, allowing them to think together without face-to-face meetings. This growth in consumer power is also important from the sharing economy's point of view, and the digital community is gaining strength. A good example is crowd-funding, which is a new form of financing. In these cases, the implementation of a start-up company is not funded by a financial institution but by individuals. Furthermore, we can highlight another aspect of community power by developing open-source software and/or products. In the case of this activity, individuals share their knowledge. Knowledge and money sharing are usually classified as a sharing economy if there is an economic interest in the activity.

2.1.2. Impact of the Well-Being Society

To understand consumer behavior, it is important to recognize the level of the target groups using Maslow's pyramid (physiological needs, safety and security, love and belonging, self-esteem, and self-realization). Experiences lie at the top of Maslow's pyramid of need [51,52]. Due to the ever-changing environmental, technological, and sociological conditions, the significance of experiences is changing; the experience is becoming more and more important in the lives of consumers [53]. We can identify different areas of experience: entertainment, education, desire to escape, and esthetic experience [54] Furthermore, Uriely [55] notes the blurring of the perception of the differences between work and leisure. Typical motivational factors for traveling in a welfare society are: widening horizons, learning something new, enjoying communication with others, promoting creativity and openness, individual risk-taking, and experimentation [32]. Interpersonal sharing activities can be a new experience for many consumers, and this is something we are exploring in our research.

2.1.3. Eco-Trends and Sustainability

The focus was on sustainable development in 1987, when the United Nations World Commission on the Environment and Development published their work entitled 'Our Common Future' [56]. Here we find the definition that is still used today by many: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". There are three pillars to sustainable development, namely the economic, environmental, and social pillars. [57] Consumers sensitive to sustainable development are striving to become sustainable consumers, which has created the concept of conscious consumption. This may be related to the consumer's self-interest (price awareness, quality awareness, health awareness), or the interests of the public and society (environmental awareness, social awareness). Within this, we can identify the LOHAS target group, which is an environmentally and health conscious group (LOHAS = lifestyle of health and sustainability) [58], they are playing an increasingly dominant segment in many markets [59]. Sustainable consumption is increasingly important, including understanding the needs of consumers and persuading consumers. In the case of a vehicles' purchase, for example, it is an important factor that the consumer centric total cost of ownership could be cheaper compared to internal combustion engine vehicles and hybrid electric vehicles. [60] It is important to point out that several studies have confirmed that there is a difference between an eco-friendly attitude and real action [43,61]. Activities in the sharing economy basically might be a solution that can both support the right business model towards eco-friendly activities, and support the prevention of overproduction and/or overconsumption. We assume there is a connection between the conscious consumer's behavior, and the same consumer's openness toward the sharing economy.

2.1.4. Globalization and Urbanization

The globalization of markets has now become a reality including for standardized consumer products, multinational commercial cooperation, and distribution [62]. It has also impacted the tourism industry; tourists receive standardized services at the hotels in most places, and standardized products in many cities [63]. It affects consumer behavior as a counter-trend; sooner or later consumers will need individual, non-standardized products and services, and they will want to learn about local culture and local customs.

To sum up, there are some typical characteristics of consumers who have more of an affinity for social, technology, and economic trends: they like to be broadly informed, to be in the community (even virtually), focused on experiences, to be environmentally aware, and they prefer uniqueness and local characteristics.

2.2. Strategies and Communication Messages of Companies Operating in the Sharing Economy

In the following, we present the activities of some companies involved in the sharing economy and their communication strategies. Our aim is to show that companies in the sharing economy emphasize features in their marketing strategy and, consequently, in their communication that attract the attention of trend-sensitive consumers and thus make them more open to trying out new/alternative services. In recent years, there has been intense competition between companies in the sharing economy and those who are operating in the traditional industry. Typical examples could be the hotels versus Airbnb competition in the accommodation market, and the taxi companies versus Uber in the passenger carrier market. It has to be emphasized because, due to the reduction in transaction costs, a significant number of companies in the sharing economy are able to provide their services at a more affordable price (versus companies in the same industry), and this is the primary consumer motivation to use them [43,64], however communication strategy typically does not call attention to discount pricing, but to other attributes that fit consumer trends. Because of the combined effect of many factors, the sharing economy can be very successful, and technology-driven development is only one of many factors.

Airbnb is focusing on an authentic, local experience. Adventure tourism is becoming more widespread, and tourists, more and more, are seeking unique impressions. In 2015, a survey confirmed the fact, with 86% of Airbnb users saying they had used Airbnb because of encounters with locals [65]. Uber is focusing on human relations, personal stories, and trying to influence people's emotions. Lime is a vehicle sharing company in many countries, and their communication message is "sustainable—spanning countries & communities". In one sentence, they target three different trends: the environment, community, and globalization. Starterkit is a crowd-funding association, but they never explain that they lend money to start-up companies. Their stated mission is to help bring creative projects to life. Kaptár is a co-working place for freelancers in the capital of Hungary. They use the following keywords: community, inspiration and freedom, and central location. They do not rent offices, but rather an opportunity to build relationships, experiences, and inspiration.

3. Material and Methods

We had multiple aims for this study: firstly, we examined the openness of Hungarian residents towards sharing economy services and how customers' openness is affected by socio-demographic factors, different consumer attitudes (in particular, attitudes related to megatrends), and Internet usage habits. Based on our definition, those consumers who would use or definitely use or have already used sharing economy services are open toward sharing economy services; openness is willingness to participate. Secondly, we aimed to construct a logistic regression model, taking into account the factors identified above, to determine which attributes most influence openness toward sharing economy services, if we examine the effect of factors in a common model.

3.1. Consumers' Openness; Correlation between Openness and Different Socio-Demographic, Attitudinal, and Internet Usage Patterns

The survey was conducted on a nationwide representative sample of 3520 people in December 2017 in Hungary. Data were collected through personal interviews with interviewers. Key examined demographic factors that were asked were gender, economic status, marital status, age (generation), education level of the respondents, place of residence, and financial status. A total of 47.1% of respondents were male and 52.9% were women. According to the economic status of respondents, 56.2% were active workers, 27.9% were retired, 8.5% were students, and 7.4% had an inactive and unemployed economic status. A total of 17.1% of respondents have lived in capital city (Budapest), 21% of the respondents live in the county seat or county town, 33.1% live in another town, and 28.8% of the respondents live in the municipality. The respondents' financial situation was identified based on their assets and income. According to the classification, respondents were examined along with the following lines: lower (19.6%), lower-middle (20.7%), upper-middle (39.4%), and upper (20.2%). We also looked at the marital status of respondents. Here we have distinguished two categories, family and non-family status. Namely, the respondents with a child (ren) under 18 years were of family status. Based on this, 35.2% of respondents were the family category, while 64.8% of respondents fell into the non-family category. We also investigated the age of respondents: 3% of the respondents belonged to the Z generation (age 14–25), 37% to the Y generation (age 26–39), 31% to the X generation (age 40–59), and 28% to the Baby Boomers (age above 60). In terms of respondents' educational qualifications: 21.5% of them had a maximum primary school education, 26.9% had vocational qualifications, 31.7% had graduated from grammar school, and 19.9% had a university or college diploma (see in Table A1 in Appendix A).

Openness towards the sharing economy was examined as follows. We listed six different sharing economy services, and since the familiarity with these types of services is not necessarily specific, we described for each service what and under what conditions the service is provided, and then named the most typical companies for that activity. We then asked if he/she had ever heard of the service or considered using it if it was available to them. The detailed questionnaire is attached in Appendix B.

Services in the questionnaire:

1. Hotel reservation/accommodation (e.g., Airbnb, San Francisco, CA, USA).
2. Intra-urban passenger transport (e.g., Uber, San Francisco, CA, USA).
3. Ridesharing service between cities and/or countries (e.g., BlaBlaCar, Paris, France).
4. Sharing an electric car within the city (e.g., GreenGo, Budapest, Hungary).
5. Bike-sharing (e.g., MOL BUBI, Budapest, Hungary).
6. Sharing household items within a local community (e.g., miutcank.hu, a virtual community, Budapest, Hungary).

The services were chosen arbitrarily, but we also relied on the results of our previous, non-representative study [43], in which the listed services were relatively well known.

In the next step in the analysis, we combined the responses and focused on how many people in Hungary are generally familiar with sharing economy services and how many would use these services. Based on this aggregated data, we formed two groups: (1) Acceptors; if respondent said 'considers to use', or 'would definitely use' or 'have already used'—at least one service. In our study, 'acceptors' are those consumers who are open toward sharing economy services. (2) Refusers; who said in the case of each service that they 'would definitely not use it' or 'probably not use it'.

We then examined whether there was a correlation between the respondents' openness and different socio-demographic, attitudinal, and Internet usage patterns. We analyzed the effect of socio-demographic factors and attitudinal differences on openness to services by using a cross-table method and examined the effect of different Internet usage patterns on openness. The data were analyzed using SPSS software, version 23 (IBM Corp., Armonk, NY, USA).

Hypothesis 1 (H1). *From the socio-demographic data point of view, we assumed was that there is a correlation between examined socio-demographic factors and consumers' openness toward sharing economy services.*

From the *consumer attitudes* point of view, we assumed that those people who are more sensitive to current trends that impact consumer behavior are more open toward sharing economy services.

Hypothesis 2 (H2). *Environmentally and health conscious persons are more open toward sharing economy services.*

Hypothesis 3 (H3). *Those people—who like to be in the community—are more open toward sharing economy services.*

Hypothesis 4 (H4). *Those people who enjoy traveling while gathering experience are more open toward sharing services.*

Hypothesis 5 (H5). *Those people who are willing to pay for quality things are more open toward sharing economy services.*

Hypothesis 6 (H6). *Those people who believe that the digital world is a positive thing are more open to sharing economy services.*

Hypothesis 7 (H7). *Finally, we examined the habits of Internet users more narrowly. Our hypothesis was that those people who use the Internet more often are more open to sharing economy services.*

3.2. Logistic Regression Model

We constructed a *logistic regression model*. In this model, the dependent variable was openness. This assumes two values, that is, we classified people according to whether they are open (acceptor) or not. The explanatory variables (independent variables) were divided into three broad groups of the *Internet user population*: socio-demographic variables, attitude type variables, and a group describing Internet usage habits. We assumed that these various factors each have a significant effect on openness. At the current status, we did not test the correlation among the independent variable. In the final model, we examined if when these factors were taken into account together, which factors remained significant. This approach may, however, exclude potentially irrelevant factors from the model. The result will be a reduced version of the explanatory variables, which are the most important features of openness (Figure 1).

The national representative sample was reduced to the population using the Internet during the construction of the logistic regression model, because in most cases, sharing economy services can only be accessed using the Internet. The sample of Internet users is also representative of Hungarian Internet users. Within the total population, 49% of Internet users and only 11% of non-Internet users are open to this new type of service. If we had undertaken regression modeling for the entire population, then Internet users would have been most open to services and other attitudes would be been pushed into the background. Based on this, the demographic pattern of the Internet population was as follows: 2513 responded that they were engaged in activities on the Internet. Respondents were 48% male and 52% female. According to the economic status of the respondents, 70% were active workers, 11% were retired, 11% were students, and 7% had an inactive economic status (e.g., unemployed). A total of

35% of the respondents belong to the family category and 65% to the non-family category. We also looked at the age of the respondents; 24% of respondents belonged to Generation Z, 29% to Generation Y, 35% to Generation X, and 13% to the Baby Boomers. We also asked about the education of the respondents, according to which 12% of the respondents had primary education qualifications, 27% had a vocational education, 46% had graduated from grammar school, and 15% had a university or college diploma. A total of 19% of the respondents lived in Budapest, 23% in the county seat, 32% in the city, and 27% in the village. Their financial situation, based on their assets or their income, classified the respondents into four categories (lower, lower-middle, upper-middle, and upper). According to the classification, respondents were surveyed according to the following ratios: lower (16%), lower-middle (18%), upper-middle (43%), and upper (23%). This data is also available in Appendix A.

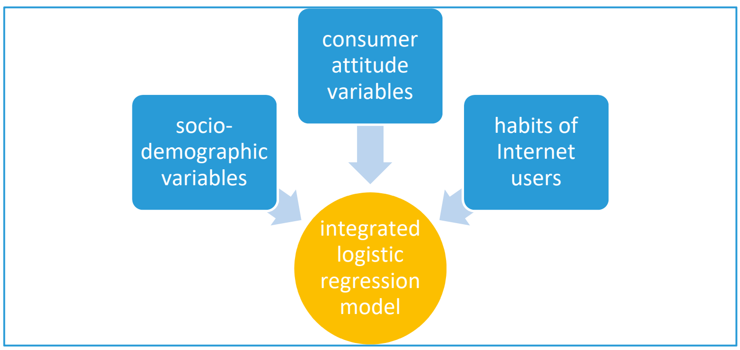

Figure 1. Structure of the logistic regression model, own editing.

During the regression modeling, we distinguished two phases. In the first phase, three separate models were constructed: one examining demographic factors exclusively, one examining consumer attitudes, and one examining Internet usage habits. Throughout the modeling, we worked with the ENTER method (all independent variables are entered into the equation in (one step), also called "forced entry"), so we did not filter for significant factors. Finally, in the second phase, to compare the effect of each group of independent variables, we constructed a complex final logistic regression model involving all independent variables, the results of which are presented below.

4. Results

4.1. Openness

Analyzing the responses of the Hungarian nationally representative sample, we found that at least 12% of people are open to one of the sharing economy services. A total of 12.3% of respondents said they were open to borrowing and lending household appliances. The ratio of the respondents who are open toward different sharing economy services (respondents who said 'would use', or 'would definitely use', or 'have already used') is: 12.3% for borrowing or lending household appliances; 15.8% for public car-sharing (e.g., DriveNow, Munich, Germany); 23.7% for public car ride-sharing (e.g., BlaBlaCar, Paris, France); 21.5% for private car-sharing within the city (e.g., Uber, San Francisco, CA, USA); 23.2% for public bike-sharing; and 20.1% for private flat-sharing (e.g., Airbnb, San Francisco, CA, USA).

We then aggregated the data according to the methodology described above, into the 'group of acceptors' and 'group of refusers'. Those who, for each question, answered that they would not use the service or may not use it, fell into the group of 'refusers'. Everyone else fell into the 'acceptors' group. Based on this, 38.4% of the Hungarian population is open toward sharing economy services

(11.3% open to one thing, 8.5% open to two things, 6% open to three things, 12.6% open to at least four), while 61.6% of the respondents are not open to sharing economy services.

4.1.1. Socio-Demographic Data versus Openness

The following socio-demographic features were examined: gender, economic status, marital status, age (generation), education, settlement type, and financial status of the respondent. Cross-table and pairwise correlation analyses were performed to determine whether socio-demographic factors influence openness (tested based on groups of acceptors and refusers).

Gender: the gender of respondents did not influence openness towards shared services. A total of 38.4% of the total sample was open toward sharing economy services (as acceptors), this included 39.8% of the men, and 37.1% of the women. The effect of gender is not significant ($p = 0.095$).

Economic status: Openness is overrepresented among active workers and students, with a significant relationship ($p = 0.000$, $Chi^2 = 318.4$ df = 3, Cramer's V = 0.301). While 38.4% of the total sample was open to sharing economy services, 46.7% of active employees and 56.8% of students were open to sharing economy services, meaning they were proportionally over-represented compared to the total sample. By contrast, only 15.5% of retirees were open to sharing economy services. Among the demographic factors examined in this study, the impact of this economic status was one of the strongest elements.

Family status: The family status of the respondent influences openness. Here, two categories were distinguished, namely, those respondents who had a minor child were considered as family subjects. The relationship is significant ($p = 0.000$, $Chi^2 = 48.346$ df = 1, Cramer's V = 0.117). We found that families are more open toward sharing economy services. While 38.4% of respondents in the full sample were open to the sharing economy services, 46% of respondents with a family were open to these service.

Generation: Belonging to particular generation influences openness. The correlation is significant, and it is the strongest influencing factor among the examined factors ($p = 0.000$, $Chi^2 = 361.001$ df = 3, Cramer's V = 0.320). The Baby Boomers is negative, 84% of this generation refuse sharing economy services (significantly overrepresented), compared to a rejection rate of the entire sample of 61.6%. Furthermore, we found that while 38.4% of the population in the total sample is open to shared services, the proportion of those showing openness within the Y and Z generations is higher (Y: 53.9%, Z = 52.4%), which means that these generations are much more open to using sharing economy services.

Education: Educational level influences openness. The effect is significant, though the relationship is weaker than the previous indicators ($p = 0.000$, $Chi^2 = 144.715$, df = 3, Cramer's V = 0.203). Within the group who are open to sharing economy services (38.4%), those who have a graduation or university diploma are overrepresented (group with graduation: 45.4%, group with a diploma: 50.8%).

Residence: We found that the type of place of residence of the respondent influences openness; the relationship is significant but weak ($p = 0.000$, $Chi^2 = 26.077$ df = 3, Cramer's V = 0.086). A total of 38.4% of respondents were open to shared services, in which 37% of Budapest residents, 45.5% of residents of towns and cities with county seats, 38.9% of residents of smaller towns and villages, and 33.6% of residents of villages are open. Based on this, residents of county seats and cities with county rights are the most open to using the sharing economy services.

Financial situation: We found that the financial situation influences openness. The respondents were classified into four categories (lower, lower-middle, upper-middle and upper) based on their financial position. As a result of the cross-table analysis, we found that the higher the income category of the respondent, the more open they were to sharing economy services. The effect is significant, and the association is moderately strong compared to the other demographic factors examined in the study ($p = 0.000$, $Chi^2 = 227.786$ df = 3, Cramer's V = 0.254). More than half (56.3%) of those in the upper class, 43% of the upper-middle class, 28.9% of the lower-middle income group, and only 20.8% of the lower income group were open to sharing economy services.

In conclusion, the socio-demographic factors examined (economic status, marital status, age (generation), educational attainment, type of settlement, and financial status) do indeed influence openness to shared services, and only the gender of the respondent (male/female) does not affect openness. Based on this, our original Hypothesis 1 was rejected because we assumed that all the examined socio-demographic data would influence the openness.

4.1.2. Consumer Attitudes versus Openness

Nearly forty questions related to consumers' attitude were asked on the following topics: socio-relationships (extrovert vs. introvert, health and/or environmental awareness, risk-taking), leisure activities (frequency and type), product/service purchase attitude (price vs. quality), and attitudes toward the digital world. Factor analysis was performed on each of these four topics.

(1) Social Behaviors

The factor analysis resulted in thirteen observed variables aggregated into four factors. We identified the following factors: risk-taking factor, social factor, conscious factor, and recycling factor (Table 1).

Table 1. Factors of social behavior attitudes.

Social Behavior—Factor Analysis	Risk Taking Factor	Social Factor	Conscious Factor	Recycling Factor
It is important for me to stand out from the crowd and get noticed.	**0.801**	0.237	0.047	0.05
I am willing to pay for home cleaning to make my life more comfortable.	**0.777**	−0.157	0.155	0.117
I like to take risks.	**0.757**	0.287	-0.099	0.031
I always want to feel safe in myself.	**−0.52**	0.086	0.358	0.044
I like meeting new people.	0.177	**0.779**	0.12	0.103
It is important for me to fit in with my friends.	0.036	**0.77**	0.116	0.001
I like to help other people, even unknown people.	−0.052	**0.525**	0.284	0.477
I am conscious of my health.	0.129	0.095	**0.778**	−0.02
It is worth the extra effort to be environmentally conscious.	0.092	0.329	**0.668**	0.112
I cannot stand the mess at home.	−0.278	0.07	**0.647**	0.034
I like to spend most of my free time at home.	−0.401	−0.291	**0.418**	0.274
I do not always want new things, many times buying used products.	0.057	−0.091	−0.095	**0.844**
What I no longer need, but still is usable, I sell or give away.	0.082	0.331	0.185	**0.649**

Extraction method: rotated component matrix. The bold indicates which variables belong to which factor.

In future analyses, we will use these factors in relation to social behavior.

(2) Leisure Activity

We identified the following factors: the simpler daily leisure factor (friends, entertainment, computer games), and the higher quality leisure factor (e.g., museums, traveling, wellness programs, gastronomy tours). The results are shown in Table 2.

Table 2. Factors of leisure activity attitudes.

How Often Do You Do These Leisure Activities?	Quality Leisure Factor	Daily Leisure Factor
Visit to a museum, exhibition	**0.7**	0.293
Travel or vacation abroad	**0.694**	0.365
Wellness programs (e.g., sauna, massage)	**0.69**	0.307
Cooking for gastronomic purposes (so no housework!)	**0.626**	−0.015
E-book reading	**0.589**	−0.007
Meeting, chatting with friends	−0.01	**0.772**
party in club, disco, etc.	0.215	**0.72**
Computer activity (games, social networking on Internet, viewing emails, browsing)	0.196	**0.685**

Extraction method: rotated component matrix. The bold indicates which variables belong to which factor.

(3) Attitudes Related to Willingness to Pay

We identified the following factors: the quality-sensitive factor and price-sensitive factor (Table 3). Quality-sensitive factor means that people are willing to pay for quality, while the price-sensitive factor means that people compare the prices of products and the possibilities, and may not always choose the better quality.

Table 3. Factors of attitudes related to willingness to pay.

How Much Do You Agree with the Following Statement?	Quality Sensitive Factor	Price Sensitive Factor
I would love to pay more for better quality.	**0.821**	−0.081
I am willing to pay more for a product that is specifically tailored to my needs.	**0.79**	−0.149
I am happy to pay more for environmentally friendly products.	**0.781**	−0.007
I can only trust the leading brands.	**0.691**	−0.149
I always know what's new and cool.	**0.686**	−0.129
Brand name alone tells a lot about a product or service.	**0.656**	0.182
When shopping, I compare product prices and look for a really good deal.	0.143	**0.761**
Before buying, I look through the advertising newspapers and check out the promotions.	0.082	**0.757**
Price is more important than brand name.	−0.289	**0.743**
I always choose the cheaper product.	−0.393	**0.665**

Extraction method: rotated component matrix. The bold indicates which variables belong to which factor.

(4) Openness to the Internet

Finally, we looked at how people relate to the digital world and computers. Five questions were asked and only one factor was obtained using the factor analysis method. Related variables are presented in Table 4; we named this the digital factor.

Table 4. Attitudes toward the digital world.

How Much Do You Agree with the Following Statement?	Digital Factor
I can't even imagine life without the Internet.	0.875
On the Internet, one expresses himself more easily than in reality.	0.825
The computer is not for me.	−0.731
I try to be the first to try the latest developments.	0.687
I always prefer online shopping.	0.612

Extraction method: factor analysis, component matrix.

After dimension reduction, the factors were specified, and we examined the relationship between factors and openness to the sharing economy using an independent sample *t*-test. After generating and naming the factors, we examined whether there was a difference in factor scores between acceptors versus refusers. To do this, we measured the average of each group and looked for significant differences. In the case of the original variables, a higher numerical value means that someone was using the given function and a lower numerical value means that someone does not use that function. In this case, a lower average value indicates that the given factor is less typical for the group. Similarly, a high average value in a group indicates that the group is characterized by the use of elements belonging to that factor. The openness variable classifies people into two categories, so we tested the significance of the difference in means with two-sample *t*-tests. When presenting the results, we indicate the average of the factors in parentheses.

From the social relationship point of view, those people who are more open toward sharing economy services are:

- taking more risks (average of acceptors' group: 0.2; average of refusers' group: −0.13);
- those who prefer social events and meeting unknown people (average of acceptors' group: 0.07; average of refusers' group: −0.05);
- who are more health and environmentally conscious (average of acceptors' group: 0.35; average of refusers' group: 0.01).

We obtained a special result in terms of the recycling factor: average of acceptors' group: −0.01; average of refusers' group: −0.05. This means that the attitude toward recycling is similar for both groups. Here, we have to highlight that recycling attitude is only one element of environmentally and health conscious people's attitudes.

Taking into consideration all the results Hypothesis 2 was accepted, environmentally and health conscious persons are more open toward sharing economy services.

From the point of view of *leisure activity*, those people who are more open toward sharing economy services are:

- participating more often in a quality, active leisure activities, (average of acceptors' group: 0.35; average of refusers' group: −0.22);
- likely to be off during the week (average of acceptors' group: 0.47; average of refusers' group: −0.3).

Based on the results, Hypothesis 3 was accepted: those people—who like to be in the community and relax with friends—are more open toward sharing economy services. Furthermore, Hypothesis 4 was also accepted: those people who enjoy traveling and collecting experiences are more open toward sharing services.

Concerning the pricing of products/services, those people who are more open toward sharing economy services are:

- those who can and do pay for branded and/or quality and/or environmentally friendly products, (average of acceptors' group: 0.46; average of refusers' group: −0.28);
- who are not price-sensitive, do not search through promotional ads, (average of acceptors' group: 0.07; average of refusers' group: −0.04).

Based on these results, Hypothesis 5 was accepted: those people—who are willing to pay for quality things—are more open toward sharing economy services.

Regarding the perception of the digital world, those people who are more open toward sharing economy services (among Internet users) are:

- those who use the Internet, consider it as a part of their daily life, and buy online (average of acceptors' group: 0.5; average of refusers' group: −0.33).

Based on the results, Hypothesis 6 was accepted: those people—who believe that the digital world is a positive thing—are more open to sharing economy services.

Taking into consideration all the consumers' attitudes which were examined in the questionnaire, we identified that the characteristics of the group of acceptors are similar and parallel to the specific features of current megatrends. There is one interesting exception: the attitude toward recycling is similar for both groups. The price sensitivity attitude is more typical of the refuser group, but this does not contradict our basic hypothesis, price sensitivity is not a feature of current megatrends. The summary diagram is shown in Figure 2.

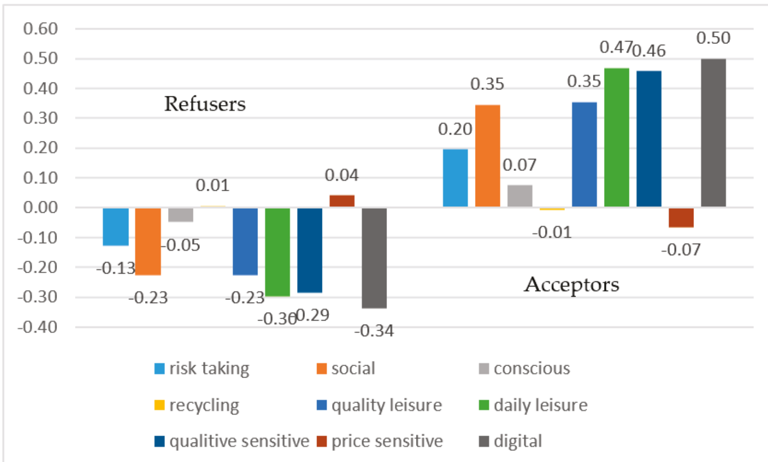

Figure 2. Different consumer attitudes versus openness toward the sharing economy, *Source: Own data collection and processing*, 2017.

4.1.3. Different Types of Internet Activities versus Openness (Subgroup, Analysis among Internet Users)

Internet activities could include simpler or more complex activities. We looked at the relationship between different Internet activities and openness (within the same two groups of acceptors and refusers). Of the total sample, 2534 used the Internet, and their answers were considered in the factor analysis.

In the questionnaire, 23 questions were asked about Internet activity. From these 23 variables, we created factors, by exploration, and there was no specified factor structure that we could confirm. Four factors were generated and the following indices were obtained: KMO (Kaiser-Meyer-Olkin) value is 0.909, which is above the expected value of 0.7, so the result is acceptable. The next item to consider was communality, where the value of each variable was above the threshold of 0.25, so no variables needed to be subtracted from the initial set of variables. The combined explanatory power is 49.36%, well above the expected level of 30%, so we consider the result acceptable.

The following names were given to the resulting factors:

Internet activities for entertainment—Related to the following Internet activities: on-line movie, streaming of films and series; downloading of films and series; downloading music; online radio listening; games; posts in forums.

Complex Internet activities—Related to the following Internet activities: on editing own blog; designing your website; home-based work; online photo hosting; on-line web hosting; e-learning.

Social Internet activities—Related to the following Internet activities: on online social sites; Internet chat, instant messaging programs; on-line video sharing; Internet phones, videophone.

Browsing, e-mail, purchase—Related to the following Internet activities: on work-related or private; browsing of websites (for information, entertainment); purchasing.

The results of the T-tests for the factors of Internet activity:

- entertainment factor ($t = -10.116$, df = 2112.266, $p = 0.000$);
- complex factor ($t = -3.485$, df = 2152.96, $p = 0.001$);

- social factor ($t = -8.633$, df = 2356.336, $p = 0.000$);
- browse—email–purchases ($t = -8.843$, df = 2360, $p = 0.000$).

After generating and naming the factors, we examined whether there was a difference in factor scores between acceptors and refusers. To do this, we measured the mean of each group, as before, and looked for significant differences. The results are presented in Figure 3.

- entertainment factor (average of acceptors' group: 0.2; average of refusers' group: −0.2);
- complex factor (average of acceptors' group: 0.1; average of refusers' group: −0.1);
- social factor (average of acceptors' group: 0.2; average of refusers' group: −0.2);
- browse–email–purchase (average of acceptors' group: 0.2; average of refusers' group: −0.2).

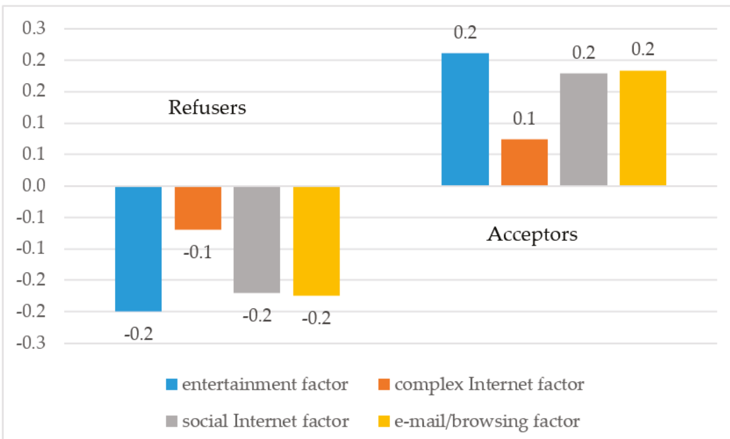

Figure 3. Internet usage habits versus openness toward sharing economy, *Source: Own data collection and processing*, 2017.

There is a significant difference in the means for all four variables. In each of the four cases, it can be seen that the acceptors' groups achieves a higher average, that is, all four activities are more typical for the acceptors' group. Observing the averages, it is worth pointing out that there is the smallest difference between groups in the case of complex Internet activities. Based on these results, Hypothesis 7 was accepted.

4.2. Logistic Regression Model

Finally, regression modeling was used to determine which of the various socio-demographic, attitudinal, and Internet activity characteristics had the greatest impact on openness. The use of the Internet greatly influences the openness towards the sharing economy, therefore we used only the population using the Internet in the regression model study.

First, we constructed the regression models one by one in the following order: socio-demographic, consumer attitudes, and Internet usage patterns.

4.2.1. Socio-Demographic Regression Model

We looked at gender, economic status, generational affiliation, settlement type, wealth segment, education, and family status. Based on this, *generational affiliation, financial status, and educational qualification* have a significant effect on openness, the results of which are also shown in Appendix C.1. The regression model, which is based on socio-demographic factors, has 60% explanatory power. That is, if we know the generational affiliation, income level, and educational background, we can determine with 60% good faith whether or not a person is open to sharing economy services. Within the generation factor, the Baby Boomers is the least open, and the X generation twice as open (exp (B): 2.048), the Y generation three times as open (W: 28.5, exp (B): 2.929), and the Z generation four times as open (exp (B): 4.121) towards sharing economy services, relative to the Baby Boomers. In terms of income level, respondents in the lowest income category are the least open, with the lower-middle 1.7 times, upper-middle 1.8 times, and upper income respondents 2.6 times more open. The third independent variable in the case of socio-demographic factors is education, which has a significant impact on openness. People with a primary education level are the least open, followed by vocational graduates (exp (B): 1.532), high school graduates (exp (B): 1.986), and university or college graduates (exp (B): 2.155). All the results are linked in Appendix C.1.

The aim of the regression model, in this case, was to find the most open target population along with socio-demographic factors. The results show that Generation Z people with a high income and college education are the most open, meaning they should be targeted by various marketing tools.

4.2.2. Regression Model Based on Consumer Attitudes

In our basic research, we investigated different consumer attitudes and, from the answers given to a significant number of behavioral questions, we identified the following factors: (1) social behaviors: risk-taking factor, social factor, conscious factor, recycling factor; (2) leisure activity: daily leisure factor and quality leisure factor; (3) attitudes related to willingness to pay: quality-sensitive factor and price-sensitive factor; and (4) openness to the Internet: we have only one factor. Examined individually, these factors showed a significant association with openness, and we now present the results of regression modeling. The aim was to determine which factor has an effect and how strong it is in this model. The regression model, which is based on consumer attitude factors, has 67.9% explanatory power.

Taking into consideration all the factors, in the case of regression modeling, the following factors show significant correlation with openness: social factor (exp (B): 1.256), product quality sensitive factor (exp (B): 1.271), both leisure factors (higher quality activities: exp (B): 1.738, and simpler activities: exp (B): 1.615), and Internet usage factor (exp (B): 1.514). This means that people who engage in more leisure time activities (travel, cultural programs, meeting friend, etc.) are more open to sharing economy services, and this is an even more important indicator than the frequency of Internet usage. The results are linked in Appendix C.2.

4.2.3. Regression Model Based on Internet Usage Patterns

In the previous factor analysis, we obtained four different factors for analyzing Internet use activities: (1) entertainment factor (watching movies online, downloading music, playing games); (2) complex activity factor (own blog, website editing, e-learning); (3) social factor (social networking sites, video sharing); (4) email, browsing, and shopping. Based on these factors, we have found that the more frequently respondents conduct these Internet activities, the more open they are to using sharing economy services. According to the results of the regression model, all four factors show a significant correlation with openness. Entertainment factor (exp (B)): 1.575), social factor (exp (B)): 1.457), and e-mail/browsing factor (exp (B)): 1.477) show similar strong openness. The regression model, which is based on Internet usage patterns factors, has 65% explanatory power. The detailed results are linked in Appendix C.3.

4.2.4. Integrated Regression Model

After examining separately the socio-demographic, consumer attitudes, and Internet usage patterns, we investigated which factors have the strongest effect in consideration towards sharing economy services. The explanatory power of all three models was above 60%, and several independent variables were significant in each model. To compare the effect of each group of independent variables, we built a large final model involving all the independent variables. The explanatory power of the integrated regression model is 69%.

Although in the first phase, many demographic factors and almost all attitude-type factors significantly explained openness, by putting all variables into one model, we can see that demographic factors lose most of their effect, whereas attitude-type independent variables retain it. Overall, it is more important to know people's attitudes and Internet habits if we would like to estimate openness, than to know their socio-demographic data. However, it is important to note that the two demographic factors (generation and financial status) that remain in the final model have a stronger impact than attitudes in general. Based on this, the following factors show a significant correlation with an openness toward the sharing economy: generation, financial status, and attitudes toward social events, quality sensitivity factor, both leisure activities factors and frequency of Internet usage factor. Within this, the most open target group is generation Z. Within generation Z, those who are the more open who like to travel, go to museums, do wellness programs, and enjoy gastronomic tours. The results are presented in Figure 4, and further detailed results are in Appendix C.4.

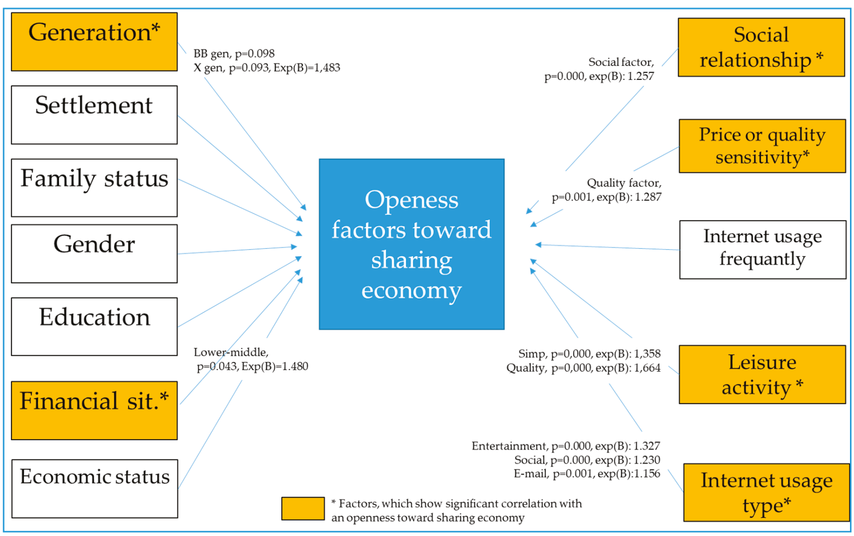

Figure 4. Results of the integrated logistic regression model.

5. Discussion and Conclusions

Sharing economy is a relatively new phenomena and brings up novelties in many scientific areas. Although we have carefully defined the hypotheses of our research and reviewed the related literature, our study has some limitations. At the time of the survey (end of 2017), some of the respondents had not even heard of these type of activities. In the questionnaire, we explained the different type of services in details, but it is still possible that someone responded to their intention to participate in sharing economy without fully understanding the nature of the services. Furthermore, to our knowledge, there is no uniformly accepted list of consumer trends, there are many changes that may become trends over time. The presented trends and the related attitudes have been arbitrarily selected. We have selected the trends that we believe are currently the most influential on consumer behavior.

Taking into consideration the limitation, in conclusion, there is a relatively high degree of openness among consumers around the use of sharing economy activities (38.4% of the Hungarian population). Among the motivations of consumers, preference is given to low prices, which would suggest that price-sensitive, less well-off consumers are the primary target group, and that they are more open to this type of service. However, the following elements appeared among the users as secondary motivational factors: experience gathering, digital payment opportunity, personal human relations, and sustainability aspects. These elements drew our attention to the fact that future users will not necessarily choose the service because of the price, but because they are more receptive to the present megatrends. In our national representative research, we wanted to support this hypothesis, which we succeeded in doing. Cross-table methods were used to investigate the correlation between openness and different socio-demographic and attitudinal correlations. Among other things, we found that it is not the price-sensitive and less affluent consumers who are most open to shared services, but rather well-off people. We also found that consumers who are more sensitive to megatrends are more open to sharing economy services. Further, people who are more environmentally conscious, like to spend leisure time with friends, for whom traveling is important to them, who like to gather experience in the local community, are willing to pay for quality things, and consider the opportunities offered by the digital world to be positive are more likely to be open to sharing economy services. Finally, we were curious as to which of the many socio-demographic, attitudinal, and Internet usage habits are the key elements that truly determine who are the most open to the sharing economy. The result of a logistic regression model showed that the strongest determinant is the consumer's attitude towards spending leisure time. The most open consumers are those who spend their free time in active recreation. We distinguished between quality and simpler forms of recreation that can be done daily. Both factors show a very strong correlation with openness. Additionally, generational affiliation, financial status, and Internet use frequency have become the most important determinants. That is, people of generation Z who are otherwise well-off and who like to spend their free time actively, and also who use the Internet more often than their peers, are the most open segment.

In recent years, some research has been looking for which factors may influence participation in sharing economy. Important statement that there is a gap between attitude and behavior related to participation in collaborative consumption [43]. Hamari et al. identified that participation in collaborative consumption is motivated by many factors such as its sustainability, enjoyment of activity, and economic gains [43]. Albinson et al. identified respondents' perceived sustainability as the strongest predictor of participation in collaborative consumption. Further factors are "trust, generosity, risk-seeking, materialism, power distance, long-term orientation, and collectivism" [66]. We have confirmed that perceived sustainability and the risk-seeking factor are relevant, and completed several factors related to leisure activities', social relationship's, price- and qualitative sensitive's, and digital behavior's attitudes.

Recognizing changes in consumer behavior is one of the most important factors in the long-term success of a company. The success of the sharing economy, among other things, can be achieved by offering opportunities and/or solutions that attract the consumer. With Airbnb, it is worth offering travel experiences instead of just accommodation, and sharing a community bike should be promoted not as a means of transport, but as an opportunity to protect the environment. Our results can also be used by companies operating in the traditional business model. There are some industries where traditional companies are threatened by the sharing economy firms (accommodation, travelling, creative agencies, financial sector, etc.). From one side, based on our results, they can identify the most endangered segments, from the other side, they can also use some elements of the mentioned success factors. There are already examples where traditional companies are taking over an innovation from a sharing economy company. Evaluation of the services from the users' side is already available not only at Airbnb and Uber, but currently several hotels are evaluated at least in some market places. This is related to consumers' empowering. Application was used firstly by Uber, where passenger could follow the ordered car, now a lot of taxi companies also use a similar application. This is related to the digital innovation.

In addition, one of the most important trends today is to do more to achieve a sustainable world. Several elements of the sharing economy offer opportunities for this, and it is our responsibility to make the most of this opportunity.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Socio-Demographic Data of Representative Sample, Total Base, 3520 and Internet User Base, 2513.

	Total Base (3520)		Internet Users (2513)	
Gender	**Frequency**	**Percent**	**Frequency**	**Percent**
Man	1660	47.1	1225	48.7
Woman	1860	52.9	1289	51.3
Total	3520	100	2513	100
Family	**Frequency**	**Percent**	**Frequency**	**Percent**
Family	1259	35.8	1112	44.2
Non-family	2261	64.2	1402	55.8
Total	3520	100	2513	100
Economic Status	**Frequency**	**Percent**	**Frequency**	**Percent**
Active workers	1977	56.2	1742	69.3
Retired	981	27.9	296	11.8
Students	301	8.6	300	11.9
Inactive	261	7.4	176	7.0
Total	3520	100	2513	100
Education Level	**Frequency**	**Percent**	**Frequency**	**Percent**
Primary school	750	21.3	333	13.2
Secondary school	937	26.6	604	24.0
High school	1120	31.8	942	37.5
University	712	20.2	635	25.2
Total	3520	100	2513	100
Residence	**Frequency**	**Percent**	**Frequency**	**Percent**
Capital (Budapest)	750	21.3	469	18.6
County seats	937	26.6	563	22.4
Other towns	1120	31.8	819	32.6
Municipality	712	20.2	662	26.4
Total	3520	100	2513	100
Financial Status	**Frequency**	**Percent**	**Frequency**	**Percent**
Lower	705	20.0	324	12.9
Lower-middle	719	20.4	392	15.6
Upper-middle	1387	39.4	1158	46.1
Upper	710	20.2	639	25.4
Total	3520	100	2513	100
Generation	**Frequency**	**Percent**	**Frequency**	**Percent**
Z (14–25)	550	15.6	529	21.1
Y (26–39)	776	22.0	713	28.4
X (40–59)	1135	32.3	922	36.7
Baby Boomers (60+	1059	30.1	349	13.9
Total	3520	100	2513	100

Appendix B. Questionnaire

Q1	In the Following, I Would Like to Ask if You Have Heard of Certain Types of Services. So, Have You Heard of the Possibility that . . . ?									
Q2	**What Do You Think, if You Needed such a Service and It Was Available to You, Would You Use It? Or Have You Already Used such a Service?**									
		Q1 Have you heard of it?			Q2 Would you use it?					
		Yes	No	NA	definitely yes	may be yes	may be no	definitely no	NA	Already used it
1	. . . Instead of a hotel room you can take a private apartment/room directly from the owner (e.g., Airbnb, San Francisco, CA, USA)	2	1	9	4	3	2	1	9	8
2	. . . transported within the city by a private individual instead of a taxi for a favorable pricing (e.g., Uber, San Francisco, CA, USA)	2	1	9	4	3	2	1	9	8
3	. . . carpooling allows you to enter empty spaces of others while traveling from one to another city for an agreed fee. (e.g., Oszkar, Budapest, Hungary; BlaBlaCar, Paris, France)	2	1	9	4	3	2	1	9	8
4	. . . .renting an electric car, using the system's own cars for a fee, then parking it and leaving it to someone else (e.g., GreenGo, Budapest, Hungary);	2	1	9	4	3	2	1	9	8
5	. . . possibility to use shared bike within the city" (e.g., MOL BUBI, Budapest, Hungary)	2	1	9	4	3	2	1	9	8
6	. . . Lending or borrowing household items (lawn mowers, bicycles, toys, etc.) to members of an on-line community (e.g., miutcank.hu, Budapest, Hungary)	2	1	9	4	3	2	1	9	8

Q3	Now I Read Statements that Others Have Made about Themselves. To What Extent Do You Agree with These Statements? There Is No Good Answer or Bad Answer, We Are Curious about Your Opinion. Please Respond Using the Statements on the Card.					
	I Completely Agree	**I'd Rather Agree**	**I Agree and Disagree**	**I rather Disagree**	**I totally Disagree**	**Don't Know/No Answer**
I always want to feel myself in safe.	5	4	3	2	1	9
I like to take risks.	5	4	3	2	1	9
It is important for me to stand out from the crowd and get noticed.	5	4	3	2	1	9
I'm conscious of my health.	5	4	3	2	1	9
I am willing to pay for home cleaning to make my life more comfortable.	5	4	3	2	1	9
I have to be very sick to go to a doctor.	5	4	3	2	1	9
I like to spend most of my free time at home.	5	4	3	2	1	9
It's important for me to fit in with my friends.	5	4	3	2	1	9
I can't stand the mess at home.	5	4	3	2	1	9
It is worth the extra effort to be environmentally conscious.	5	4	3	2	1	9
I like meeting new people.	5	4	3	2	1	9
I do not always want new things, many times buying used product.	5	4	3	2	1	9
What I no longer need, but still usable, I sell or give away.	5	4	3	2	1	9
I like to help other people, even unknown people.	5	4	3	2	1	9

Q4	How often Do You Do These Leisure Activities?	Several Times a Week	Once a Week	1–3 Times per Month	Several Times per Half a Year	Once per Half Year	Yearly or Less Frequently	Never	Don't Know/No Answer
1	party in club, disco, etc.	1	2	3	4	5	6	7	9
2	Travel or vacation abroad	1	2	3	4	5	6	7	9
3	Visit to a museum, exhibition	1	2	3	4	5	6	7	9
4	Meeting, chatting with friends	1	2	3	4	5	6	7	9
5	Wellness programs (e.g., sauna, massage)	1	2	3	4	5	6	7	9
6	Cooking for gastronomic purposes (so no housework!)	1	2	3	4	5	6	7	9
7	Computer activity (games, social networking on Internet, viewing emails, browsing)	1	2	3	4	5	6	7	9
8	E-book reading	1	2	3	4	5	6	7	9

Q5	Now I Read Statements that Others Have Made about Brands and Products. How Much Do You Agree with the Following Statement?	I Completely Agree	I'd rather Agree	I Agree and Disagree	I rather Disagree	I totally Disagree	Don't Know/No Answer
1	I am willing to pay more for a product that is specifically tailored to my needs.	5	4	3	2	1	9
2	I always know what's new and cool.	5	4	3	2	1	9
3	I'm happy to pay more for environmentally friendly products.	5	4	3	2	1	9
4	When shopping, I compare product prices and look for a really good deal.	5	4	3	2	1	9
5	I always choose the cheaper product.	5	4	3	2	1	9
6	Price is more important than brand name.	5	4	3	2	1	9
7	A brand name alone tells a lot about a product or service.	5	4	3	2	1	9
8	When shopping, I compare product prices and look for a really good deal.	5	4	3	2	1	9
9	I'd love to pay more for better quality.	5	4	3	2	1	9
10	I can only trust the leading brands.	5	4	3	2	1	9

Q6	Now I Read Statements that Others Have Made about Themselves. To What Extent Do You Agree with These Statements? There Is No Good Answer or Bad Answer, We Are Curious about Your Opinion. Please Respond Using the Statements on the Card	I Completely Agree	I'd rather Agree	I Agree and Disagree	I rather Disagree	I totally Disagree	Don't Know/No Answer
1	I try to be the first to try the latest developments.	5	4	3	2	1	9
2	The computer is not for me.	5	4	3	2	1	9
3	I can't even imagine life without the Internet.	5	4	3	2	1	9
4	On the Internet, one expresses himself more easily than in reality.	5	4	3	2	1	9
5	I always prefer online shopping.	5	4	3	2	1	9

Q7	In the Following, I Ask about Internet Usage Habits, Regardless of the Device (Computer, Smartphone, Tablet) or Where the Internet Is. How often Have You Been Online in the Last Month?
1	every day
2	several times a week
3	once a week
4	once or twice a month
5	did not use the Internet
9	don't know/no answer

Q8	Do You Use the Internet for Any of the Following Purposes on a Regular Basis?	Yes	No	Don't Know/No Answer
1	Browse websites (for information, entertainment)	2	1	9
2	Internet chat, instant messaging programs	2	1	9
3	Internet telephony/video telephone	2	1	9
4	Online Video Share Platforms (e.g., YouTube, San Bruno, CA, USA)	2	1	9
5	Online social networking sites (Facebook, Snapchat)	2	1	9
6	Watching Online TV	2	1	9
7	Watching movies online, watching episodes when you don't have to download a movie	2	1	9
8	Online watching/streaming of movies, series	2	1	9
9	Private e-mail	2	1	9
10	Work-related e-mail	2	1	9
11	E-learning	2	1	9
12	download of movies, series	2	1	9
13	download music	2	1	9
14	posts in forums	2	1	9
15	editing your own website	2	1	9
16	edit your own blog	2	1	9
17	online web storage (e.g., Google drive, Dropbox, OneDrive)	2	1	9
18	Online photo storage	2	1	9
19	Homeworking	2	1	9
20	Participation in distance learning	2	1	9
21	Online shopping	2	1	9
22	Listening online radio	2	1	9
23	Game	2	1	9

Respondents Data	
1	**What is your gender?**
	Man Woman
2	**Date of birth**
3/1	**Family status**
	Unmarried Married Divorced Widow
3/2	**Do you have a child?**
	Yes, under 18 Yes, above 18 No
4	**Educational level**
	Primary school Vocational school Grammar school College or university Don't know/no answer
5	**Economic status**
	Active workers Students Retired Inactive Don't know/no answer
6	**Place of residence**
	Capital (Budapest) County seats Other town Municipality Other
7	**Financial income**
7/1	**Net income**
	Amount Don't know/no answer
7/2	**How do you feel financially?**
	They live without problems They have to split the salary, but you get along well They are coming out of their monthly income Month after month they have financial problems Don't know/no answer
7/3	**Do you have car?**
	Yes No Don't know/no answer

Appendix C

Appendix C.1. Results of Regression Modeling of Socio-Demographic Characteristics versus Openness to the Sharing Economy, Own Editing

Regression Model of Socio-Demographic Data	B	S.E.	Wald	df	Sig.	Exp (B)
Baby Boomers			34.58	3.00	0.00	
X generation	0.72	0.20	13.35	1.00	0.00	2.05
Y generation	1.07	0.20	28.56	1.00	0.00	2.93
Z generation	1.42	0.35	15.95	1.00	0.00	4.12
Capital			12.04	3.00	0.01	
County seats	0.28	0.13	4.40	1.00	0.04	1.32
Other towns	0.08	0.12	0.39	1.00	0.53	1.08
Municipality	−0.14	0.13	1.12	1.00	0.29	0.87
Lower			40.66	3.00	0.00	
Lower-middle	0.53	0.16	11.18	1.00	0.00	1.71
Upper-middle	0.64	0.14	21.07	1.00	0.00	1.89
Upper	0.96	0.15	40.22	1.00	0.00	2.61
Gender	0.00	0.08	0.00	1.00	0.97	1.00
Primary school			19.45	3.00	0.00	
Secondary school	0.43	0.20	4.68	1.00	0.03	1.53
High school	0.69	0.19	12.82	1.00	0.00	1.99
University	0.77	0.20	14.47	1.00	0.00	2.15
Family	0.15	0.09	2.69	1.00	0.10	1.17
Active workers			2.69	3.00	0.44	
Retired	0.00	0.20	0.00	1.00	0.98	1.00
Students	0.33	0.20	2.69	1.00	0.10	1.39
Unemployment	0.04	0.17	0.04	1.00	0.84	1.04

Appendix C.2. Results of Regression Modeling of Consumer Attitudes versus Openness to the Sharing Economy, Own Editing

Factors	B	S.E.	Wald	df	Sig.	Exp (B)
Risk taking	−0.06	0.06	1.31	1.00	0.25	0.94
Social	0.23	0.06	14.04	1.00	0.00	1.26
Conscious	0.05	0.05	0.99	1.00	0.32	1.06
Recycling	0.09	0.05	3.13	1.00	0.08	1.09
Daily leisure	−0.55	0.06	96.34	1.00	0.00	0.58
Quality leisure	−0.48	0.07	47.41	1.00	0.00	0.62
Quality sensitive	0.24	0.07	10.66	1.00	0.00	1.27
Price sensitive	−0.09	0.06	2.80	1.00	0.09	0.91
Digital attitude	0.41	0.08	26.29	1.00	0.00	1.51

Appendix C.3. Results of Regression Modeling of Internet Usage Patterns versus Openness to the Sharing Economy, Own Editing

Factors	B	S.E.	Wald	df	Sig.	Exp (B)
Entertainment	0.45	0.05	97.22	1.00	0.00	1.57
Complex	0.17	0.05	12.25	1.00	0.00	1.18
Social	0.38	0.04	73.62	1.00	0.00	1.46
E-mail/browsing	0.39	0.04	77.42	1.00	0.00	1.48

Appendix C.4. Results of Integrated Regression Modeling

			B	S.E.	Wald	df	Sig.	Exp (B)
Socio-demographic factors	Generation	Baby Boomers			6.292	3.000	0.098	
		X	0.394	0.235	2.821	1.000	0.093	1483
		Y	0.501	0.245	4.177	1.000	0.041	1651
		Z	1.044	0.441	5.620	1.000	0.018	2842
	Settlement	Budapest			4.238	3.000	0.237	
		County seat	0.225	0.160	1.969	1.000	0.161	1.253
		Another town	0.101	0.153	0.431	1.000	0.512	1.106
		Municipality	−0.052	0.164	0.099	1.000	0.753	0.950
	Financial situation	Lower			5.692	3.000	0.128	
		Lower-middle	0.392	0.193	4.115	1.000	0.043	1.480
		Upper-middle	0.228	0.170	1.809	1.000	0.179	1.257
		Upper	0.074	0.189	0.154	1.000	0.695	1.077
	Gender	Gender	−0.021	0.107	0.040	1.000	0.842	0.979
	Education	Primary school			3.759	3.000	0.289	
		Secondary school	0.354	0.242	2.134	1.000	0.144	1.425
		High school	0.465	0.243	3.668	1.000	0.055	1.592
		University	0.406	0.259	2.458	1.000	0.117	1.501
	Family status	Family status	0.002	0.113	0.000	1.000	0.988	1.002
	Economic status	Active workers			0.451	3.000	0.929	
		Retired	0.086	0.252	0.118	1.000	0.732	1.090
		Students	0.018	0.246	0.005	1.000	0.943	1.018
		Unemployment	0.124	0.204	0.367	1.000	0.545	1.132
			B	**S.E.**	**Wald**	**df**	**Sig.**	**Exp (B)**
Consumers attitude factors	Social behavior	Risk taking	−0.039	0.062	0.384	1.000	0.535	0.962
		Social	0.229	0.065	12.428	1.000	0.000	1.257
		Conscious	−0.003	0.060	0.002	1.000	0.961	0.997
		Recycling	0.066	0.054	1.466	1.000	0.226	1.068
	Income	Quality sensitive	0.252	0.078	10.324	1.000	0.001	1.287
		Price sensitivity	−0.012	0.060	0.043	1.000	0.836	0.988
	Leisure time	Quality	0.184	0.092	3.945	1.000	0.000	1.664
		Simpler, daily	0.509	0.064	64.180	1.000	0.000	1.358
	Internet usage	Frequently of Internet usage	0.306	0.078	15.417	1.000	0.047	1.202
			B	**S.E.**	**Wald**	**df**	**Sig.**	**Exp (B)**
Internet factors	Internet usage type	Entertainment	0.283	0.056	25.832	1.000	0.000	1.327
		Complex	0.008	0.057	0.020	1.000	0.888	1.008
		Social	0.207	0.056	13.740	1.000	0.000	1.230
		E-mail, browse, purchase	0.145	0.057	6.550	1.000	0.010	1.156

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Example of a German Free-Float Car-Sharing Company Expansion in East-Central Europe

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Abstract: This study examines the expansion of a German free-float car-sharing company in Hungary from financial and sustainability perspectives. BMW and Daimler recently created the joint ventures ShareNow, ChargeNow, ReachNow, FreeNow, and ParkNow, which are having a significant global impact, as their services are now available in 14 different countries. We also expect further market development, since ShareNow started to operate in Hungary in May 2019. The whole EU market is just one step away from being covered by the same professional service, and the future might bring a real globally available free-float car-sharing service provider. Our review used a combination of two methodologies: financial statement-based business analysis and sustainability analysis. On the basis of this study, we concluded that these companies are primarily operated for profit and not on a sustainable operation basis. Additionally, it was also found that the current statistical data collection method does not measure precisely these activities. Financial reporting and sustainability reporting are connected, but they cover different areas. As a subject of further research, we suggest examining whether it is possible to establish a clear connection between these methodologies in the foreseeable future.

Keywords: Car2Go; DriveNow; GreenGo; MOL LIMO; sustainability; economies of scale; sharing economy

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1. Theoretical Background

The objective of this study was to examine the performances of free-float car-sharing entities in Hungary and compare them to those of their German counterparts from financial analysis and sustainability perspectives. On the basis of actual financial results in Hungary, they appear to be less profitable businesses compared to other rental service companies. Recently, Car2Go and DriveNow created joint ventures, which generated significant competition because they entered the Hungarian market in May 2019.

In Hungary, free-float car-sharing companies might follow different business models, which can cause unusual results. We also reviewed the available sustainability reports to define a possible connection to financial statements. Additionally, we tried to evaluate these companies from the sustainability perspective.

1.1. Business Model Review

The free-float car-sharing business model was categorized, defined, and described in a car-sharing business model review by Deloitte [1]. Since then, other studies reviewed the model and the markets itself, for example that of Munoz and Cohen [2]. Several studies raised sustainability-related questions regarding sharing economy models.

Reitmann and Lieven [3] examined how policy measures succeeded in promoting electric mobility in 20 countries by measuring the influence of monetary incentives, regulations, and charging infrastructure. Hartl et al. [4] addressed the gap between business-to-consumer (B2C) and peer-to-peer (P2P) car-sharing services from the customer's perspective. Overall, these previous studies on free-float car-sharing businesses support the initial assumption that these entities are profit-oriented, and their operations can be questioned from a sustainability perspective. From the business model perspective, in Hungary, there is a unique situation for free-float car-sharing companies, considering the impact of the international lease regulation changes. A wide range of studies, such as those of Wheeler and Webb [5] and Barone et al. [6], have provided summaries on the expected impact of lease capitalization and its effect on profitability and leverage ratios. Giner and Pardo [7] reviewed the value relevance of operating lease liabilities.

1.2. Sustainability Reviews

Sustainable business model (SBM) types were introduced to describe groupings of mechanisms and solutions that may contribute to building a business model for sustainability. Examples are: Maximize material and energy efficiency; Create value from 'waste'; Substitute with renewables and natural processes; Deliver functionality rather than ownership; Adopt a stewardship role; Encourage sufficiency; Re-purpose the business for society/environment; and Develop scale-up solutions [8].

Geissinger et al. [9] described and classified the sustainability connotation of sharing-economy platforms for Sweden. Indeed, sharing economy can be considered as a path towards sustainability [10]. Bernardi and Diamantini [11] explored how sharing economy, adopted by an increasing number of cities, may be integrated into the urban agenda, fostering its positive aspects (like decreased carbon emissions [12]), while avoiding its negative externalities, and focused, as examples, on Milan and Seoul. Ma et al. [13] proposed an alternative governance model to improve the effectiveness of a collaborative governance regime towards urban sustainability. Albinsson et al. [14] developed a two-dimensional sharing economy matrix for sustainability reviews, which focuses on collaborative consumption users vs. non-users in the US and Indian markets. Ma et al. [15] argued that the two-level transformations, triggered by the disruptive innovation of the sharing economy and led by urban change towards sustainability, mutually influence each other in the fast-changing urban context in Shanghai.

1.3. Sharing Economy Reviews

The emergence and rapid spread of the 'sharing' or 'collaborative' economy is one of the most significant social-economic challenges of our time. The success of the concept can be traced back to the economic crisis. It focuses on usage and not on owning goods. The debate over the regulation of the sharing economy has become polarized between those who are radically opposed to any intervention and those who favor some form of regulation (Table 1).

Table 1. Opinions on the regulation of the sharing economy.

Point of View	Authors	Main Messages
All interventions are rejected	[16–20]	Excessive regulation eliminates consumer benefits and efficiency gains. Using platforms reduces market failures.
Some regulation required	[21–28]	Innovative and intelligent regulation that enforces consumer protection without disrupting innovation. Certain areas of the sharing economy are suitable for regulatory intervention, others for self-regulation. Co-regulation: responsibilities are shared between government and industry. A new legal framework is needed to regulate the sharing economy, as according to the current legal framework many inadequate practices in the sharing economy do not require any regulation as they pertain to the private sphere.

Table 1. *Cont.*

Point of View	Authors	Main Messages
Strict regulation required	[29]	Taxation of sharing economy companies is possible by law, although questions about law application may arise. Everyone involved should be submitted to regulations (for example, in the case of car-sharing services, licenses issued to drivers, and identification of drivers).

Sharing economy platforms can be represented in a two-dimension matrix. The first dimension of the matrix classifies sharing platforms into for-profit (FP) and not-for-profit (NFP) activities. The second dimension follows the B2C–P2P axis [30]. Car-sharing business models are for-profit, B2C sharing economy platforms and therefore belong to group 4. (Figure 1).

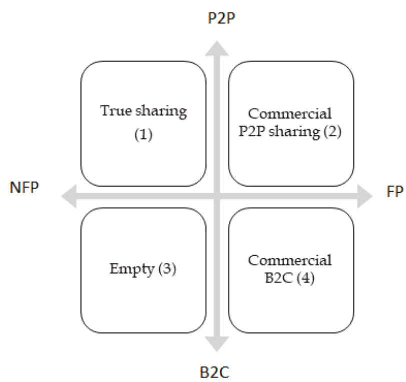


Figure 1. Two-dimensional sharing-economy matrix [31]. P2P: peer-to-peer, B2C: business-to-consumer, NFP: not-for-profit, FP: for-profit.

2. Materials and Methods

From the available financial and legal information, the following elements were reviewed:

- The list of entities in Hungary based on the principal operational activity code (TEÁOR) classification in the companies' court register
- Profitability review based on published financial statements
- Certain aspects of the lease accounting regulation and comparison between the International Financial Reporting Standards (IFRS) 16 Leases and the Hungarian Accounting Law
- Car-sharing companies' fleet size, car-sharing costs, opinions of registered users in Hungary and Germany.

Sustainability was reviewed on the basis of Penz et al. [32], exploring and explaining how, why, and when a sustainable operation is adopted and participation in the sharing economy becomes key, as well as how sharing economy models and sustainability (sustainable sharing economy, SSE) correspond conceptually in the collected articles. Seven sustainability aspects were addressed, of which four refer to car-sharing (Table 2).

Table 2. Sustainability aspects of car sharing.

Producing Less	
Idle Capacity and Under-Utilized Physical Assets	"As cars stand idle 95% of the time, any sharing scheme that makes cars accessible to non-owners would reduce the number of cars required for a given mileage level." [33]
Reduce Waste	
Resource Efficiency through Using rather than Owning	"Car sharing contributes to a more efficient and rational mobility (with a lower number of vehicles per capita among members, lower demand for parking space, lower fixed costs, and a complement to public transport." [34]
Extended Use Pattern	
Low Ecological Footprint/Low Carbon	"Carbon dioxide emissions and copper usage decrease with the diffusion of car- and ride-sharing services." [35]"With a lower consumption of physical and economic resources, car-sharing can also contribute to the reduction of energy and environmental impacts" Baptista et al. [34]
Own Less, Interact More, Build Social Capital	Different studies document the high impact of car-sharing on car ownership. [36]

3. Results and Discussion

3.1. Free-Float Car-Sharing Business Models in Hungary and Germany

Specific free-float service providers are defined as companies offering the service of car-sharing, i.e., the use of vehicles that can be rented and parked freely throughout the entire business area without having to determine the start and the end of the rental period in advance. The beginning and end of the rent are established for all vehicles through a specific smartphone application. Payment is based on usage and according to a fixed minute rate.

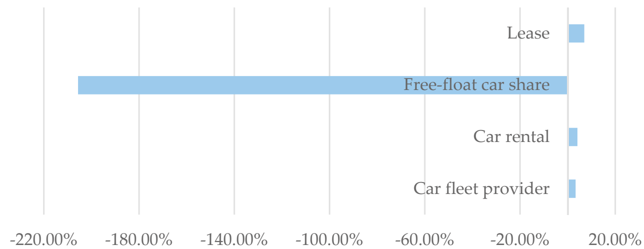
Comparing this market to the sharing economy review models, according to Codagnone and Martens [30] (Figure 1), free-float car-sharing entities are B2C entities focused on profitable operation, and this requires strict regulation (Table 1). This business model represents a different resource utilization with respect to P2P-based common sharing, which motivated us to perform a parallel profitability and sustainability review.

To accurately identify all key free-float companies, the complete database of the firm registry was reviewed, considering the defined principal operational activity of each company. This classification (TEÁOR'08) is "identical and fully harmonized with the European one, NACE Rev.2. Statistical Classification of Economic Activities in the European Community, 2008 (Nomenclature des activités économiques dans les Communautés européennes) [37]. Based on Regulation 1893/2006/EC, with effect from 1 January 2008, TEÁOR'08 is used to determine the principal activities of enterprises, in the calculation of economic and social indicators as well as for the publication of statistical data." The car-sharing activities are classified under Section "N" as administrative and support service activities, in division 77, group 77.1, and class 77.11 "renting and leasing of cars and light motor vehicles". From the registered Hungarian companies' database, 362 companies were identified. This analysis covers all Hungarian operational entities. In order to include recently established objects, all companies above 10 staff headcounts were investigated, according to the EU commission-defined categories. On the basis of a detailed review, 28 companies were identified, as presented in Appendix A (Figure A1).

According to the Hungarian Accounting Regulation Act C of 2000, in Hungary [38], companies need to file a financial statement by the end of the fifth month after the fiscal year. Consequently, the latest reports available were for 2017.

From Appendix A, on the basis of their financial statements, as of April 2019, only 2 companies out of the total 28 entities, i.e., #11 GreenGo Car Europe Korlátolt Felelősségű Társaság (hereinafter: GreenGo) and #20 MOL Limitless Mobility Korlátolt Felelősségű Társaság (hereinafter: MOL LIMO), were real flee-float car-sharing companies, and both operate in Budapest. This list contained all free-float service providers but did not represent the total lease market, because financial lease activities are classified in a different statistical segment, in section K Financial and insurance activities, divisions 64–66. It did, however, represent all non-micro-level free-float car-sharing companies. This is the consequence of the unclear current statistical data, which do not identify specific lease, rental, or free-float services. In the case of a larger population, it would be challenging to sort out such companies manually; sub-sections could be created to evaluate lease and rental services accurately in the statistical classification. In 2017 for Hungary, free-float car-sharing represented a 110.7 million Hungarian forint (HUF) (€358,300) market.

In the analyzed group from the profitability perspective, it was visible that the free-float car-sharing service providers delivered significantly worse results in Hungary compared to lease and rental service companies in 2017, as shown in Figure 2.



	Car fleet provider	Car rental	Free-float car share	Lease
Average Profit before tax / revenue	3.32%	4.10%	-205.65%	6.98%

Figure 2. Changes in asset structure, GreenGo (2014–2017 in EUR) [39].

To gain a better understanding of the situation, each Hungarian free-float service was separately examined and later compared to German service providers.

3.1.1. Financial Statement Analysis and Review of the Financing Model

GreenGo was established in 2014 as the first free-float car-sharing service in the Hungarian market, where it was the only market participant until 2017. The first day of real operation, when the company started to provide services, was in November 2016, with 45 electric cars.

From the financial perspective, the assets and liabilities of the company looked as follows. Assets: The long-term assets value continuously increased from HUF 69 M in 2019 to HUF 102 M on 2017, which consists of intangible assets of HUF 43 M, tangible assets of HUF 58 M, and other investments of HUF 1 M. This breakdown would give the reader important information if we included the published data from January 2018 when GreenGo reported 168 vehicles, which in case of purchase, should be recorded as property, plant, and equipment (PPE). It appears that HUF 58 M/168 vehicles = HUF 0.34 M (approx. €1060) per car is a very unreasonable figure. The only reasonable explanation is if the company applied operational leases, and these assets are off-balance-sheet financed items. Later in this review, this business model will be compared to that of the other Hungarian competitor. Below in Figure 3 is a summary table related to the asset items for the period 2014–2017:

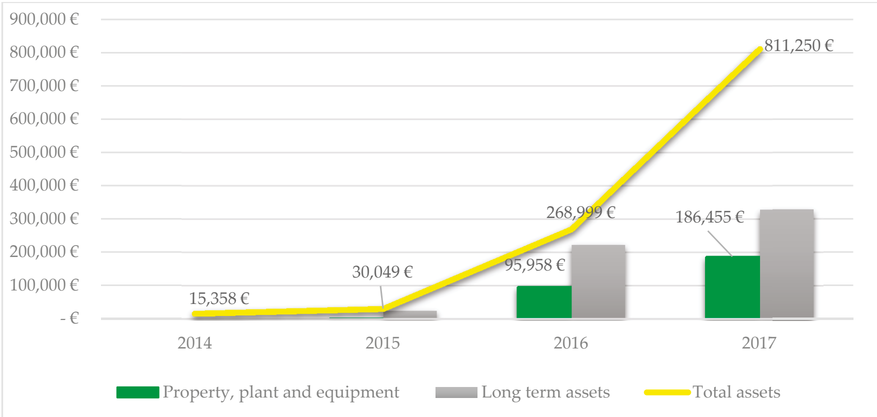


Figure 3. Changes in asset structure, GreenGo (2014–2017 in EUR) [39].

Liabilities, equity: The equity value remained relatively the same over 2016–2017, i.e., HUF 43 M; however, the generated loss increased significantly from HUF 18 M (€59,000) to HUF 158 M (€512,600), which was compensated by the equity contribution from owners. The debt/equity ratio also significantly increased in relation to the liabilities increase by HUF 129.3 M, mainly as a result of the short-term shareholders' loans of HUF 115 M and the long-term related parties' credit of HUF 16 M. Profit and loss statement: The realized revenue increased from the 2016 value of HUF 8 M (€26,000) to the 2017 value of HUF 111 M (€358,000), while the expenses increased from HUF 27 M to HUF 275 M. This was the principal reason for the generated loss as the company did not realize enough revenue to compensate for the increased material expenditures. Below in Figure 4 is a summary of the statement of profit and loss of GreenGo for the period of 2014–2017.

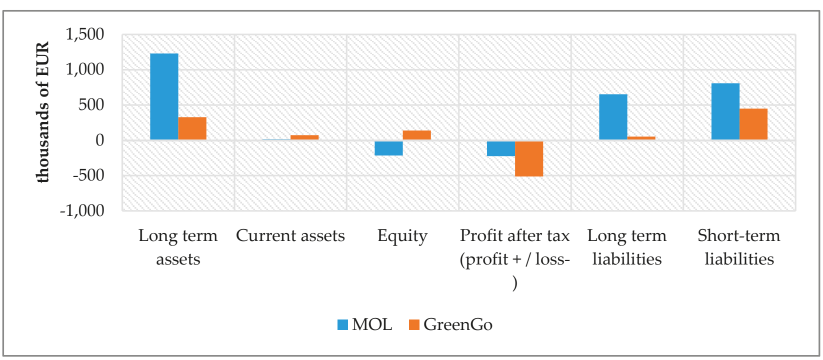


Figure 4. Comparison of assets and liabilities of MOL Limo and GreenGo (2017) [39]

In 2017, MOL Limo entered the market with secured funding from the listed Hungarian Oil-and-Gas Company (whereas GreenGo owners are private investors). MOL Limo market presence did not cause the reported increasing loss of GreenGo, because, in 2017, it did not realize any revenue. In Table 3, a comparison between the profit and loss statements of these two entities is presented.

Table 3. Comparison of the profit and loss statement for MOL Limo and GreenGo (2017) [39].

2017 Statement of Profit and Loss and Other Comprehensive Income (Data Translated to €)	MOL LiMo	GreenGo
Revenue	0	374,391
Results from operation (profit +/loss −) (EBIT)	−215,512	−484,509
Results from financial activities (profit +/loss −)	−9392	−27,408
Profit before tax (profit +/loss −)	−224,904	−511,918

MOL Limo generated a significantly higher loss compared to GreenGo, but 2017 was the year of its establishment, with a large scale of operation and considerable fleet investment, as presented in Table 3. The difference in asset value is related to a specific accounting regulation difference in lease accounting. MOL Limo prepared an IFRS-based financial statement, and GreenGo prepared a simplified national accounting-based financial report.

From the operation perspective, it is essential to mention that GreenGo only uses electric vehicles differently from MOL Limo. The total number of 400 electric vehicles operated by these two companies represents approx. 10% of the registered fully electric (excluding hybrids) cars in Hungary, as presented in Table 4. It should also be highlighted that hybrid vehicles increased more significantly in Hungary compared to fully electric ones from 2017 to 2018. This trend seems to continue and could be a subject of future investigation.

Table 4. Registered electric vehicles in Hungary and comparison MOL LIMO and GreenGo fleets [39].

Description	2017	2018
Registered number of vehicles in Hungary	3,471,997	3,641,823
Budapest total number of registered vehicles	633,554	659,513
Registered "green plate" vehicles in Hungary	4543	8482
Registered hybrid vehicles in Hungary	2414	4709
Registered number of electric vehicles in Hungary (5E category)	2129	3773
GreenGo fleet	168	300
MOL Limo electric fleet	100	100
GreenGo and MOL fleet electric vehicles	268	400
Car-sharing % of electric vehicles in Hungary	12.59%	10.6%

3.1.2. Lease Accounting Differences

Lease accounting is significantly different in the C Act of 2000 compared to IFRS. According to Hungarian Accounting Law (HAL) and IFRS, the definition of lease is different, and other fundamental accounting difference regard, for example, operating leases, which are not required by HAL to be recorded in the balance sheet, as shown in Table 5. Also, in the disclosure requirements, as in the HAL-based financial statements, operational leases only appear in the profit and loss statement.

Table 5. Comparison of operational lease accounting between the Hungarian Accounting Law and IFRS 16 from the lessee perspective.

Denomination	Hungarian Accounting Law		IFRS 16
	Finance Leases	Operating Leases	All Leases
Assets		—	
Liabilities	$$	—	$$$$$$$
Off-balance sheet rights/obligations	—		—

IFRS 16 key objective was to record the operational lease committed rights (rights of use, ROU) as assets and committed liabilities to reduce the off-balance sheet items. For the entities reporting under HAL regulation, this is not a requirement, and in case of an independent financial analysis or a credit strength testing, they can be invisible. The recorded off-balance sheet value can be significant from a creditor's or financial analysis' point of view. GreenGo reported under HAL regulation, where the operational leases as off-balance sheet items might create a business advantage from the presentation perspective because the leverage ratio does not show the total minimum of liabilities from the lease obligations.

3.1.3. Comparison to German Entities

Germany has the most significant car-sharing market in Europe, with several service providers and over 30,000 registered users, as summarized below in Table 6 in comparison to Hungary.

Table 6. Comparison of German and Hungarian entities' published users, fleet size, and serviced cities.

Provider's Name	Registered Users	Fleet Size	Service Available in the Number of Cities
Free-float car share providers in Germany			
Share Now (car2go and DriveNow)	3,000,000+	20,000+ out of 3200+ electric	31
Flinkster (DB)	315,000	4000	300
Cambio	77,000	1600	22
Stadtmobil	63,000	2600	100
Book N Drive	43,000	1015	14
teilAuto	35,000	1000	19
Free-float car share providers in Hungary			
GreenGo (HUN)	30–40,000	300 electric	1
MOL LIMO (HUN)	40,000	100 electric350 petrol	1

From this table, it can be concluded that German free-float car-sharing companies operate significantly larger fleets and have a substantially larger number of registered users in absolute terms. Hungarian companies operate only in one city, namely, Budapest, with a total of 750 vehicles for a 525 km^2 city area, where the population is approx. 1.75 M. In contrast, only one company, ShareNow, operates approx. 4000 cars in Berlin for an 891 km^2 city area with a 3.6 M population. For additional comparison, in the capital city in the region with the most similar population, Vienna, only ShareNow operates, with 2000+ vehicles for a 1.8 M population and a 415 km^2 city area.

The service fees can also be compared, because in April 2019, ShareNow announced to extend the operation in Budapest as well, with approx. 240 vehicles (of which, 40 electric BMW i3). Table 7 shows the fee and car type comparison.

Table 7. Comparison of free-float service costs between ShareNow, MOL Limo, and GreenGo (2019) [39–41].

Provider's Name	Service Fee	Car Type	Additional Conditions
ShareNow (BMW and Daimler)	from 99 HUF/min (0.32 cent/min)	Mini, BMW	38.7 €/h
GreenGo	from 65 HUF/min (0.21 cent/min)	VW Up	
MOL LIMO	from 66 HUF/min (0.21 cent/mind)	VW Up, Mercedes A class	

ShareNow provides services across the EU and, in 2019, established the most significant European fleet; additionally, it published a plan to invest further €1 billion. With 20,000+ vehicles, joint companies operate in 24 countries globally. It is only a matter of time to utilize the economies-of-scale advantage and provide service in all European countries. A coverage map for Car2Go and DriveNow is shown in Figure 5.

From the operation and financial analysis perspectives, an apparent market concentration is happening now in Europe, which is a successful business model. Without doubts, it supports sustainability; however, there is no core sustainability element in this business model. The more effective utilization of the resources has an impact on sustainability, but it is based on a usual corporate profit model.

Figure 5. Car2Go and DriveNow joint coverage.

3.2. *Sustainability*

From the sustainability perspective (Table 2), three statements (out of a total of seven) appeared in the official communications of the reviewed companies, presented in Table 8.

Table 8. Sustainability-related aspects of car-sharing [32,39–41].

Sustainability-Related Aspects of Car-Sharing	GreenGo	MOL Limo	BMW DriveNow	Daimler Car2Go
Resource efficiency through using rather than owning	There is less of an emphasis on parking infrastructure and road expansion		Digital parking service Park Now	The smart ForTwo can fit in almost any parking spot and can maneuver around even the most intense downtown rush hour traffic jams.
Low ecological footprint/low carbon	300 electric * cars	The VW MOL Limo fleet is 450-strong (100 electrical and 350 gas-powered vehicles)	900 Electric vehicles in Europe, 1300 in the USA	
	Shared cars are smaller than those in the average household.			
Own less, interact more, build social capital			Digital networking	Over 50% of Car2Go members do not own a car.

* Electric cars have two main advantages: unlike gasoline, electricity can be generated from various sources including renewable ones, and electric vehicles can reduce urban air pollution from road transportation. "However, while electric cars can reduce gasoline use, they increase electricity consumption. Depending on how the electricity is generated, emissions of particular air pollutants may reduce or increase" [42]. In Appendix B (Table A1), we list the vital sustainability-related statements from car2go and DriveNow sustainability reports; the reviewed sustainability reports are all related to Corporate Social Responsibility (CSR) orientation.

3.3. *Analytic Hierarchy Process*

To resolve the lack of reconciliation between financial and sustainability reporting, potential decision-support models, such as the analytic hierarchy process model, can be utilized to present the connection between the different reporting systems. It is crucial to determine the factors and to apply proper weights for the specific items. To measure impacts, the method of the analytic hierarchy process (AHP) was used, where the weights of the factors were identified in order from the most to the least significant from the investor decision's perspective.

When constructing the decision-making environment, it is crucial to identify issues or attributes that may be helpful [43,44], which brings the disharmony of traditional financial performance measuring attributes and sustainability aspects into perspective. The AHP theory aims to find the preferable alternative by weighing the priorities of the involved factors on a 1–9 scale (1: equal importance, 9: higher importance with respect to another component) and carrying out pairwise comparisons and standardization of the results to validate the overall ranking of factors [43,44]. Considering the findings of the current study, six elements were selected and weighed (w), as shown in Figure 6.

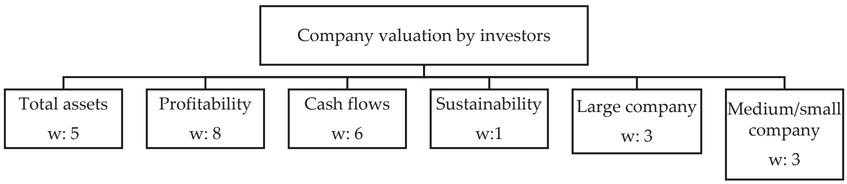


Figure 6. Decision factors and assumed weights.

In the analysis process, pairwise comparisons were developed for each criterion using linear integer scaling, summarized in a 6×6 matrix, which was then normalized using natural logarithms $(\ln(A))$ [45]. Using the AHP template and methodology of Goepel [46], the results were then averaged by rows, and the impacts were measured by the Eigenvector method (EVM). The summary matrix is presented in Figure 7.

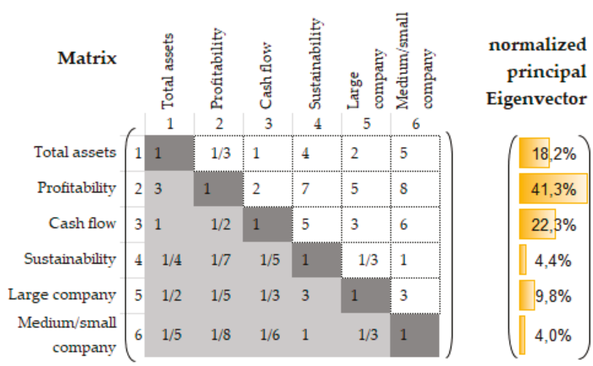


Figure 7. Summary of the analytic hierarchy process (AHP) matrix.

Additionally, the Eigenvalue (or λ, consistency measure), the consistency index (CI), the mean relative error (MRE) of the weights, and the consistency ratio (CR) were calculated [47]. If the Eigenvalue (the matrix product of normalized principal Eigenvectors) equals the sample size (6), perfect consistency can be identified ($\lambda = n$), which in our case corresponds to the value of 6.091.

The priorities pi in the input matrix were transformed into a near-consistent model using the EVM. In the pairwise $n \times n$ comparison matrix $A = a_{ij}$, where $\Omega_1, \Omega_2, \ldots, \Omega_n$ are comparable elements with a positive numerical value, the transformation procedure is as follows:

$$\left\{ \begin{array}{c} \Omega_1 \\ \cdots \\ \Omega_n \end{array} \right\} \xrightarrow{\text{measurement procedure}} \left\{ \begin{array}{c} w_1^{(1)}, \ldots, w_1^{(n)} \\ \cdots \\ w_n^{(1)}, \ldots, w_n^{(n)} \end{array} \right\} \quad (1)$$

with the use of EVM, the measuring procedure can be adapted to pairwise comparisons: $\sum_{k=1}^{n} a_{ik}w_k = \lambda_{max}w_i,\ i = 1, \ldots, n$, where $\lambda_{max}w_i$ are the principal Eigenvectors [48].

The normalization process is as follows:

$$p_i = r_1 / \sum_{i=1}^{N} r_i \tag{2}$$

The CI was calculated by:

$$\text{CI} = \frac{(\lambda - n)}{n-1} = 0.18\% \tag{3}$$

Error calculation of the priority vector w_i with the used EVM followed:

$$\Delta w_i = \sqrt{\frac{1}{n-1}\sum_{k=1}^{n}\left(\frac{n}{\lambda}a_{ik}w_k - w_i\right)^2},\ i = 1, \ldots, n = 19.0\% \tag{4}$$

In the CR, the Alonson/Lamata linear fit was used: $\text{CR} = \frac{\lambda - n}{2{,}7699n - 4{,}3513 - n} = 1.4\%$ [47].

From the hierarchical structure and from the potential AHP model presented in Figure 7, profitability remains the most significant factor in an investor company valuation with a normalized principal Eigenvector of 41.3%, followed by the cash flows (22.3%) and total assets (18.2%). From the investor decision's perspective, as long as sustainability reporting does not harmonize with financial reporting, the sustainability aspects tend to have a low impact factor (4.4%). In conclusion, the AHP statistical method is usable for the prioritization of factors, but it should be emphasized that the applied weights of the factors can be depend on subjective evaluations.

4. Conclusions

From the financial and sustainability reports, the following conclusions can be made related to the Hungarian free-float car-sharing market:

1. The market competition is increasing, and Hungarian companies have so far generated only losses from the financial statement's perspective and are not competitive with respect to their German counterparts. Market concentration seems to be increasing since the end of April 2019, when ShareNow started to provide services in Hungary. Additionally, we found that the reviewed companies follow a business model and not a sustainability model. Tóth et al. [49] defined truly responsible enterprises and developed a sustainability ranking model based on three key aspects i.e., local economic role, environmental impact, and social responsibility, which are measured on a five-point scale, ranging from destructive to sustaining operations. From the environmental impact and social responsibility perspectives, car-sharing entities may be considered even as sustaining or public-spirited entities, but with the international market concentration, their local economic role is reduced; solutions should be found to achieve a more sustainable operation.
2. From the statistical data collection's perspective, on the EU level, a separate car-sharing sub-category should be created because, at the moment, rental and lease companies are not separated in statistical reports.
3. In the reviewed sustainability reports, four areas were compared for Car2go and DriveNow, as follows: (a) new business model; (b) geographic expansion; (c) public transport; (d) electric vehicles. The basic idea of sustainable mobility is simple: "We need to shape our city mobility in such a way that the ease and safety of our everyday movements now and in the future will not diminish but grow, and the quality of life will not suffer but improve for us and for the generations to come" [50]. For sustainability achievement, three key areas can be defined as the targeted goals for the reviewed entities: (a) Efficiency of resource utilization, (b) Low carbon footprint, and (c) Build of social capital.

Sustainability reports in the examined sample cannot be connected to the financial statements, whereas harmonization is essential and should be a subject of future studies.

4. This study provides additional information and evidence regarding financial and sustainability report harmonization, confirming the "importance of environmental accounting on financial performance" [51,52] and policy development in the car-sharing industry.
5. Future research studies can focus on harmonization development between the different reporting standards and the next harmonization steps planned by the International Accounting Standard Board (IASB) in this area.
6. Considering the available information and the early stage of harmonization, this paper has certain limitations. We concluded that no clear connection exists between financial and sustainability reporting, but we could not precisely link those reporting standards; financial statements were only available until 2017.

Author Contributions: A.T. and C.S. initiated the study and performed the conceptualization, A.T. prepared the literature review, designed the methodology and collected the data, C.S. validated the results, A.T. and C.S. wrote the paper.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

#	Company name	Registered address	Establishment year	Employees	Data in THUF Revenue 2017	PBT 2017	Profit %	Key operation
1	ALD Automotive Magyarország Autópark-kezelő és Finanszirozó Korlátolt Felelősségű Társaság	1133 Budapest, Váci út 76.	2001	108	16 471 970	1 108 227	6,73%	Lease
2	ARVAL Magyarország Járműparkkezelő kft.	1113 Budapest, Bocskai út 134-146.	2002	46	9 598 635	976 847	10,18%	Lease
3	AUTO ReFAIRent Autókölcsönző és Szolgáltató Korlátolt Felelősségű Társaság	2220 Vecsés, Ecseri út 21.	2010	52	1 733 054	158 709	9,16%	Car rental
4	AVALON Car(e) Services Korlátolt Felelősségű Társaság	1142 Budapest, Tengerszem utca 106.	1989	24	371 938	29 593	7,96%	Car rental
5	BÉR-ELEK Flotta és Autópark Kezelő Korlátolt Felelősségű Társaság	1138 Budapest, Váci út 113.	2007	25	1 612 429	99 194	6,15%	Car rental
6	Business Lease Hungary Kereskedelmi és Szolgáltató Korlátolt Felelősségű Társaság	1124 Budapest, Csörsz utca 41. Gellért torony. ép. 3. em.	2003	29	5 351 868	376 017	7,03%	Lease
7	EuRent Autókölcsönző Kft.	1238 Budapest, Szentlőrinci u. 195853. hrsz.	1989	59	3 218 105	65 175	2,03%	Car rental
8	EuroFleet Gépjármű Flottakezelő Zártkörűen Működő Részvénytársaság	9111 Tényő, Kossuth L. u. 39.	2008	34	2 207 047	332 127	15,05%	Lease
9	Euroleasing Kereskedelmi Szolgáltató Korlátolt Felelősségű Társaság	1134 Budapest, Lőportár utca 24.	1995	56	561 959	3 304	0,59%	Lease
10	GAS-CAR Gépjárműkölcsönző, Autópark-kezelő és Szolgáltató Korlátolt Felelősségű Társaság	8600 Siófok, Fő utca 262.	1994	56	1 044 191	11 304	1,08%	Car rental
11	**GreenGo Car Europe Korlátolt Felelősségű Társaság**	**1075 Budapest, Rumbach Sebestyén utca 15.**	**2014**	**20**	**110 788**	**-158 291**	**-142,88%**	**Free-float car share**
12	HARUM INVESTMENT Gépjármű Üzemeltető Zártkörűen Működő Részvénytársaság	1118 Budapest, Rétköz utca 5.	1999	12	1 128 502	4 402	0,39%	Car fleet provider
13	IVANICS Autópark -kezelő Kereskedelmi és Szolgáltató Korlátolt Felelősségű Társaság	8097 Nadap, Haladás út 56.	2005	14	3 283 259	68 525	2,09%	Car fleet provider
14	KÉSZ&GO Flotta és Gépjárműkezelő Korlátolt Felelősségű Társaság	6000 Kecskemét, Izsáki út 6.	1993	13	1 195 742	39 497	3,30%	Car fleet provider
15	LAFUT Service Kereskedelmi és Szolgáltató Korlátolt Felelősségű Társaság	3527 Miskolc, Zsigmondy út 2.	2015	22	74 246	722	0,97%	Car rental
16	LeasePlan Hungária Gépjárműpark Kezelő és Finanszírozó Zártkörű Részvénytársaság	1113 Budapest, Bocskai út 134-146.	1994	95	22 451 936	2 082 167	9,27%	Lease
17	Mercarius Flottakezelő Korlátolt Felelősségű Társaság	1142 Budapest, Komáromi út 36-38.	1996	81	4 539 377	767 564	16,91%	Lease
18	Mercur Rent a Car Autókölcsönző és Szolgáltató Kft.	2220 Vecsés, Hertz u 2.	1995	80	5 498 329	291 926	5,31%	Car rental
19	Mobil Credit Kereskedelmi Korlátolt Felelősségű Társaság	4026 Debrecen, Bem tér 14. A. ép. 1. em. 3.	2000	14	1 272 146	116 266	9,14%	Car fleet provider
20	**MOL Limitless Mobility Korlátolt Felelősségű Társaság**	**1117 Budapest, Október huszonharmadika utca 18.**	**2017**	**32**	**0**	**-69 543**	**N/A**	**Free-float car share**
21	NELSON FLOTTALÍZING Eszközbérbeadó és Autóparkkezelő Korlátolt Felelősségű Társaság	8000 Székesfehérvár, Vörösmarty tér 1.	1992	38	2 917 894	139 365	4,78%	Lease
22	Otokoc Hungary Autókölcsönző és Szolgáltató Korlátolt Felelősségű Társaság	1134 Budapest, Kassák Lajos utca 19-25.	2015	29	2 031 185	-24 873	-1,22%	Car rental
23	Porsche Lizing és Szolgáltató Kft.	1139 Budapest, Fáy u. 27.	1993	54	29 728 668	1 047 108	3,52%	Lease
24	Rapid Rent Autó Kereskedelmi és Szolgáltató Korlátolt Felelősségű Társaság	1037 Budapest, Zay u. 24.	2011	25	529 054	1 067	0,20%	Lease
25	RELEASE Zártkörűen Működő Részvénytársaság	1054 Budapest, Zoltán utca 8. 2. em. 2.	2009	19	592 100	41 393	6,99%	Lease
26	UniCredit Leasing Kereskedelmi Korlátolt Felelősségű Társaság	1118 Budapest, Budaörsi út 64.	1995	24	1 206 524	-162 445	-13,46%	Lease
27	VR Transport and Rental Korlátolt Felelősségű Társaság	2141 Csömör, Bence utca 22 (3397. hrsz.).	2017	10	45 974	6 089	13,24%	Car rental
28	ZENIT-AUTO RENT Szolgáltató és Kereskedelmi Korlátolt Felelősségű Társaság	3519 Miskolc, Miskolctapolcai út 25-27.	2017	14	177 215	10 350	5,84%	Car rental

Figure A1. TEÁOR 77.11 main renting or lease activity of companies with at least 10 staff headcounts in Hungary [25].

Appendix B

Table A1. Aspects of the sustainable sharing economy (SSE) [40,41].

	BMW	Daimler
New business model	"The focus will continue to be placed on the development, production, and sale of vehicles, with a wide range of innovative mobility services on top." (p. 11) "Providing opportunities to test the BMW i3 as part of our DriveNow car-sharing scheme." ([40], p. 60)	"Transport infrastructure and transport systems frequently operate at their limits, especially in urban areas. That is why Daimler has developed a range of pioneering mobility concepts." ([41], p. 55)
Geographic expansion	"DriveNow is currently available in 13 European cities. On 8 April 2016, the BMW Group launched an advanced car-sharing program in the USA under the name ReachNow." ([40], p. 73)	"The 300 new vehicles are being used in Berlin, and additional models will also be introduced to other cities in the future." "In 2016, car2go launched in the Chinese megacity of Chongqing with the brand suffix "JíXíng" (roughly translated as: "drive off immediately"). "car2go is the first international company to implement the free-floating car-sharing concept in China." ([41], p. 55)
Public transport	"DriveNow in Copenhagen is operated by the city's public transport company Arriva. With their "Rejsekort," a card for almost all mobility services in the whole of Denmark, users also gain access to DriveNow. ([40], p. 74)	"From the car-sharing provider car2go and the mobility platform Moovel to the taxi app Mytaxi, the coach company Flixbus, and the Bus Rapid Transit (BRT) system." ([41], p. 55)
Electric vehicles	"The fleet for both programs currently comprises more than 6000 vehicles in Europe, of which around 15% are purely electric BMW i3 vehicles. A further 1300 vehicles are available in the USA. DriveNow is one of the strongest drivers of electromobility in Germany". (p. 71) "Copenhagen is the only city in Europe in which we have operated our car-sharing service from the start with a fleet of purely electric BMW i3 cars. The good charging infrastructure in the city offers ideal conditions for this." ([40], p. 74)	"Car2go has added 20 smart ForTwo electric vehicles to the local fleet. This is the first step in evaluating the feasibility of using electric vehicles in our fleet by relying on Montréal's existing charging infrastructure, as well as determining how the city's climate conditions impact vehicle range and availability." https://www.car2go.com/NA/en/nextgen/

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Circular Economy and its Comparison with 14 Other Business Sustainability Movements

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Abstract: Circular economy is not the first, and probably not the last "movement" in the arena of sustainability macroeconomic and business solutions. In this article we produce a—not full—list of similar movements from the 1990s, publish a comparative table and propose a simple framework to decide the significant points of the life cycle of such a kind of movement. For significant points and statistics, we use simplified content analysis from normal and scientific research engines. Finally, we use this framework to make a forecast about time for the circular economy approach "to stay on the top" and conclude if these movements are "Much Ado about Nothing" or they help us on our way to a sustainable planetary, social and economic system.

Keywords: business sustainability movements; circular economy; life cycle; sustainable development; human economics

1. Introduction: Hypes, Movements, Scientific Schools

Circular economy and sustainable development goals of the UN are far the most popular topics in the last two years in the business sustainability arena. This was not the case five years ago. It is an interesting question to try to forecast whether it will be the same in 2–5 years' time. To decide that, in this paper we will look at the popularity of other similar movements. We will examine the hypothesis that these movements come and go as fashion, or they keep up the interest for sustainable development, as a whole approach, to prepare a paradigm change from unlimited growth to sustainable development.

The first sentence of the Book of Genesis (and the whole Bible) is: "In the beginning God created the heaven and the earth". If once the "bible" of the modern business-environmental movements would be written, it could start with such a sentence: "In the beginning environmentalist created Recycling!"

Indeed, recycling is a very old approach. Written sources mention paper recycling from 1031 from Japan [1,2], and the second utilization of resources were used as nation-wide strategies in World War 2 UK and USA. However, recycling, as an "environmental movement" or techno-scientific approach is much younger. The first mention of recycling in *Google Scholar* is from the early 1800s, and we have altogether 1730 records till 1900. Currently it is about 20–60 thousand in a single year (32,500 Google Scholar hits between 1 January 2018 and 26 June 2019, 22,800 between 1 January and 26 June 2019, 308,000 since 1 January 2015.) and 2.8 million in total.

If we look at (normal) *Google* hits, recycling is a very popular topic. Its product life cycle is similar to Coca-Cola from marketing (*Life cycle* and *life cycle assessment* is used in two meaning in this article. The main meaning is from marketing science: How long a product can stay in the market, before it gets technically or fashionwise obsolete. Some exceptional): The product does not get obsolete, it does not go out of fashion, it stays on the top. If we hit the research phrase "recycling" to Google, we get approximately 332 million results (This article heavily relies on normal Google searches, Google Science hits and time series of hits etc. from *Google Trends*. It is necessary to deduce the "noise" and severe short-term time fluctuation of results. For this reason, all hits are from a period of three days:

27–29 June 2019, unless otherwise indicated). With these numbers, recycling is far the most popular movement among the 15 we are considering in this article, its dominance *in everyday use* is "oppressive" and irreversible, *in scientific publications* it is only highly outstanding and unquestionable.

This is the point to explain why we use the term *movement*. We could call these fifteen things *hype*, as they have characteristics of fashion, people are enthusiastic about them, but then they go out of fashion. However, they are too well supported and scientific to be called a hype. We could also call them *scientific schools*, as they are well defined, we have scientific evidence behind them in forms of monographs [1,3], primary research [4,5], journal articles [6–8]. For example, literature supports that circular economy can contribute to the energy [9] and material [10,11] perspectives, embracing topics from residential photovoltaic systems [9] to sewage sludge biogas solutions [12]. New movements are widely documented with systematic literature reviews [13,14].

However, most of these studies come from semi-scientific sources like the consultancy sphere [15] or the European Commission [16]. These institutions—although making excellent and reliable research with hard work—have a primary interest to spread what they consider good politically, and these forecasts are often positively biased. So, these things do not show the characteristics of scientific schools in the long run, they might be called one scientific school *(the business sustainability school)* in the long run. It is also often the case that a thing has a look of a scientific school or looks like a hype, but then another characteristic of it becomes more dominant. Marxism is an example for that: If it did not turn into a social movement with the aim to change the world very pragmatically, we would probably consider Marxism as one of the most elaborate schools of economics. However, the political movement faded this characteristic of being a scientific school.

We could also look for other expressions like *paradigm*, *meme*, *program*, etc., but we find that the connotation of the world of *movement* is the most proper for our purposes. This is the strongest common term but saying that we do not ignore that the 15 movements have different characteristics. For instance, *recycling*—apart from being a movement—is a very practical approach to waste management, *zero emission* is mostly known in the car industry, *cleaner production* is a very highly ranked scientific school with an excellent dedicated journal, and so on. For the sake of simplicity and our intention to compare these things, we call them movements. So, let us see, what similar movements can we consider as predecessors of the circular economy.

2. Dataset: A Catalogue of 15 Business Sustainability Movements

We can pick a list of 15 movements showing similar characteristics to circular economy. They often have common fields, so in order to define them we describe them shortly, to have a common understanding. In the list below (Figure 1) we use the most widespread definition and one-paragraph description of the movement, if it is not available from secondary source, we produce a short summary. In some cases we put the most well-known symbol or "founding father" (namely 1. *Recycling* logo, 3. *Cleaner Production*—UN logo, 10. *Corporate Social Responsibility* explaining graphic, 11. Günther Pauli with *Blue economy*, 12. Michael Porter with *Creating shared value*, and a 15. *Circular economy* explaining chart, referring back to the beginning of the list: product life cycle). This list could be extended with phrases like eco-efficiency or eco-design, but a list of 15 significant movements is strong enough to see differences, commonalities, and most of all meet our primary goal: To depict the life cycles.

Figure 1. The 15 business sustainability movements in our focus.

2.1. Recycling

Recycling is a procedure to convert waste materials into useful objects again, that is to produce new products from old (vs. so-called virgin) material. Most common examples are paper, glass, and metal recycling. Compound products are harder to recycle, cars or electronics are made of a number of carefully combined materials, which does not ease detachment and reutilization. Recycling is normally considered as an environmentally friendly solution opposite to waste disposal (dumping), incineration (utilization of the energy content) is half-way. The waste mitigation hierarchy or the three 'Re' are often cited [3,16] that is Reduce-Reuse-Recycle. In this sense the best environmental solution is (i.) not to produce and consume, than (ii.) to use things for the same purpose without an energy-intensive de- and remanufacturing (e.g., selling mineral water again in the same glass bottles), and (iii.) finally convert material through handicraft or industrial processes into new products. As we will see, recycling is the first and far the best known movement in our list.

2.2. Waste Minimization (WM)

Waste minimization is a systematic approach to reduce, and if possible, to prevent the "production" of unintended by-products and other waste material, including fluent and gaseous emissions. Ojovan and Lee [17] defines waste minimization as a process of reducing the amount and activity of waste materials to a level as low as reasonably achievable. WM strongly relies on the waste mitigation hierarchy: reduce-reuse-recycle (as shown in Figure 2). Sometimes other 'Re's are added like *rethink*, *redesign*, *refuse*, *replace*, *reengineer*—but the point is the same, this is mostly playing with the words. As Rosenfeld [18] states, the objective of WM is to decrease the amount of hazardous waste bound for energy recovery, treatment, and disposal facilities. Utilization for the same purpose in the same form (reuse), in a modified form (remanufacture) and in a new form (recycle) is sought instead. Although waste minimization is already mentioned in 1974 [19], it became a massive movement from the 1990s, propagated by prestigious organizations like the US EPA, specialized UN agencies, etc. 1984 the US Congress passed amendments to the Resource Conservation and Recovery Act (RCRA) declaring waste minimization to be national policy [20].

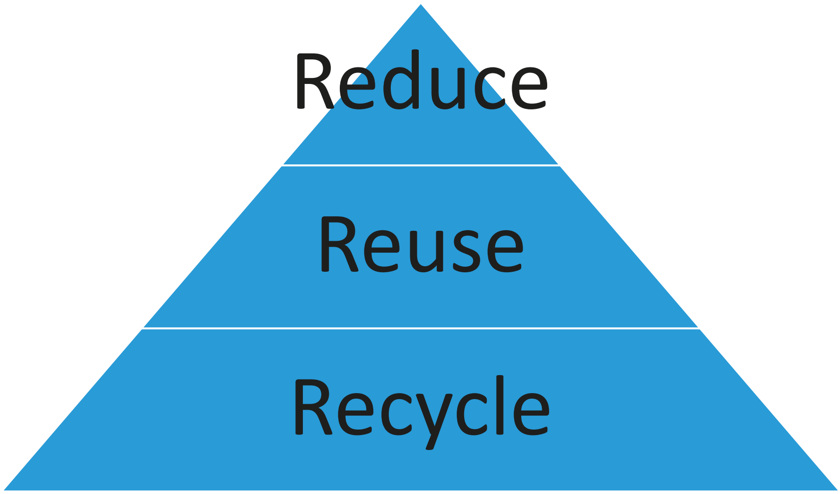

Figure 2. The 3 'Re's—the waste avoidance/utilization hierarchy.

2.3. Cleaner Production (CP)

The methodology, earlier also termed pollution prevention, is based on preventive solutions as opposed to end-of-pipe technologies. Besides being logical it has also been proved by several studies that if a procedure is originally formulated so as not to create pollution or waste it is not only environmentally positive, but also financially advantageous. This way materials and energy obtained at high costs are not wasted by low efficiency. In contrast, end-of-pipe solutions leave production processes unchanged, but add supplementary devices, e.g., filters, cleaners, to them. These supplements have extra cost on the one hand, and on the other many times just transform one type of pollution into another (e.g., Sludge, energy-plant ash). They are of course needed and handy in everyday practice, but our main perspective should be prevention. Cleaner production is propagated through the international network of CPCs, Cleaner Production Centers.

The promotion of energy efficiency can be taken as a special manifestation of cleaner production. Here our aim is to keep wasted energy at the lowest possible level at an organization or in a building. As a result of CIPEC (Canadian Industry Program for Energy Conservation), for example, 5000 companies, responsible for 98% of the total industrial energy consumption, decreased their energy intensity by 9.1% between 1990 and 2004. Energy conservation is usually attained by the combination of two types of measures: "hard" measures are technological changes (like recuperative devices, installation and reuse of thermal energy waste), while the "soft" ones request behavioral or administrative modifications only. Experience shows that at least half of the environmental problems would be prevented by responsible behavior. Looking at it from another angle, the development of technologies will never be an answer to mankind's environmental problems by itself, to reach this goal we have to change our own behavior [21].

2.4. Zero Emission

Zero emission is a well-researched topic and its connection to other movements like CP or LCA are apparent in the literature [8,22]. Some even assume that this approach could be a holistic tool to bring about a sustainable society [23]. Nevertheless, the most well-spread use of the term is in the automotive industry, hinting that zero emission is a narrow focused methodology referring to an industrial or mechanical process, motor, or engine, emitting no waste products of any kind that pollute the environment or contribute to climate change. Nieminen [5] shows that this approach is very closely linked to best available technologies (BATs), eco-efficiency and LCA. A complex approach to zero emissions was first published in 2002 [24] (Dixon, Porche and Kulick), but much earlies it gave birth to ZERI—Zero Emissions Research and Initiatives in 1994. The movement than was reborn in the Blue Economy movement by the same think-tank, Günter Pauli.

2.5. Zero Growth, Decroissanse

Actors of the business sphere are more practical minded than to be easily put off by some conceptual obscurity about how to define sustainability in every-day use. Especially because from the 60's they have been susceptible to strong attacks first in the name of environmental protection, then sustainable development. Some even started talking about zero growth as the practical realization of sustainable development [25,26]. Zero growth is obviously contrary to the growth myth running in the blood of both micro and macro level decision makers in economy [21,27].

2.6. Green Economy (GE)

The green economy can be defined "as economy that aims at reducing environmental risks and ecological scarcities, and that aims for sustainable development without degrading the environment" [28,29]. GE is closely related with environmental and ecological economics, but it has a more politically applied focus. Although the UN Environmental Program adapted the idea, its concept is at least more than two decades older: David Pearce, a prominent environmental economist published his report entitled "Blueprint for a Green Economy" already in 1989 [30]. The book had been prepared by the London Environmental Economics Centre (LEEC), a joint venture by the International Institute for Environment and Development (IIED) and the Department of Economics of University College London (UCL). The Pearce Report demonstrated models where environmental elements in threat of being polluted can be costed. The green economy concept urges systems of taxation which would both reduce pollution by making it too costly and generate revenue for cleaning up the damage. A central GE concept is therefore "the polluter pays" principle.

2.7. Triple-Bottom-Line, Alias 3P

Big enterprises made up their own well operationalized concept of sustainable development ("Triple bottom line" also used as TBL, 3BL, People, Planet, Profit, originates from John Elkington, the influential English founder of SustainAbility, from 1994 [31]). As a matter of fact—though not to the satisfaction of all—consensus is about to be reached on the basis of "something is better than nothing". According to this corporate sustainability is the outcome of a triple optimization, or "triple bottom line". It is a three-legged model in which the foundations are the three columns of ecological, social and economic sustainability. The operationalization of corporate sustainability usually means that eco-efficiency is taken for ecological responsibility, keeping to basic norms (such as improving working conditions, giving financial aid, not using child labor and abuse) stands for social sustainability and economic sustainability is clearly understood as the enterprise's long term profitability [21,31].

2.8. Life Cycle Assessment (LCA)

The method of Life Cycle Assessment embraces environmental impacts of the product during all stages of its life-cycle. Such an assessment contains all the in- and outgoing material and energy flows separately in the phases of the production of raw materials, processing/manufacturing, usage and becoming waste, not forgetting to consider the transportation linking these phases. Once we have drawn the "boxes" representing these processes (which might amount to thousands within a somewhat more complicated industrial framework like that of manufacturing automobiles) and their input-output flows, we can proceed to summarize the impacts using natural indicators, ending up with an eco-balance. Here we can apply different methods to adapt the different measures into comparable measurement units. Available software (e.g., Gabi) can be of great help, especially because of their evaluation methods in the background (e.g., BUWAL). The major steps of LCA are setting the system limits, inventory analysis and, finally, impact assessment. A number of ISO 14,000 standards deal with LCA [21].

2.9. Sustainable Consumption

Sustainable consumption and production aim to promote resource and energy efficiency, sustainable infrastructure. Its strategic goal is to provide access to basic services, green and decent jobs and a better quality of life for all. It is one of the 19 Sustainable Development Goals (SDGs) of UN by 2030, under the name "responsible production and consumption" [32]. Already in 1992, at the United Nations Conference on Environment and Development (UNCED) the concept of sustainable consumption was established in chapter 4 of the Agenda 21. In 2002 a ten-year program on sustainable consumption and production was created at the World Summit on Sustainable Development in Johannesburg. The definition proposed by the 1994 Oslo Symposium on Sustainable Consumption [33] defines it as "the use of services and related products which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations" [33].

2.10. Corporate Social Responsibility (CSR)

It is written in the EU Green Paper on CSR [34] "most definitions of corporate social responsibility describe it as a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis." The Commission recognizes that CSR "can play a key role in contributing to sustainable development while enhancing Europe's innovative potential and competitiveness" [34–36]. According to EU initiatives enterprises "over comply" legislation in collaboration with their stakeholders.

According to the WBCSD "Corporate social responsibility is the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large" [37] (p. 6).

The so-called "deep" definition for CSR is the following: "The Truly Responsible Enterprise (i) sees itself as a part of the system, not a stowaway concerned only about maximizing its own profit, (ii) recognizes unsustainability (the destruction of natural environment and the increase of social injustice) as the greatest challenge of our age, (iii) accepts that according to the weight they carry in economy, governments and enterprises have to work on solutions, (iv) honestly evaluates its own weight and part in causing the problems (it is best to concentrate on 2–3 main problems), and (v) takes essential steps—systematically, progressively and focused—towards a more sustainable world" [21].

2.11. Blue Economy

The Blue Economy concept was officially laid down in the same titled book of Günther Pauli in 2010 [38], but it refers back to the Zero Emission movement by the same author. It began as a project to find 100 of the best nature-inspired technologies that could affect the economies of the world, with the condition of providing basic human needs—potable water, food, jobs, and habitable shelter—in a strictly sustainable way. Hundreds of technical innovations were found and described, that could be bundled into systems functioning similar to ecosystems.

2.12. Creating Shared Value (CSV)

Creating shared value is the latest "hype" in our catalogue, it was first introduced in an often-cited Harvard Business Review article *The Link between Competitive Advantage and Corporate Social Responsibility* [39]. The business concept was proposed by Michael E. Porter, a leading authority on competitive strategy and head of the Institute for Strategy and Competitiveness at Harvard Business School, and Mark R. Kramer, Kennedy School at Harvard University and co-founder of FSG, "a mission-driven consulting firm". The main premise behind CSV is that of "extended CSR". Authors are very ambitious about their concept: They promise CSV has the power to unleash the next wave of global growth and to redefine capitalism [39]. On the other hand, critics say that "Porter and Kramer basically tell the old story of economic rationality as the one and only tool of smart management, with faith in innovation and growth, and they celebrate a capitalism that now needs to adjust a little bit". They regard CSV as a "one-trick pony approach" with very little chance that an increasingly critical civil society would buy into such a story [40]. It is not clearly explained, if the current income from products in the market are not shared in a moral, just way, why would this happen in the case of "creating more value" (basically increasing retail prices due to more value added). This is not Porter's first approach, he basically connects competitiveness with many trendy approaches, like efficiency, the environmental cause or CSR [41].

2.13. Industrial Ecology

Industrial ecology aspires further than cleaner production since its ambition is not the optimization of a specific process, but the creation of a certain industrial eco-system. Here the waste produced by a process or a factory is the base material for another. Its tool kit does not contain too many new elements though, but, besides recycling, is made up of the same as that of the forenamed cleaner production, life cycle assessment and eco-design [21].

2.14. Sharing Economy

In the sharing economy, persons rent or "share" things like their cars, rooms, houses or apartments to other people. Also, personal time is not sold, but shared in a peer-to-peer fashion [42,43]. Sharing economy is a basically new approach to the ownership, use and marketing of products and services and has the highest chance to turn the current form of market economy into something slightly or dramatically different. The term is used to describe distributing goods and services differently from the traditional business models via hiring employees and selling products to consumers (as depicted in Figure 3). Others call it "access-economy", which might be a more proper, but less used term [7]. Uber and Airbnb are just two iconic examples of the sharing economy, generating massive and fierce debate among professionals, regulators, and researchers. Sharing economy is not fully dependent, but in its current form heavily relies on Internet-based social networks: a feeling of trusting—formerly unknown people through—the Network substitutes the traditional feeling of trusting your friend, group member or other peer in the local, personal society.

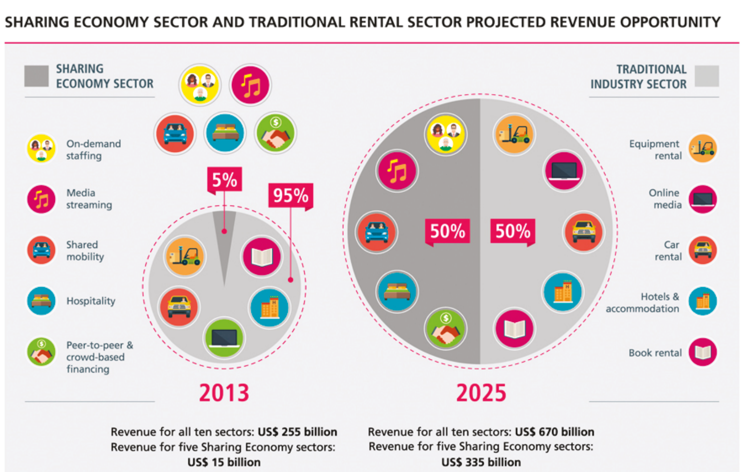

Figure 3. The bright future of sharing economy by PWC—from 5% market share in 2013 to 50% in 2025.Source: PricewaterhouseCoopers, 2014 [15].

2.15. Circular Economy

According to the definition of Merli, Peziosi and Acampora [13] circular economy "aims to overcome the take-make-dispose linear pattern of production and consumption, proposing a circular system in which the value of products, materials and resources is maintained in the economy as long as possible". Kirchherr, Reike and Hekkert [14] analyses 114 CE definitions and conclude that it is most frequently associated with a combination of reduce, reuse and recycle activities, which they held a mistake, lacking a systemic shift towards social equity and sustainable development. I agree with their conclusion that CE must aim at far beyond mainstream goals of economic prosperity, at a paradigm shift towards sustainable and human development. The concept of CE can be traced back to the works of David Pearce 1989 [30], Kenneth Boulding 1965 [44], and Tim Jackson 1993 [45].

After discussing the fifteen movements in detail, let us turn our attention to their common life cycle.

3. Method: A Proposed Life Cycle

According to our hypothesis, a hypothetical life cycle of the business sustainability movements can be constructed. They are known and practiced long in history, for example [1,2] mention *paper recycling* from 1031 Japan, *waste minimization* was probably a practice—although not under this name—in all historic times, due resource scarcity and common sense. William Foster Lloyd in 1833 [46], and Garrett Hardin [47], popularizing him in 1968 described the sharing economy in the *Tragedy of Commons*, which was rather the mainstream and not the exception before the massive enclosure in the 18th century England. However, waste minimization and sharing economy did not appear as a comprehensive and broad movement until the recent decades. So "historic times" on Figure 4 can take centuries or millennia, but as a movement, hype, widely spreading business initiative or public policy instrument by the UN, EC and other respected international agencies is normally taking place from the 1990s, when global environmental problems have been commonly understood and accepted. The historic (latent) period and the fashion (explicit) period is depicted on Figure 4 with red turning to green respectively. The figure proposes a life cycle as well: Steady and slowly accelerating growth, peak and going out of fashion, where the horizontal axis is a logarithmic scale.

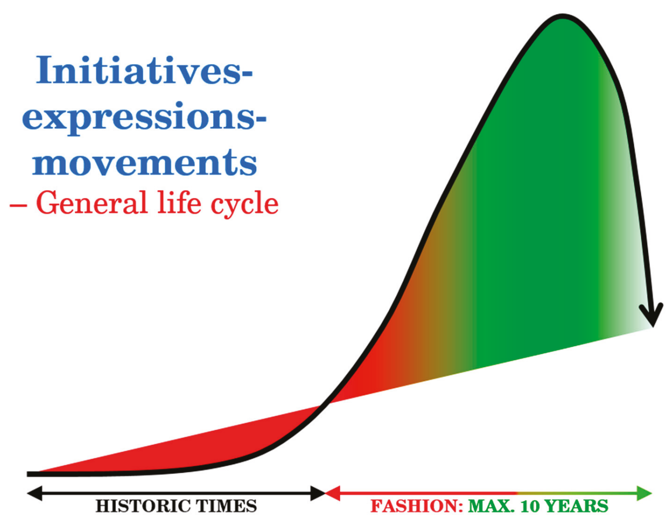

Figure 4. A hypothetical life cycle of a business sustainability movement, time (horizontal) and popularity (vertical).

Compering historic practices and modern renaissance of these approaches we could conclude that modern societies keep on reinventing the wheel. What is worse, from the catalogue of the previous section we could conclude that we have reinvented at least 15 different wheels. As we emphasized, these movements we consider one wheel, although varying in shape, material and other important characteristics. Only the business sustainability movement is a wheel, with slight variations.

However, the main purpose of this article is not to create a catalogue of business sustainability movements, but to look at their respective life cycle. Is it true that they really emerge, fly high and disappear? Do they add new peaks and keep up public interest for business sustainability? In the next session we will see, that this hypothesis is only partly true, at least with our methodology: It is easy to be present on the Internet, it is hard to top the hit lists, but what is really impossible to disappear from there.

On Figure 5 we tried to depict a somewhat pessimistic hypothesis: business sustainability movements come, flourish and go. The thin color curves represent recycling, waste minimization, cleaner production, blue economy etc., the heavy grey curve represents the business sustainability movement in general. Colors extend a bit the total life cycle, but unless new hypes come, public interest will turn to other topics, in this accelerated and pulsing era of big data and mass information.

Figure 5. The individual LCs and consolidated hypothetical life cycle of business sustainability movements, time (horizontal) and popularity (vertical).

This would mean that we have to produce hypes in every 5–10 years, and repeat the tedious efforts of defining, finding positive examples, publishing handbooks, case studies, technical guides and policy documents, etc. This would also mean that these approaches hardly come to the boardrooms and university textbooks or they disappear very quickly. In the next section we use statistics of Google searches and hits in both the public pages and the scientific arena, in the last fifteen years. Google trends gives and excellent tool to produce time series in all different combinations.

Basically, our method is relatively simple: as we look at fashion and popularity AND presence in scientific publications in parallel, we look at 1) overall Google hits [this is what we call "normal", without any screening] AND 2) hits in qualified scientific databases. The latter is twofold: Google Scholar and Science Direct. Normal and scientific hits normally correlate, but not necessarily: sometimes they show fairly different results (as seen on Figures 6 and 7, e.g., sharing economy is very popular in normal Internet, but not visible in Google Scholar).

4. Analysis: The Comparative Table and Citations

In the table below (Table 1) we summarized the main characteristic points of fifteen sustainability movements of business and economics. In column II is the oldest paper in Google Scholar. Columns III–V are calculated values from Google Trends (as of 28 June 2019), showing the respective hits in Google and Google Scholar. We show highest and lowest values and their time (year and month). Columns III–V consider a 15-year period between January 2004 and June 2019. Column VI is again a somewhat anecdotal piece of information, but it is mostly agreed upon and easy to check. In column VII we cross-check Google trends and choose the scientific database over the common one: We decide the approximate length of the movements' fashion based on hits in Science Direct (as of 20 July 2019. We consider a movement "on top", if Science Direct lists minimum 100-300-1000 papers per annum, in relation to the total hits, to keep a balance and add a positive discrimination to less visible movements).

Table 1. The comparative table of 15 business sustainability movements—simplified content analysis.

	I.	II.	III.	IV.	V.	VI.	VII.
	Movement	First sci. mention	Top year, G. &G.schol. hits	Bottom year, G.& G.s. hits	Google & G. sc. hits 2019	High as movement	Sci Dir hits **years** on top
1.	**Recycling**	Platon, 4th century B.C.	04-2008: 100 02-2004: 100	02-2015: 58 07-2017: 18	06-2019: 85 06-2019: 26	Since WW2: 1939–1945	429,476 **80**
2.	**Waste minimization**	P.R. Taylor, 1974 [1] [19]	01-2004: 1 02-2004: 6	01-2004: 1 01-2004: 0	06-2019: 1 06-2019: 1	1970s 1980s	4541 **10**
3.	**Cleaner Production (CP)**	UNEP-UNIDO, 1992 [48]	02-2004: 1 04-2004: 12	01-2004: 1 03-2004: 0	06-2019: 1 06-2019: 7	NCPCs & NCPPs 1994	25,567 **22**
4.	**Zero emission**	US Congress, 1970 [49]	09-2009: 1 01-2004: 13	01-2004: 1 04-2004: 0	06-2019: 1 06-2019: 1	ZERI 2004	11,849 **12**
5.	**Zero growth, decroissanse**	Meadows, 1972 [50]	04-2004: 1 04-2005: 7	01-2004: 1 02-2004: 0	06-2019: 1 06-2019: 1	OECD 1985	3565 **8**
6.	**Green economy**	Pearce, 1989 [30]	05-2008: 1 04-2004: 11	03-2004: 0 01-2004: 0	06-2019: 1 06-2019: 2	ICC 2012	2737 **8**
7.	**Triple-bottom-line, alias 3P** [2]	Elkington, 1994 [31]	02-2004: 1 09-2004: 9	01-2004: 1 01-2004: 0	06-2019: 1 06-2019: 1	2000s: Co. sust. Reports	3515 **9**
8.	**Life Cycle Assessment**	Vigon, 1994 [51]	01-2004: 1 02-2007: 7	02-2004: 0 01-2004: 0	06-2019: 1 06-2019: 1	US-EPA 2010	23,420 **11**
9.	**Sustainable consumption**	Oslo Symposium, 1994 [33]	01-2004: 1 01-2004: 12	01-2004: 13 05-2004: 0	06-2019: 1 06-2019: 1	UN 2000s	3620 **7**
10.	**Corporate Soc. Responsibility**	Goodpaster-Matth., 1982 [52]	04-2004: 5 03-2004: 7	07-2006: 2 02-2004: 0	06-2019: 2 06-2019: 1	2000s: Co. CSR reports	9842 **8**
11.	**Blue economy**	G. Pauli, 2010 [38]	11-2018: 1 06-2006: 2	01-2004: 1 01-2004: 0	06-2019: 1 06-2019: 1	WWF 2018	321 **3**
12.	**Creating shared value (CSV)**	M. Porter, 2011 [39]	06-2004: 1 11-2007: 1	01-2004: 0 01-2004: 0	06-2019: 1 06-2019: 0	EC 2010s	873 **5**
13.	**Industrial ecology**	Frosch-Gallo-poulos, 1989 [53]	05-2004: 1 05-2005: 23	01-2004: 1 01-2013: 1	06-2019: 1 06-2019: 1	2000s	5497 **7**
14.	**Sharing economy**	Benkler, 2002 [54], Lessig, 2008 [55]	10-2014: 1 07-2007: 1	01-2004: 0 01-2004: 0	06-2019: 1 06-2019: 1	Last 5 years	1552 **4**
15.	**CIRCULAR ECONOMY**	Boulding, 1965 [44] Pearce, 1989 [30] Jackson, 1993 [45]	02-2019: 2 02-2019: 23	03-2004: 0 01-2004: 0	06-2019: 1 06-2019: 23	Last 3 years	5918 **4**

[1] This date is mistyped in Google Scholar, as 1874. In reality it refers to the foundation of the Kroll Institute for Extractive Metallurgy (KIEM) at the Colorado School of Mines. KIEM focus areas included minerals processing, extractive metallurgy, *recycling* and *waste minimization*. [2] People-Planet-Profit (or **Profit** ... people ... planet?).

Composing the comparative table of the business sustainability movements in a precise way is harder than expected. In column II, should we specify the first historic example? The first proven use of the expression? The first scientific book or article solely devoted to the topic? We used a mixed approach. For example, even Wikipedia denotes that Platon spoke about recycling 2500 years ago. However, most of much of Platon's and Aristotle's work was lost, the latter for example only survived in Arabic translations and were later translated back to Greek and Latin. Most of the movements, as we keep on emphasizing, refers back to some ancient and modern wise philosophers, scientists. A good example is the last line in the table, where Kenneth Boulding [44], David Pearce [30] and Tim Jackson [45] are referred to as "founding fathers", but also the Tragedy of the Commons (and herewith Hardin 1968 [46] and Lloyds 1833 [47]) are specified as theoretical basics. Anyway, roots and exact "who said first" is not so important, we could refer this question to monographs dealing with the specific movements (e.g., in CSR [21]).

What is more important from our special perspective, is the recent "web-footprint" and scientific records of the movements in question. The first we approximated with the (normal) Google hits of the last 15 years, the second with the hits in Google Scholar and we made a cross check through Science Direct. We specified some characteristics of these time series in the comparative table.

Our analysis also has some deficiencies: for example, in cell 5/III–IV it is hard to believe that *Zero growth* is on the peak and in its lowest mention in a period of three months. The French term *decroissanse* has a more profound, every day meaning—in English *degrowth* is devoted to the movement, the French *decroissanse* also means *decay, decreasing, reduction*. This means we cannot look for Google searches for *decroissanse* without being extremely biased with our results.

Google Trends is an excellent tool for time series analysis (from intervals of days and hours to a maximum period of 15 years), it gives area specific and detailed geographical information. Its main disadvantage that it is primarily for marketing, not for scientific purposes, its main advantage is that it normalizes hits on a scale of 100. This is the scale we used in the comparative table in columns III–V.

The first result is very apparent from the table: Recycling is far the oldest and most searched referred term of all 15 movements. If we put it to the comparative analysis, other movements become almost invisible (although in scientific articles the difference is much smaller). For this reason, we put the five less known and newer approaches on a joint graph (Figure 6). It is obvious, that single prophets (like Günter Pauli behind the *blue economy* or Michael Porter behind CSV) can have a huge added value in marketing, but this is still a short-term and relatively small push. If it is a long-term strategy and a giant agency as UNEP and UNIDO behind *cleaner production*, the effect is harder and longer. Nevertheless, general, easy-to-understand and appealing approaches like *sharing economy* and *circular economy* are the most successful in the evolution of business sustainability movements. Even the whole business sphere with all pioneering multinationals and their sustainability reports can have a relatively small leverage effect compered to this general appeal to the public. In the case of *circular economy,* Google Trends show us another interesting aspect: at one point around 2004–2005, 2 of the 5 related search terms included *Ellen MacArthur*, a champion yachtswoman from England. After retirement from professional sailing (at the age of 34) she established the *Ellen MacArthur Foundation*, a charity that works with business and education to accelerate the transition to a circular economy. One famous individual can do a lot to popularize the public good.

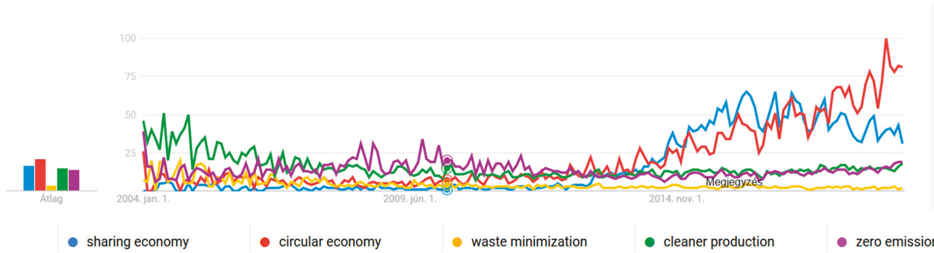

Figure 6. Frequency of normal Google searches for the terms *circular economy*, *sharing economy*, *waste minimization*, *cleaner production* and *zero emission*. Data and graph from Google Trends, as of 27 June 2019 (Hits normalized on a scale of 100).

On Figure 6 we see a limited effect of fashion: *Sharing economy* was very popular around 2015, but interest is significantly lost in the last 2–3 years. *Circular economy* was almost invisible till 2013, since that time its carrier is boosting. In science, however, the picture is slightly different. Sharing economy is very little discussed, and cleaner production keeps its positions much better.

We can observe significant regional differences in different countries. As apparent from Figure 8, sharing economy is still almost more popular in Germany, than circular economy. In the USA, the latter has clearly taken over. As well, in a new market economy, like Russia, where sustainability is probably less on the top of the agenda than in the EU or US, we see basically no evaluable activity. *Zero emission* is a more well-known term in the USA than in other countries, probably due to the fact that car development is more regulated by the market in the US, and more by the EC in the European Union (emission standards for passenger cars).

One major conclusion we can already draw here is that instead of competing movements, we should concentrate on strengths of each: *Cleaner production* has a very high scientific literature and technical background through the *best available technics* (BATs), *circular economy* is the newest concept with the contemporarily strongest appeal, *sharing economy* has the highest community (social network and 'apps') support, also there is the most fight around it taking the form of market regulation (Uber vs. taxi companies, Airbnb vs. hotel chains, pirate music sharing vs. traditional recording companies and Amazon, etc.). These fights create significant losses and some bankruptcies but are beneficial for the somewhat halted evolution of modern business towards a sustainable economy.

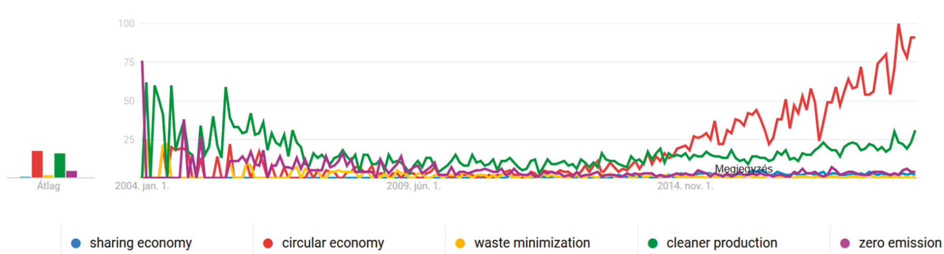

Figure 7. Frequency of Google Science searches for the terms *circular economy, sharing economy, waste minimization*, *cleaner production* and *zero emission*. Data and graph from Google Trends, as of 27 June 2019 (Hits normalized on a scale of 100).

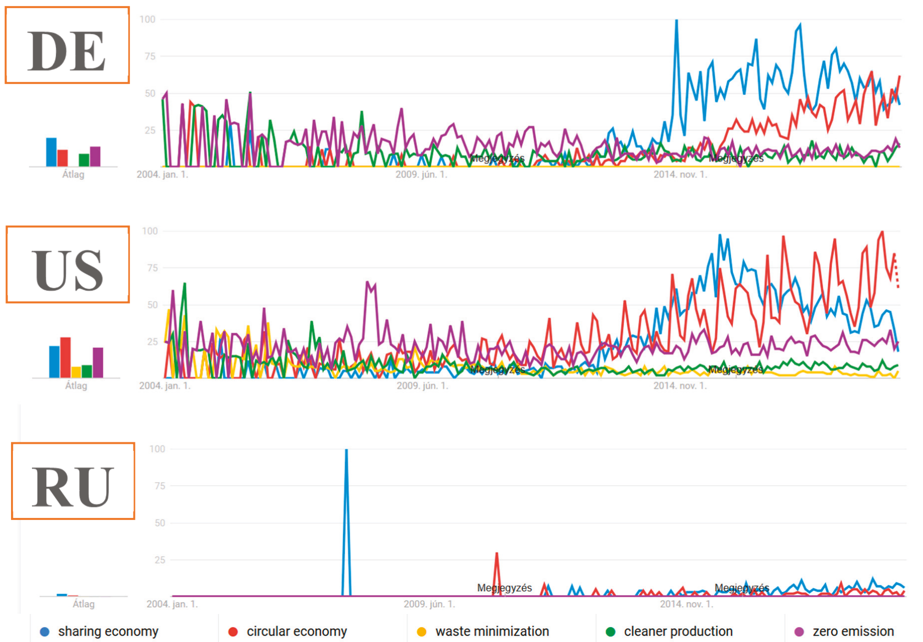

Figure 8. Frequency of normal Google searches for the terms *circular economy, sharing economy, waste minimization, cleaner production* and *zero emission* in Germany, the USA and Russia. Data and graph from Google Trends, as of 27 June 2019 (Hits normalized on a scale of 100).

On Figure 9 we can see that *circular economy* is the strongest in Scandinavian countries, South America, South Africa, sharing economy is strongest in Russia, US, core of the EU, Australia. However, a new finding is that cleaner production has very strong support and leads the poll in Brazil and Iran. Instead of looking at these selected pictures, I strongly recommend putting these five phrases to Google Trends, select the 15-year period, and look at individual, interactive maps and charts. If we look at the five individual world maps, one major learning is that the US is strongest in everything, which is connected to the Internet.

On Figure 10 we disclose one of these individual world maps, namely for *circular economy*. Apart from the spatial distribution we also see the most common connected terms, which (including the other 14 movements) could be the topic of further investigation.

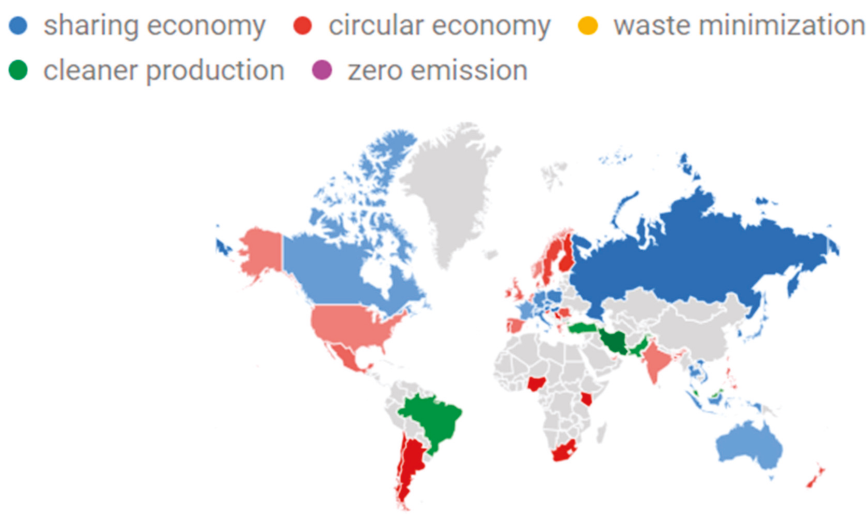

Figure 9. Geographical representation of normal Google searches for the terms *circular economy, sharing economy, waste minimization, cleaner production* and *zero emission*. Data and graph from Google Trends, as of 27 June 2019.

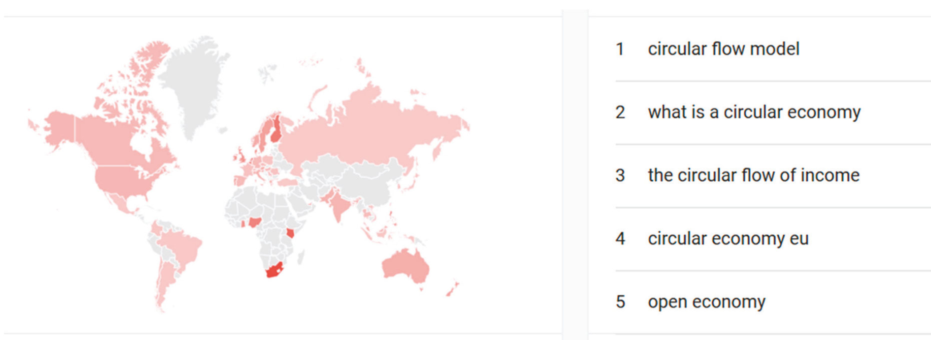

Figure 10. Google searches (hits) for the term *circular economy* by regions, and most frequent connected terms. Data and graph from Google Trends, as of 27 June 2019.

In Figures 11 and 12 we compared hits for another set of five of our selected business sustainability movements. As already pointed out, recycling is far most the winner, although its lead is less obvious in Google Scholar than in normal WWW content. In the normal arena, even the second sustainable development is hardly visible (see averages on the left), in science in rare cases it takes over recycling. Recycling is with no question the most technical and least scientific general approach of all.

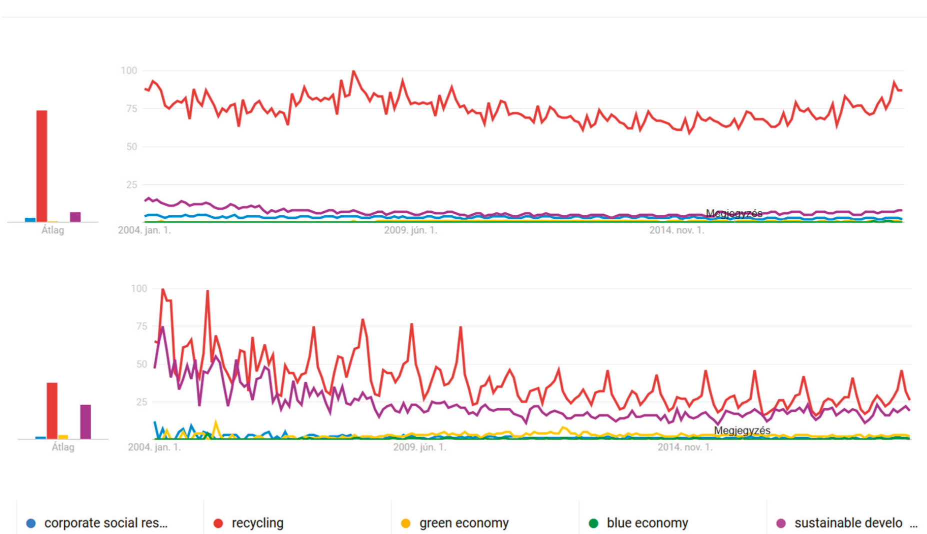

Figure 11. Frequency of normal and scientific Google searches for the terms *recycling*, *sustainable development*, *corporate social responsibility*, *green economy*, and *blue economy*. Data and graph from Google Trends, as of 27 June 2019.

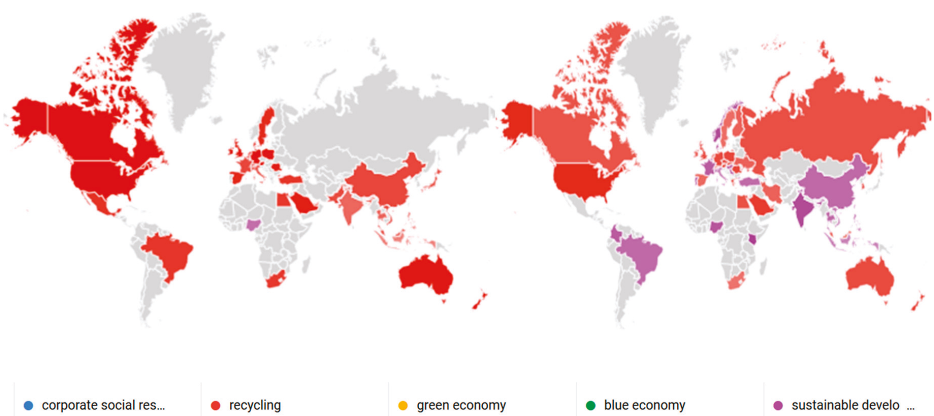

Figure 12. Geographical representation of normal and scientific Google searches for the terms *recycling*, *sustainable development*, *corporate social responsibility*, *green economy*, and *blue economy*. Data and graph from Google Trends, as of 27 June 2019.

We could create other graphs and maps, but Google trends has two severe numeric restrictions: It cannot compare more than 5 search phrases on the one hand, and cannot produce logarithmic axis on the other hand, to screen out the powerful dominance of *recycling*. However, we showed a comparative table and massive statistics to justify, modify or falsify our original hypothesis.

At last we can produce a top list of business sustainability movements and draw conclusions (the top 5-6 movements are highlighted in the first column of Table 1). It is remarkable, that we have to use exactly the 5 right search phrases from the 15 potential, and it is also important in what order we type them in to the statistical analyzer. It would be obvious to put the five top terms, but then *recycling* (whose gold medal is not questioned) would fade the other four. So, we look at the comparative table and look for ranks number 2–6, based on the last column: most recent Science Direct hits. We got a slightly different list from Figures 6–9 (*sharing economy* and *waste minimization* are omitted, LCA and CSR are added). Although circular economy is ranked only sixth in the list of total Science Direct hits, if we consider time—apart from recycling—it leads the list. *Cleaner production* takes the second place now, but it was leading at the beginning of the period (after 2004). It is clear from Figure 13, that they changed place.

Finally, we have to put our vote whether we consider general Google searches or the scientific realm more important. We should decide about the second, but if we decided about normal Google hits, CSR would dominate the whole ranking.

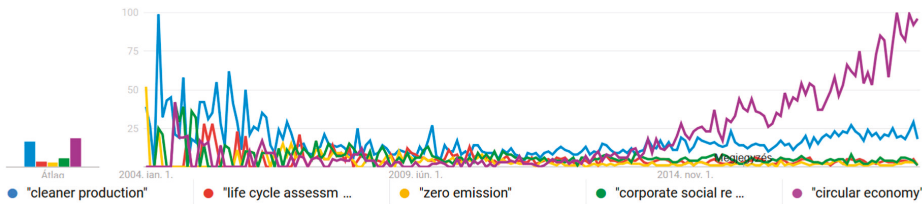

Figure 13. Frequency of scientific Google searches for the terms *circular economy, corporate social responsibility, life cycle assessment, cleaner production* and *zero emission*. Data and graph from Google Trends, as of 23 July 2019.

Our analysis can create a basis for a new tool for ranking different business sustainability movements (to be proposed as a future work). If we employ a critical analysis of our results, we can say that Google hit time series is a good first approximation of fashionableness, but does not provide deep scrutiny, compare content of movements, or assess their contribution to sustainability.

5. Conclusion: Little Competition, Much Synergy

Google trends is not a 100% precise analytic tool calibrated for scientific analysis, but due to its comprehensive nature, enormous access to data, and ease to use, it is an optimal tool to make quick analyses about an arbitrarily chosen to set of research phrases. Hereby we used it to see the popularity of fifteen business and economic sustainability movements and their change over time.

This approach is fresh but not unprecedented, for instance Denise Reike, Walter J.V. Vermeulen, and Sjors Witjes very recently published an article [56], looking at the Scopus hits of 12 movements similar to circular economy between 1970 and 2016. There is some overlap between the two studies, but apart from *recycling* and *cleaner production*, there are no common terms in the analysis. The reason for that is that we looked at circular economy from a broader perspective of sustainability, the Reika 2018 article is more precise and technology focused. They also used AND analysis, e.g., *circular economy* AND *reverse logistics*. Trends are very similar but focus of the study is also a bit different: we tried to look at life cycle of the business sustainability movements, and whether they can be seen as independent, competing, or symbiotic and mutually reinforcing concepts.

Another line of research does not take such a wide scope but tries to find common and differential points among some of the movements we proposed, for example between the *blue economy* and *circular economy* [57,58], *cleaner production* [59], *environmental accounting* [60] or specific areas of (nonsustainability) management [56]. A very popular line of papers deploys the concept of circular economy for a certain industrial application, like a factory or a domestic industry [58,61].

One of our basic questions were whether the 15 analyzed business sustainability movements are *independent*, *competing*, or *symbiotic and mutually reinforcing*? We have enough evidence to say that they are symbiotic. If we look at the number of publications in Science Direct, we see that all movements are on steep rise in the last 5 years. In other words, our presumed life cycle (on Figure 4) is valid to 80–85% only: till the absolute maximal point on the figure. In reality after that point the trend does not drop, only its acceleration is slower, the curve might level-off or keep on rising, but at a more moderate pace.

The last phase of the trend line does not resemble the falling tail of a Gauss-curve, but a sigmoid curve. In a non-mathematical language: the business sustainability movements live in harmony, they refer to older movements as predecessors, the common field is much bigger, than the differences. I think, this is good news for all, who do not only seek publication credentials, but hope to contribute to make the economic system more ecologically and socially sustainable! We have a strong basis to hope that we do "much ado about SOMEthing".

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Differences, Constraints and Key Elements of Providing Local Sharing Economy Services in Different-Sized Cities: A Hungarian Case

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Abstract: The business models of sharing economy services can differ from each other in different-sized cities. This paper provides a deeper understanding of the implementation of locally operating services for car, bicycle and office sharing in the urban environment. Our goal is to reveal the differences between the capital city and an economically well-developed city in order to provide beneficial findings to the development of the presently operating services, or to the possible implementation of future services. Methodology of the paper applies the Business Model Canvas approach (BMC). We introduce a comparative analysis using data from the Hungarian database, which records details of all the publicly visible sharing economy services countrywide. The results show that BMC can reflect the main differences, constraints and key elements in the business models of sharing economy services. We can say that, in the case of a bike sharing service operated in the non-capital city, there is more segmentation than seen in the same service in the capital. There are significant price differences, especially in the case of long-term tickets. The number of inhabitants and private capital remain the biggest constraints in the case of car-sharing services, but there is also a possibility of implementation in the non-capital cities by applying small-scale services with a good value proposition and segmentation.

Keywords: service-based economy; sharing economy; car-sharing; bike-sharing; shared office; Business Model Canvas

1. Introduction

The rationale of this research is to highlight the importance of supporting the currently increasing trend in sharing economies. Available comparative analyses in the literature that focus on the differences between capital and non-capital cities (the latter having smaller populations) in having the economic potential to give a place for sharing economy services, are rarely available. Our basic assumption is that while there are effective sharing economy service models in capital cities, due to the modern concept of sharing economy, it is also crucial to implement and improve services in other cities. Applying the Business Model Canvas (BMC) approach in the analysis of local cases enables this comparison and will find differences, constraints, and key elements, especially in the strategies of the service provisions.

We formulate the comparative analysis of some local cases around three research questions:

(Q1) What are the main differences in the business models of those sharing economy services which are represented in both the capital and in the chosen city?

(Q2) Besides the number of inhabitants, what are the main constraints in implementing a sharing economy service in a chosen city, which is operating well in the capital?

(Q3) What are the key elements of implementing a sharing economy service in the chosen city, which is operating well in the capital city?

Hungary is an interesting case for analyzing sharing economy services, because the sharing economy services in Budapest (the capital) are in their upcoming trend. There are more and more opportunities available each year, which means the market of sharing economy services and the taste of customers toward the sharing economy are not saturated. Besides adapting some European business models, there are many unique ways for sharing economies, which can provide customized business model elements that can be valuable input into sharing economy practices. In this paper we analyze local sharing economy services: Only those ones that have no national, European or worldwide coverage. This step contributes to the comparative analysis, in which we focus on services which are represented both in the capital and in the chosen city, and services which are presented only in the capital. The "chosen city" is Győr, located in the western part of Hungary. In terms of economic output, it is the richest city after Budapest. The world's biggest engine factory operates in the city, and the car manufacturing industry is the most important economic strength of Győr [1]. Due to the so-called Győr Cooperation Model, the stakeholders (local government, local companies, university and civil organizations) of the city are working together successfully on the development of the city [2]. We introduce the multifaceted application of the Business Model Canvas with the goal of revealing the main differences between the business models of presently operating sharing economy services in the capital and in the chosen city. We also reflect on the key elements and constraints in implementing sharing economy services, which are present in the capital city and not present in the chosen city. We focus on bike-, car- and office-sharing services. Although the sharing economy has been part of human society for a long time, it has taken a new form and has grown considerably during the last two decades. With transformations in technology and the increase in per capita income, the transport industry has registered phenomenal growth in the last few decades, with the number of passenger cars reaching over 1.2 billion in 2015 for the first time ever [3]. Increasing numbers of cars and massive migration into cities have resulted in congestion, traffic jams, parking problems, increased accidents and deaths, as well as growing pollution in cities. These have given birth to new ideas in car sharing in a variety of ways, such as shared taxies, single rides, carpools, ride-sourcing and many more. Implementation of bike sharing is less costly than car sharing. It is interesting to look at how it is shaping its market in a city which lacks the attributes of a capital city.

The first part of this article highlights the modern concepts of the sharing economy and gives a short summary of the evolution of car-sharing services in Europe, the largest car-sharing region based on membership data. After that, we introduce the research concept, comparing the local sharing economy services in a capital and a chosen city, which could also be appropriate for making multi city comparisons. Findings in the article are presented in the last section. The main differences, key elements and constraints are highlighted as practical contributions. The application of BMC is presented as a theoretical contribution.

2. Theoretical Background

The modern concept of the sharing economy has evolved not only based on a variety of quantifiable factors. The theoretical framework of the paper firstly highlights the concepts which are the closest to our understanding of sharing economy services. After this, there is a short collection of statistical data represented in order to underline the rationale of the analysis.

2.1. Modern Concepts in the Sharing Economy

With massive growth of cities, lack of parking space, traffic congestion and air pollution, sustainable urban transport has become a modern necessity. According to Suchanek and Szmelter-Jarosz, growing cities and their populations have become a challenge for today's researchers, local authorities and business decision-makers. One of the problems troubling the current politics is meeting the requirements of sustainable transport, especially when urban residents present the opposite needs [4]. This has given birth to car and bike sharing in urban and semi-urban areas. A variety of models of the sharing economy have emerged based on local conditions and the needs of customers. Growth of cities and populations are not the only increasing factors of a sharing economy. Consumer behavior, like new aspects in sustainable mobility or changing working habits, are also strengthening the need of sharing economies. These aspects include the weakening desire for ownership, economic stagnation and economic crises, reduction in disposable income due to growing unemployment, urbanization, evolution of new innovative sharing concepts, environmental considerations and availability of new technological tools and platforms [5]. Consumption can be based on time, space or at a fixed price. The consumer chooses such access when they are not able to afford the objects in question, or they do not wish to own them for reasons of maintenance, space, cost and so forth. The consumer is acquiring consumption time with the item and, in market-mediated cases of access, is willing to pay a premium price for use of that object [6]. Thus, the consumer–object relationship in access-based consumption may be different from that in ownership. The owner has the right to regulate or deny access to use, sell and to retain any profits yielded from the object's use, as well as to transform its structure [7].

According to Grondys, the sharing economy is treated as an alternative consumption model, aiming to increase the efficiency of the resources used and create a new value for society [8]. Development of new technologies, particularly Internet, IT platforms, social media and IT applications have facilitated the evolution of this model. Fransi et al. hold the view that the sharing economy has become a new socioeconomic activity that allows the co-creation, production, distribution and consumption of goods and services between individuals, driven by Web 2.0 and e-word-of-mouth [9]. Access-based services have emerged as an alternative and/or complementary to traditional ownership-based services and they are enabled by means of Smart Product–Service Systems (SPSSs) that integrate smart products and e-services into a single solution [10].

According to Rifkin [11], although a property continues to exist, it is less likely to be exchanged in the market. Instead of buying and owning properties and goods, consumers want access to goods and prefer to pay for the experience of limited and temporary access. As stated by Chen [12] and Marx [13], ownership is no longer the ultimate expression of consumer desire. During the last decade we have seen a proliferation of access systems in the market place that go beyond traditional forms of access. For example, access can be gained through memberships to clubs or organizations, where multiple products owned by a company can be shared [14,15].

Modernity characterizes the current social conditions in which social structures and institutions are increasingly unstable and are undergoing change and therefore they cannot serve as frames of reference for human actions and long-term life strategies [16]. Increasingly, institutions, people, objects, information and places considered solid during the last century have tended to dematerialize and liquidize [17]. Similarly, consumer identity and ethics are also becoming more fluid. Values are constantly changing. Emotional, social and cultural ownership embedded in a property is becoming flexible, transient and liquid. Access has emerged as a way to manage the challenges of a liquid society [18].

The increase in the costs of acquisition and maintenance for ownership over time, the instability in social relationships, as well as the uncertainties in the labor markets have rendered ownership a less attainable and more precarious consumption mode than it once was [19]. Many people have started wondering why they should own when benefits could be enjoyed at a fraction of the total cost with easy access and no storage and maintenance requirements. With density as a major concern of the re-urbanization movement, sustainable development, apartments and condos have increased in city centers, offering alternatives to the long commutes and the reliance on cars that dominate suburban living [20]. Urban settings have created a new set of problems that can be addressed by the sharing economy. Unlike earlier generations of information or technology-based enterprises, sharing enterprises rely on a critical mass of providers and consumers who are sufficiently close to each other or to other amenities to make their platforms work, often finding value in the very fact of the beneficial spill-overs from proximity [21]. For example, Uber transports people from one common area to another without involving idle driving or parking requirements. The driver picks up the passenger from the nearest area and after dropping picks up another passenger where the previous passenger was dropped, almost eliminating idle driving or parking. Moreover, the passengers need not navigate the heavy traffic themselves, as is the case with self-driving.

Growing awareness of environmental issues has also played its role in the evolution of the sharing economy. Air pollution in cities due to the growing vehicular population has transformed the thinking process of at least a section of the population. This section, which is no longer environmentally conscious, wishes to add new vehicles, causing additional congestion and air pollution. According to the 2014 survey by the Center for the New American Dream, 90% of Americans believe that the way they live produce too much waste, and 70% agree that Americans consume more resources and produce more waste compared to other countries. A total of 60% agree that the sharing economy lowers environmental impact [22]. Commenting on the environmental impact the report of Demailly [23], "clothing, vehicles, furniture, telephones, televisions, toys, sporting goods, home improvement, and gardening tools are all examples of the shareable goods that represent about a quarter of household expenditure and a third of household waste, not to mention the energy used to produce them".

Our understanding of the sharing economy highlights that it is an economic model which allows optimum use of individual and social assets and resources. The sharing economy in its present form is a relatively new phenomenon. Previous business models were based on the idea of complete ownership of assets and processes. Such ownership many times resulted in underutilization of assets and capacities which led to increased costs for the business enterprises and wastes of resources. The sharing economy is a highly flexible economic network that allows people to exchange tangible and intangible goods with one another in different forms of business models. Social, economic and environmental considerations are the driving force behind sharing economy models in the recent years. Socially, the desire for ownership has weakened; economically, individuals want to earn some income through temporary use their assets; and environmentally, such use helps in mitigating congestion and pollution. These models have taken a variety of forms depending on the needs of the people in different-sized countries and cities.

2.2. Evolution of the Sharing Economy through Car Sharing in Europe

Integration of digital technology with transport systems has further enhanced the transformation. Motor vehicles have provided mobility to people, goods and services in a way never seen before in the history of mankind. Today, almost 80% to 90% of the global population uses automobiles in one way or another. This movement has given birth to interactions between civilizations, cultures and customs. The tourism industry and businesses have expanded globally, across national borders. Products and services produced in any part of the world can have ingredients from many countries and continents. Similarly, finished products—agricultural as well as industrial—move rapidly across national borders. Even short shelf-life items like fruits, flowers and vegetables produced in one continent can be found in markets on another continent. The growth of the tourism industry has given rise to mélange and assimilation of cultures and customs. In short, the globalization process has been possible because of the growth of the automobile industry and its integration with digital technology. This has given birth to what is called smart transportation.

As the social status associated with car ownership became diluted and the problems of traffic jams, parking space, accidents and high operating costs (price of fuel, insurance cost, toll charges and parking fees, local air pollution, carbon dioxide emissions leading to climate change, noise pollution and road damage) started getting worse, people were forced to rethink car ownership. Moreover, there are millions who cannot afford to own a car but wish to use and experience car ownership for a limited duration on a payment basis. Environmental considerations due to very high CO_2 emissions also played a role in reshaping the concept of car ownership. Another significant problem with the car ownership model is the inefficiency of their utilization. Most cars are designed to seat five people, however the normal occupancy is only one or two. Moreover, most cars are only utilized during a small part of the day, leaving them idle most of the time. All these considerations gave birth to what is known as car sharing. Many car sharing organizations (CSOs) or transport network companies (TNCs) were established in the 1990s, mostly in Europe. These car sharing organizations were initially supported by governmental grants. Their system was quite simple—a few vehicles were involved in shared usage by a group of individuals. Due to the lack of technology and the grassroots of the car sharing system being neighborhood-based programs, it was very difficult to transfer them into a business venture model. Urbanization, congestion and modern technology gave a boost to car sharing companies.

Historically, the first commercial car sharing can be traced to a cooperative known as "Sefage" (Selbstfahrergemeinschaft), which initiated services in Zurich, Switzerland, in 1948 and remained in operation until 1998 [24]. This early effort was mainly motivated by economic reasons, since there were individuals who could not afford to purchase a car and instead preferred to share one. However, this was a limited experiment confined to a small area. Gradually the carsharing concept became popular in many European countries for the reasons given in the previous paragraph. New concepts and companies came into existence with different concepts of car sharing, including "Procotip" in France, 1971 to 1973; "Witkar" in Amsterdam, 1974 to 1988; "Green Cars" in Britain, 1977 to 1984; Sweden's "Bilpoolen" in Lund, 1976 to 1979, "Vivallabil" in Orebro, 1983 to 1998; and a "bilkooperativ" in Gothenburg, 1985 to 1990 [25,26].

According to Figure 1, a BCG report shows in 2016, that car sharing in Europe will expand relatively quickly and widely. It is estimated that the number of people living in large urban areas will grow further, and this number will be around 81 million people in Europe and 385 million globally by 2021. About 46 million people in Europe will have a valid driving license and about 14 million people will be registered with a car sharing service. About 1.4 million people will be active users, who use the car sharing service several times per month.

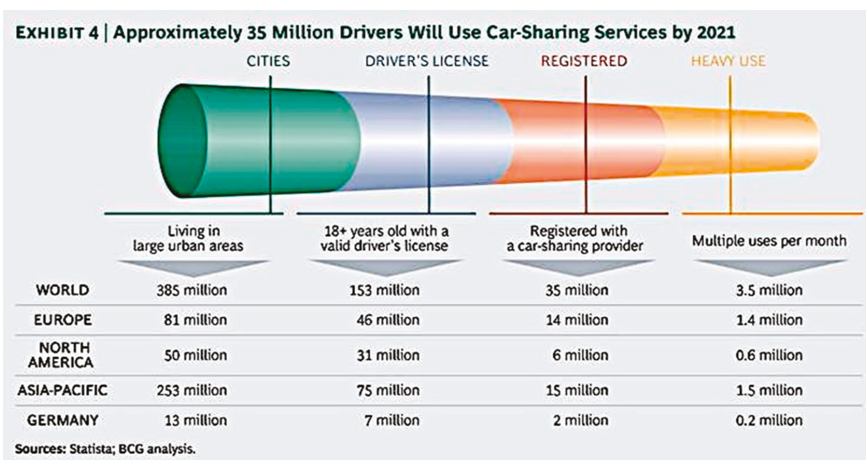

Figure 1. Expected growth of global car-sharing services by 2021. Source: Adapted from Bert et al. [27].

A growing concern regarding climate change and a yearning for social embeddedness by localness and communal consumption has made the "collaborative consumption"/"sharing economy" an appealing alternative for consumers [28,29]. The chart below (Figure 2) provides a bird's-eye view of the growth of car-sharing services in Europe.

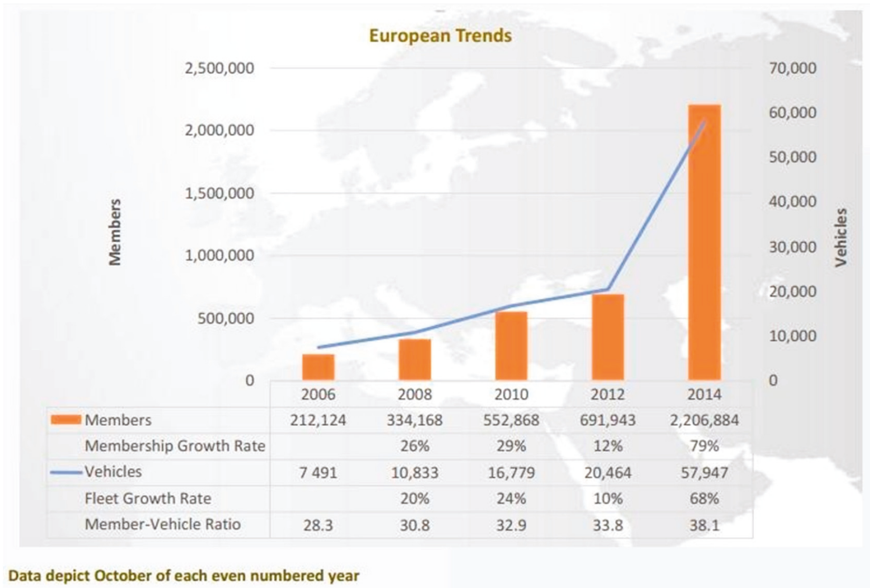

Figure 2. European trends. Source: Adapted from Shahen-Cohen [30].

Today, Europe is considered to be the largest car-sharing region based on membership, accounting for 46% of worldwide membership and 56% of global fleets [30]. In recent years, the big automakers and car rental companies in Europe have joined hands to form car-sharing companies, to keep their hold on the market.

3. Materials and Methods

As it was mentioned before, the modern concept of the sharing economy has evolved not only based on a variety of quantifiable factors. Applying the elements of BMC in local cases will find differences, constraints and key elements, especially in the strategies of the sharing economy service provisions. Comparative analyses in the literature, which focus on differences in the aspects of use of sharing economy services between the capital and big cities in non-capital positions, are rarely available.

Classically, the use of BMC has targeted creating new businesses and projects or implementing new activities within a company or organization. In our case, we apply BMC as an analytical tool in two ways:

- BMC is applied here in order to reveal the main characteristics of presently operating sharing economy services in the capital, and through this we define constraints and key elements of possible implementation in the chosen city.
- BMC is applied here in order to reveal the main characteristics of presently operating sharing economy services in the capital and the city, and through this we define the main differences between the business models and allows us to elaborate on possible improvement directions in the city.

3.1. Database, Data Collection and Research Boundaries

Our continuously refreshed and enlarged data base serves national data from eight big cities, and the capital of Hungary, since 2016 from Hungarian sharing economy service providers. It involves the following data used in the study:

- Price of the services,
- type,
- target,
- owners,
- date of foundation, and
- date of implementation in the given city.

These data input were nominated as general data.

As it was mentioned in the introduction the chosen cities are Budapest and Győr. We followed some basic approach in demarcation of the research field:

- In the selection process it was important to pick a city where the number of sharing economy services is close to the capital's.
- Those services which have national coverage were taken out from the comparison. Other services which were founded based on social media communities were also removed.
- It was also the dominant approach to pick a city in which the economic output is enough to establish new and green services, which serves the local society.

As a link to the general data, we collected the elements of BMC in the case of Budapest, along with Győr:

- Key partners,
- key activities,
- key resources,
- value proposition,
- customer relationships,
- channels,
- customer segments,
- cost structure, and
- revenue streams.

For the data collection of the elements of BMC we used publicly available websites, news and other documents (marketing brochures, service maps, annual reports and other reports). With this step, we show in this study that BMC elements have good functions for analyzing present services in order to consider their further development, or implementation of replicas in other economic and social environments.

3.2. Steps and Phases of the Comparison

Following the approach of comparing services in the capital and the other city, it was easy to compare the 15 above-listed fields of data. This detailed comparison gave the main differences, and key elements and constraints, of implementation. Following this concept of analyses gives the opportunity to compare sharing economy services on the basis of the capital–noncapital dimension, but also in a city to city context. Involving more and more service providers in this context can give important input to the further development or more effective operation of sharing economy services. In our opinion, screening value propositions are a special input in the comparison of sharing economy services. They can show how environmental protection, or "thinking green", is presented in the services.

Figure 3 shows the above-detailed steps as the concept of analysis applied in this paper.

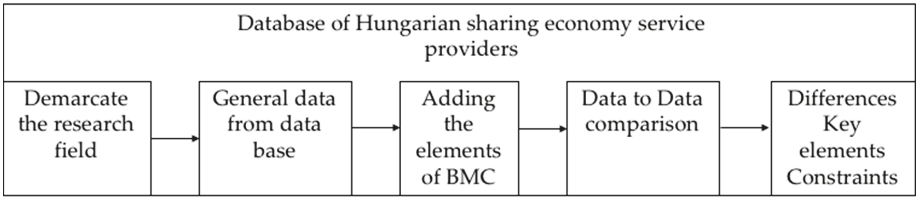

Figure 3. Concept of analysis. Source: Self-made.

4. Results and Discussion

4.1. Screening the Cities: Number and Type of Sharing Economy Services

In the case of a survey undertaken in Budapest and Győr, it was revealed that the number of enterprises and service providers in the area of sharing economy is transparent. They show an increasing tendency towards participation in the sharing economy, based on data from 19 service providers in Budapest (capital) and 4 in Győr (city). The survey also revealed that the local sharing economy enterprises are primarily concentrated in the areas of transportation and shared office space.

Based on the available information presented in Table 1, common services in the capital and the city are car sharing, shared bicycle services and co-working offices. There are no shared bicycle networks without a dockage, shared motor bicycle or scooter services, or shared small transportation bike services in Győr. There are specialized social movements or activities based on the principle of the sharing economy in both cities, mainly presented in social media platforms. As we focused on recovering the main differences and constraints of the implementation of sharing services, we did not involve social media-based sharing activities or movements. Firstly, we detailed services which can represent the main differences between the two cities: Car sharing, shared bicycle and motor sharing services, as well as co-working offices. Next, we highlighted the main differences in BMC of these type of activities.

Table 1. Services of the sharing economy in the surveyed cities (Explanation: + service is presented in the city, ++ service is present in the city with more providers, and (+) there is a system in town but does not target all member of society).

Sharing Economy Services	Capital City (Budapest)	Chosen City (Győr)
Co-working offices	++	+
Shared car services	++	(+)
Shared bicycles	+	+
Shared bicycle (without any dockage)	+	
Shared motor bicycles	+	
Shared scooters	+	
Shared small transportation bike	+	
Other sharing economy activities	+	+

4.1.1. Car Sharing

The following five companies occupy important positions in this market in Budapest: GreenGo, MOL Limo and Drive Now in Budapest follow the traditional business-to-customer model of car sharing services. Another car sharing company in Budapest, Avalon Carsharing, is undergoing an internal transformation. The company will phase out traditional customer services and confine itself to consultancy services on car sharing. BeeRides, an airport car sharing service, has been providing services at Ferihegy Airport since 2015. Although it is a Hungarian-owned company, since 2018 it has been expanding at several airports in Germany. Of the services analyzed, this is the only peer-to-peer (or in other words C2C) service. GreenGo was the first of the city car dealerships in the capital. The number of vehicle fleets based on available, refreshed data are:

- MOL Limo: 450 vehicles,
- GreenGo: 300 vehicles, and
- DriveNow: 280 vehicles.

In Győr there is a car sharing activity, namely Audi 1.2 GO, which is an internal business-to-employee car sharing service of Audi meant for employees for their movements on official duty and for movements within the factory premises. Audi has devised this online system as a perk to employees to earn their loyalty, and to make their work more efficient by facilitating their movements. Under this sharing economy model the maintenance cost of cars is borne by Audi. Given the small size of Győr and large number of Audi employees who are served by the above-mentioned car-sharing system, an independent car-sharing enterprise has not been able to launch car-sharing services in Győr yet. There is only one car-sharing enterprise, namely Up! City, in the Slovakian capital, Bratislava, which is three times larger than Győr, and this enterprise operates with a fairly small fleet of cars.

4.1.2. Bike, Motorcycle and Scooter Sharing

Besides car sharing, sharing of other transport vehicles, particularly bikes, motorcycles and scooters, is also important. GyőrBike was the second of the towns with county rights, and started operating in 2015 in Győr. Among the cities of similar size, bicycle sharing appeared later in Debrecen (2016) and Pécs (2019). Among the rural systems, GyőrBike is the largest in the country in terms of the number of bicycles, docking stations and stations. MOL BuBi has been in operation since 2014 and is the largest domestic system in every respect, maintained by the Budapest Transport Center (BKK). Additionally, MOL, which is one of the largest Hungarian companies, steps up as a sponsor for the promotion of service and mode of transport.

Donkey Republic is a Danish-owned company. The docked smartphone application was launched in 2017 in the Hungarian capital. It currently operates 200 bicycles.

BlinkeeCity is a Polish company and has launched its electric scooter-sharing service in Budapest in 2018 with 77 vehicles. Although it is not yet present in Győr, it has begun its expansion in the countryside, and since summer 2019, there are also scooters in Pécs. Lime, an electric scooter, started operations in Budapest in 2019 with 200 scooters. The US-owned firm is not planning a rural expansion yet.

Among these, the most popular and common in the two surveyed cities is bike sharing, which has a tradition going back several years. Bike sharing operates both in Budapest and Győr; thus, we can see the correlation between the number of infrastructural elements and population of the two cities (Table 2).

Table 2. Correlation in bike sharing systems: Infrastructural elements and population.

Service Provider	Bikes	Stations	Dockages	Town	Population
MOL BuBi	1526	126	2687	Budapest	1,749,734
GyőrBike	180	31	362	Győr	130,094
MOL BuBi (% of population)	0.08%	0.007%	0.1%	Budapest	
GyőrBike (% of population)	0.1%	0.02%	0.3%	Győr	

If we look at the per capita ratios, we can see that there are closing values in the number of bikes. The number of bikes available is 0.08–0.1% for one citizen. Considering the population, there are relatively more stations and dockages in Győr than in Budapest. From this data we can see that the number of bikes can depend on the local population, and the number of stations and dockages are mostly infrastructural elements which are implemented based on other approaches than number of inhabitants. We consider this fact in the BMC analysis.

In addition to the bike sharing, Budapest has enterprises providing electrically operated scooters and motorbikes. Both of these enterprises are new in the Hungarian market. BlinkeeCity started its services in 2018 and deals with electrically operated motorbikes, while Lime started its services in spring 2019 and deals with electrically operated scooters. Transport bike provider, Cargonomia, which started its operation in 2018, operates transport bike services in Budapest. These transport bikes must be dropped at the same place they are picked up from. In the price comparison, we observed significant differences:

From the price differences in Table 3 we can observe that prices show big differences, especially prices of long-term tickets. We include in this comparison only those prices which are presented in both cities.

Table 3. Price differences in bike sharing. Source: Self-made based on available data.

	GyőrBike (% in Prices of MOL Bubi)
Registration	120%
Tickets	
24 h	80%
72 h	80%
Weekly	50%
Half year	46%
Yearly	47%
Usage fee	
For less than 30 min	Free (also in case of MOL Bubi)
For less than 60 min	50%
For less than 90 min	55%
For less than 120 min	60%

4.1.3. Co-Working Offices

Co-working offices involve the use of the same office space by different enterprises on a time-sharing basis, when these enterprises do not require any specialized equipment. Such co-working offices could also facilitate networking and sharing of experiences, in addition to the cost savings. Freelancers, home-office workers and start-ups were mainly using this type of facility in both the surveyed cities. We found nine examples in Budapest and one in Győr. Same examples have also been found in other towns in Hungary. On the basis of BMC there are no significant differences among the users of co-working offices. They are working on the same model. Their principal aim is to access the structured market with minimum cost on infrastructure, as most of their business activities and documents are online. The exception in their business model is that they are providing a different variety of connected services: Buffet services, cafés, libraries, computers, consultations and workshops. The biggest co-working office in Hungary is Loffice, which also provides co-working offices at Lake Balaton during the summer months for those who wish to work during their holidays.

4.2. Business Model Canvas of Service Providers

We highlight information here from the above selected service providers, observing their communication through their websites and news connected to them. With the goal of recovering the main differences between the capital and the chosen city of Hungary, we represent the elements of BMC. To do so, we focus on main differences, in order to implement or improve service models working well in smaller cities.

4.2.1. Key Partnerships

Sharing economy models also provide solutions to ecosystem problems of large cities and not only in capitals. The selected services enter into partnerships with a variety of local players, such as municipal corporations, local people and other economic and social players and institutions. For car-sharing companies the partnerships with local municipalities and social organizations are important, since the cars are parked in public spaces and car sharing helps in reducing pollution and congestion in cities. There are private service providers behind MOL Limo, GreenGo and BeeRides. In the case of Győr Audi is the biggest engine producer and exporter in Hungary. Therefore, a car sharing service in a closed system is provided for its 12,000 employees in order to decrease the usage of cars and infrastructure of the industrial district of Audi. We can observe that, in the case of the capital, there are more private players behind bike sharing. The partnerships evolve in a variety of ways. In the case of MOL BuBi, which is a traditional bike-sharing enterprise, there is a direct partnership with the MOL Company and the state-owned Budapest Transport Company (BKK), and indirect partnerships with municipalities of the districts. In the case of GyőrBike there is a direct partnership with the municipality of the city, which founded the project. There are partnerships in Győr with Széchenyi István University and ETO FC, which is a local football club. These are not financial partnerships but are mostly important due to the placing of stations. At the university campus and student hostels, local football stadium and other sport-related venues there are several dockages. The survey revealed that the dockage at the university campus is the most-used service station in Győr. This close linkage with the university is not visible in Budapest, where there is not a concentration of dockages close to student hostels. The survey revealed that the bike-service providers who do not have dockages do not seem to have similar partnerships with local institutions. Lime, an American electrical roller-sharing company, which entered the Hungarian market in 2019, does not have partnerships with local institutions presented on their website. On the contrary, this company has many partnerships with US universities, where it has been operating for some time. For transport bikes, partnerships are very important as the users are expected to provide parking at pick-up and drop-off points. In the case of co-working offices, interaction happens naturally with other users of the office space, which leads to some sort of networking with the local enterprises.

4.2.2. Key Activities and Resources

In the case of bike-sharing companies, on the basis of BMC there is no difference between the service providers in Budapest and Győr. In both cases the bikes, the dockages, the stations, the IT applications and their maintenance are the most important elements for the bike-sharing enterprises.

4.2.3. Value Proposition

In the case of car sharing we could reflect the following value propositions:

Environment protection: According to the survey there are many differences in the value proposition of different car-sharing enterprises. GreenGo, which entered the market first, places maximum emphasis on environment protection. Its entire fleet of cars is electric operated.

Having a car: The motto of MOL Limo is simple. It says: You have a car. DriveNow, which is the latest entrant into the market, has a completely different motto. It provides only luxury vehicle BMW and Minis to the richer segment of society.

Parking: Parking fees are involved in most car-sharing services. It is therefore important to secure free parking spaces from the local authorities, as this is an important element of the overall cost of car sharing. As a result of such initiatives, electrical cars with green number plates have been allowed free parking facilities in Budapest. The fleet of GreenGo is 100% electric-operated cars, while the fleet of MOL Limo has a mixture of petrol-driven and electric-operated cars.

Short visits: BeeRides is trying to enter into a partnership with Budapest Airport for free parking spaces, as the main profile of the company is to utilize the cars of those who are leaving the city on short visits, from when they leave the airport until their return. Under this system the car owners do not have to pay a parking fee at the airport. Moreover, they earn some money by renting out their cars during their absence on visits abroad. In the case of bike-sharing services, the most important value propositions are health and the environment. Therefore, the model of a sharing economy is based on sustainability and environmental considerations, against the traditional ownership of assets. Thus, the value proposition is the main focus for all players participating in the sharing economy. In the case of co-working offices, the main focus is reduction of cost.

4.2.4. Customer Relations

Based on their respective market segments, service enterprises are focusing on their customers through their websites and other online communication channels. Since car-sharing services are still confined to a comparatively small segment of the population, communication within the segment is comparatively easy.

4.2.5. Distribution Channels and Segmentation of Customers

In the case of car-sharing services in these two cities, there is a clear market segmentation. On the contrary, in the case of bike sharing services, the customers are primarily confined to the student community, young sport lovers, and hospital visitors.

4.2.6. Cost Structure and Revenue Streams

For car-sharing enterprises in Budapest, the car rental fee is the most important source of revenue. On the expenditure side, maintenance of the cars, operation of the system and the salaries of employees are the most significant costs. DonkeyRepublic, a bike-sharing company in Budapest, does not have any linkage with docking places. Their bikes could be picked up and dropped at any place in the city. On the basis of the Business Canvas Model its business model is very similar to the traditional bike-sharing systems with dockages, but they do not incur any expenditure linked to the dockages. Their income is from the donations of users. In the case of other bike-sharing service providers, the main costs are the operation of IT platforms and cost of dockages. In co-working offices, the renting fee is the most obvious revenue stream for providers.

4.3. Differences, Constraints and Key Elements

Our goal was to reveal the differences between a capital city and an economically well-developed city by leaning on the modern concept of a sharing economy, which is led by not only the quantifiable factors like population, but also by aspects of consumer behavior. Social, economic and environmental considerations were the driving forces behind sharing economy models in the recent years, e.g., the desire for ownership is not so high anymore and there is obviously a financial motivation behind sharing.

4.3.1. Main Differences

While there is only one big service provider with dockages and stations in bike sharing in each city, there are several smaller providers in Budapest that are competing for their market share and use alternative ways to handle the cycles or collect the fee of service.

On the basis of BMC, in smaller towns there is a tendency toward segmentation, as observed in Győr. This segmentation is obvious in the car-sharing market. In the case of sharing of bikes, the segmentation is more in terms of specific groups such as students, hospital visitors and sport persons. The direct partnerships are more visible in Győr in terms of the groups of users, while the partnerships are clearer in Budapest service providers.

In the case of the capital, private ownership is more behind bike sharing. There are more service providers. Prices in Győr are significantly less for long-term tickets.

Through the analysis the role of key partners and the ownerships could be reflected. There are two general results from this: We can see the presence of foreign direct investment in the case of services in the capital, and we can see university and sport clubs as dominating key partners in the case of the chosen city.

4.3.2. Constraints

Although the car-sharing economy is expanding globally, what still really matters is the size of the cities and towns. Population remains the major factor for expansion of car-sharing services. As mentioned earlier, even in Bratislava, which is a smaller town compared to Budapest, there is only one car-sharing enterprise. The value proposition of environmental protection is linked to a wider target of possible users. As this type of service has private owners in the capital, profitability is also an important factor, which is dependent on the size of the local population. Publicity is also important to make people aware, and to create demand for these services. On the other hand, obstacles in sharing economy services can be overcome if the services are confined to a specific segment of people, as in the case of the car-sharing service to and from the airport, and for employees of a big enterprise in Győr.

Based on this, we can suggest that in case of cities with a smaller population, implementing car sharing to specific customer segments can be less risky, as it is operating in a different business model in the analyzed cases. A small-scale, segmented service supports and motivates users in their environmental consideration. We can see a trend of diversification in the analyzed bike-sharing services of the capital. This is also visible in the business models or strategies of different car-sharing service providers.

As a significant difference, it could be observed how between the capital's and the city's business models that population as a constraining factor is not the only one behind. Not having the critical mass of possible users of the services leads us to the finding that instead of following a capital's route, the creation of smaller, segmented services can be more successful than implementing widespread ones. In case of the capital the motivation behind the diversification were market-related factors like saturation. In case of an economically well-developed city with a lower population, the motivation behind the segmentation can be linked more to the modern concept of a sharing economy, which is based not only on quantifiable factors like population. Due to this, in our opinion, the optimal strategy for smaller cities is to support small-range, segmented services with a proper value proposition.

4.3.3. Key Elements

Value propositions are an important and well-presented factor of the analyzed sharing economy services. In the case of car sharing there are different value propositions, such as environmental protection, using premium category cars, having a car and designated travel routes. In the case of bikes, scooters and rollers, the main value position is predominantly environmental protection and health.

In the case of bike-sharing services, the number of bikes can depend on the local population. The number of stations and dockages is mostly infrastructural and are implemented based on other approaches than number of inhabitants. We consider this fact in the BMC analysis.

Best practice could be recovered in the transportation bike-sharing service, because in Budapest, apart from infrastructure, partnership is also a key element. The bikes can be picked up and dropped at the place of the designated partner or organization. The maintenance of the bikes and the operation of the online application are the two important cost factors. The system runs on a non-profit basis. Based on the voluntary donations received, the system is maintained. The main value proposition is sustainability and environmental considerations, and to help with last-mile connectivity.

The BMC approach was appropriate to reflect the key elements of the different value propositions in car sharing: Environmental protection, having a car, parking, short visits, health and environment, as well as a reduction of cost.

5. Conclusions

Based on the survey it is clear that the number of sharing economy enterprises is on the rise in Hungary, but they are still primarily confined to the capital. Amongst all the cities, Budapest remains the principle arena of their activities. The aim of this article was to examine various sharing economy models and their differences in Budapest and Győr, based on the BMC. The article also examined the obstacles in further expansion of sharing economy models in Győr, and the key elements for successful operation of this models. On the basis of the above we have come to the following conclusions: From the above-reflected differences we can conclude, especially in case of bike sharing, that the number and type of users are the key factors in implementing sharing economy services, and not the population. We can see that despite the fact that Győr has a smaller population, it can operate sharing services successfully, with key partnerships for the strategic placement of dockages, like the local university or sport clubs. Additionally, it is important to note that car sharing is presented in a given segment, so despite the fact that the population of Győr is not critical in terms of car sharing, the biggest corporation there is creating its own green solution for decreasing the usage of cars in its area. The abovementioned conclusions do not mean that service improvement in both cities is not needed. There are constraints and key elements which need to be considered in order to increase the number of these services.

We can say that BMC elements had good functions for analyzing the present services in order to consider their further development or implement their replicas in other economic and social environments. BMC could reflect the main differences, constraints and key elements in the models of sharing economy services. We can say that, in the case of the bike-sharing service operating in Győr, there is more segmentation than for the same service in Budapest. There are also significant price differences. In Győr, long-term tickets prices are more than 50% less than in Budapest. We can conclude that Győr would like to attract more long-term users than Budapest. The number of inhabitants and ownership are the biggest constraints in implementing car-sharing services, but there is also a chance for implementation by applying good value propositions and segmentation.

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Review

Examination of Short Supply Chains Based on Circular Economy and Sustainability Aspects

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Abstract: The sustainability of global food chains and intense agricultural production has become questionable. At the same time, the consumers' interest in short supply chains (SSCs) and direct sales from producers has increased. SSCs are connected to sustainability by researchers. Their (supposed) positive sustainability attributes are based mostly on extensive production methods and short transport distances. However, from other points of view, the economic and environmental sustainability of the short chains is questionable. Our research aims to cast light on the SSCs' role in circular economy and sustainability. By deep literature review and content analysis, we determine the sustainability aspects of short (local) chains and their effects related to economy and environment. Short supply chains are connected most widely to circularity and sustainability by the subjects of environmental burden (transport, production method, emission), health, food quality, consumers' behavior, producer-consumer relationships, and local economy. According to our experience, these factors cannot be generalised across all kinds of short chains. Their circular economic and sustainability features are dependent on their spatial location, type, and individual attitudes of the involved consumers and producers.

Keywords: short supply chains; local food; food waste; environmental burden; consumer behavior; producers

1. Introduction

Generally, it can be said that agricultural food producers have to struggle for their (successful) operation—or even their survival—at low returns. The emphasis is on economic efficiency; for this reason, the ecosystem is under severe pressure [1]. Global food systems have a significant contribution to greenhouse gas emissions at all stages of the food chains: production, processing, marketing, sub-sale, home preparation and waste phases [2], and they can be one of the main causers of environmental harm like climate change, eutrophisation or loss of biodiversity [3]. In this way, the sustainability of traditional agri-food systems has been questioned over the last decades [4]. In developed countries, food consumption can contribute to greenhouse gas (GHG) emissions by up to 15–28% (based on national studies between 2007 and 2010) [5,6]. Increasing population; increased food demand, inadequate use, and distribution of food resources and high levels of food waste in the food systems are predicting the need for more sustainable practices [7]. Furthermore, consumers may be sceptical or distrustful of the intensive agricultural systems. The environmental and health effects of certain widely-used chemical substances are debated. For example, Toretta et al. (2018) [8] presented a scientific debate on the effects of glyphosate as the most sprayed and most used herbicide in the world.

Short food chains (SFSCs) have increasing popularity nowadays [9]; however, their role in the food trade of developed countries is limited [10]. They are unable to "replace" the global food systems in the lives of consumers [11,12]. They have the potential of supporting local and regional development and contributing to food quality for consumers [9] and job creation [13]. There are indications in the literature that these chains are capable of contributing to sustainability, due to their particular characteristics and small scale, although some aspects that are considered to be beneficial are also disputed by the experts' opinions [14].

Widespread dissemination of sustainability [15,16] and circular economy [17] is a priority of the European Union. Sustainable municipal solid waste management in a circular economy view has become an important goal in EU and non-EU countries [18]. Moreover, short supply chains (SSCs) are also supported in the EU budgetary period between 2014 and 2020 [19]. The objectives of the circular economy model overlap with the aims of sustainable development [20]. This overlap refers to the environmental and resource-saving nature of economic systems and their economic and social sustainability. In September 2015, the United Nations (UN) adopted an ambitious Agenda for 2030, setting 17 sustainable development goals for economic growth, social integration, and environmental protection. Goal 12 refers to "Responsible Production and Consumption" and relates to food loss and waste management [6]. The purpose of the subpoint 12.3 is: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" [15] (p. 22). In the "Closing the Loop—An action plan for the Circular Economy" [21], there are five main priorities identified regarding circular economy, and "food waste" is one of them [22]. Worthy of mention is that sustainability and the Sustainable Development Goal 12 are related to other Goals like "Good Health and Wellbeing" (Goal 3) and "Life on Land" (Goal 15) [23].

The purpose of the current article is to systematize and consider the aspects whereby short trade chains can contribute to a circular and sustainable economic and environmental system. The sustainability of food chains includes three dimensions: economic, ecologic, and social [24–26], which can be complemented by personal health or well-being [25]. In connection with some of the objectives of the European Union circular economy package [17] and the Sustainable Development Framework [16], in our article we reviewed the following subjects: Food- and package-wastes in the (short) food chains, the environmental impact, economic and social characteristics and sustainability of the short supply chains, and short food chains. Within social characteristics, we specifically dealt with consumer welfare and health issues. Our main research question is that whether the belief in short supply chains is true that they are considered environmentally friendly compared to multi-actor retail chains and they can contribute to the development of the local economy and the well-being or satisfaction of consumers.

Our literature review was conducted by reviewing 128 sources (120 articles and 8 European Union professional materials). The most important source of our research was the Scopus database, where we searched for articles based on searching term "short food supply chain", started from the year 2011. We narrowed the search fields to agriculture, energy, environmental science, business, management, and economics. We sought to obtain information dealing with the relations of short supply chains, sustainability, and circular economy. We also used other databases such as EBSCO Discovery Service, ScienceDirect, AgeconSearch, Google Scholar, and searched for additional articles on the topics of circular economy and sustainability in general.

2. Literature Review

2.1. Conceptual Approach

In our article, on the basis of European Union subsidy policy (Regulation (EU) No 1305/2013), we consider a short supply chain (SSC), where producers sell their products to consumers directly, or through one intermediary [27]. Researchers dealing with this topic can find numerous alternative concepts, such as "short supply chain" (SSC), "short food supply chain" (SFSC) "alternative food network" (AFN), "local food system" and so on. These terms generally refer to the spatial proximity of production and (final) sales and consumption, to local food products and a low number of participants in the chains. In our article, we made no distinction in content between such names; they were used alternately based on the different source works. (The spatial aspects of short supply chains' determination are not addressed in this article.) Direct sales and direct marketing have several types [12]. The most well-known are farm shops, farmers' markets, delivery of vegetable boxes by subscription, mail-orders, producer co-operatives, solidarity purchasing groups, and Community Supported Agriculture (CSA). The popularity of certain models varies from county to country.

It is widely believed that short supply chains (SSC) are suitable for the trade of high-quality products while promoting sustainability and efficiency [28]. The literature of this subject examines aspects like the reduction of food waste, eating healthier and more sustainable food, and ethical considerations. Participants of short food supply chains have increased knowledge and information on food and its origin [29]. However, many researchers are sceptical about the general optimism towards SFSC channels. Their supporters believe that local production is more sustainable than multi-actor retail chains, but this is less quantifiable. It would be dangerous to accept the disputed or disputable issues as absolute truths [30]. Further empirical research is needed to explore the sustainability impacts attributed to the certain alternative food chains [14].

The circular economy is one of the most popular research areas in the field of sustainability [31]. The concent of circular economy aims circular flows in the economy (opposed to the "linear flows" are dominant currently) [32]. It represents an economic model based on the recycling, reuse, repair, sharing, and leasing of existing materials and products [17]. The model of the circular economy can be interpreted in food chains regarding waste reduction (and minimization of surplus), food reuse, nutrient recycling, and the promotion of more varied and effective dietary patterns. It can affect the different levels of production and consumption [7].

In the case of new EU member states (joined in 2004), sustainability easily falls into the background due to the cost-efficiency of global food chains and their high level of influence [33]. The examination of "sustainability performance" of supply chains is still in an early stage, and it is definitely true in the case of short food chains [34].

Sustainability of food chains can be measured by the following indicators: Life cycle analysis (LCA), carbon accounting, material flow analyses, ecological foot-printing, food miles, Hazard Analysis and Critical Control Points (HACCP) studies, stakeholder dialogue and surveys and converting impacts into financial analysis [25,35]. In terms of environmental impact, the importance of the water allowance coefficient (WAC)—as an indicator based on water footprint—is also increased [36].

Examinations of local food systems' sustainability are made difficult by the fact that even consolidated approaches like a Life Cycle Assesment [37] cover only a small part of sustainability factors. Many aspects of sustainability are not yet fully measurable in a complex way. From the indicators mentioned above, our study focuses mostly on the analysis of food miles, because in this respect, the most striking difference between short chains is the shorter transport distance compared to the multi-actor chains.

2.2. Waste Originates from Food Chains

The amount of waste generated at various levels of food systems is huge, even by the most optimistic estimates. This means a very serious problem. According to FAO (Food and Agriculture Organization of the United Nations) data, nearly a third part of all food destined for human consumption is "lost" or wasted every year [38]. It is estimated that in the United States [39], or the European Union [7], this proportion can be as high as 30–50%. In terms of quantity, Buisman et al. (2019) [40] estimate the annual food waste in food chains in the EU at 89 million tonnes. According to the estimation presented by Corrado and Sala (2018), [41] the food waste means 194–389 kg per person per year at the global scale, and 158–298 kg per person per year at the European scale. (Worthy of mention is that according to the "Closing the loop- an EU action plan for the Circular Economy" [21], there is no harmonised, reliable method to measure food waste in the EU. In this way, it is not surprising that the estimates are different. The "Food Waste Atlas" is a freely accessible online tool, where data about global food loss and waste from the food supply chain can be examined together [42].

An important element in achieving sustainable consumption and production is to reduce food waste [43]. Certain conventional treatments of food waste can lead to environmental, economic, and social problems. However, there are more sustainable or profitable management options. Reuse is possible, for example, in the chemical industry; consumers chemicals, acids, sugars can be synthesized from food waste, for instance. They can also serve as feedstock for biofuels and can be used in other ways [44]. However, the general, "linear" (non-circular) supply chain structures basically do not focus on reducing the negative aspects of production systems [26].

Composting, anaerobic digestion (AD) or innovative treatments as hydrothermal carbonization (HTC) are examples of food waste management. Anaerobic digestion seems to be one the most suitable solution for food waste treatment [45] and it has great potential for the disposal of the organic fraction (consequently food) of municipal solid waste [46]. This is a renewable energy source with low emissions [45]. Using products (e.g., fertilizers) created by hydrothermal processes like supercritical water oxidation (SCWO) or hydrothermal conversion (HTC) can contribute to large environmental savings [47].

Nayak and Bhushan (2019) [48] present the four basic approaches of valorization techniques of food wastes. The first is the conversion of food waste to generate biofuels; the second is to extract and (efficiently) recover various value-added components (e.g., proteins, pectins) from food waste; the third is "the conservation of food wastes via microbial activity to develop various bio-materials, in the form of bio-chemicals, bio-polymers, enzymes, single-cell protein, and bio-fertilisers" [48] (p. 364); and the fourth is to develop "effective absorbents from various bio-based food wastes for wastewater treatment" [48] (p. 365).

As food-waste can be generated at all stages of the food chain [39], efficient management for waste reduction requires the system approach of supply chains. The following methods of reducing food waste can be comprehensive and environmentally friendly: redistribution of unsold and surplus food, improving in-store promotion and stockpiling, reducing package sizes and stimulating or improving consumer perception and different consumer habits [49]. Waste reduction methods like food redistribution may have economic, infrastructural, and legal barriers [12]. For example, especially in rural areas, the network of food rescue organizations is often not tight enough to organize the transport of food surpluses from the point of origin to the food bank in an economically feasible way.

It should be noted that the primary approach of direct marketing is not based on waste reduction but on fostering community, preserving local food production, revitalizing the local economy, and protecting the environment. Furthermore, there are very few empirical studies on the impact of direct marketing on food waste generation. In the case of SSCs, the food chain is shorter and has fewer stations. The decrease in the number of intermediaries and traders—for various reasons—can significantly contribute to the reduction of food waste. In this way, losses caused by wholesale or retail may be decreased or zero. Such losses can be, for example, when they force producers to overproduce or refuse products that do not meet their standards [12].

According to a Swedish household survey, 20–25% of household food waste is related to packaging [6,50]. The sustainability of food packaging can be judged through three aspects: its direct impact on the environment, the quantity of food-losses and wastes related to packaging, and the circularity of packaging (reusability, recycling). On the other hand, food packaging also contributes to food protection; prevent it from being wasted early, becoming unfit for human consumption [51]. The role of food packaging varies in this way. Packaging minimization does not necessarily mean a complete solution to reduce the overall environmental footprint of foods [6,52]. In developing countries, much of the food loss is more likely to occur during the pre-consumer stages of the food chain, so the packaging can play a major role in protecting food. In the food chains of developed countries, waste is generated in a high proportion in the consumer phase (due to wasteful behavior) [7,38]. For this reason, the behavior of individual households must also be considered to assess the environmental impact of packaging. It is significant how the consumers transport and store food, and how food waste and packaging waste are collected by them [3]. The objectives of the circular economy model include, for example, the use of recyclable packaging and the promotion of appropriate consumer attitudes, for example, by information, labeling [17], in order to prevent or reduce the generation of household waste [21]. In short supply chains, producers use less or zero packaging material. This is due to the nature of their economic and sales activities. The amount of sold products is less, and the purchasing process is less regulated than, let us say, in large chain-stores.

Food waste can also be linked to the appearance of the products. Consumers, or the chain-stores themselves, are reluctant to buy foods that, although just externally, differ from the optimum. It is possible to increase demand for such products through price discounts, or sustainability, quality and originality campaigns and positioning [53]. We have not found a reference to this in the literature, but in our experience, aesthetically defective vegetables and fruits are easier to sell in short chains, whereas they can not be placed on the shelves of large retail chains.

Consumer attitudes towards circular products are mostly still unexplored aspects of research. For example, it may be interesting to consider how many consumers are willing to return or dispose of used products [54]. The influence of social norms can provide opportunities for healthier, more sustainable diet patterns and habits [55]. At the same time, systems such as subscribed vegetable boxes can generate more waste than a common supermarket purchase; if consumers get some products they do not like or do not know how to prepare [6,12].

Customers' decisions are greatly influenced by where, how, and under what conditions their purchased products were made [56]. In multi-actor (global) chains, it is very difficult to trace the origin of food. As the supply chains become shorter (regarding the vertical phases), the traceability of products and related transactions are improved. Consumers can make more sustainable purchasing decisions if they have sufficient (usable) information [57,58]. Del Giudice et al. (2016) [56] examined the impact of food labeling on consumers' behavior. Waste-prevention-based labeling influenced consumers' willingness to pay positively. It was more affected by the carbon footprint frame of the reference (and not so much by the water footprint). According to this result, customers were interested in buying products that cause less environmental damage. In short food chains, the consumers and the producers get closer to each other; in this way, customers get accurate information on where the products originate [59].

Regarding food package, the large-scale plastic waste (including single-use plastic bags) is greatly responsible for the environmental burden. Generally, the shops provide a great amount of plastic bags for the customers. Offering eco-friendly reusable bags is a possible solution to reduce plastic waste [60]. The successfulness of these reusable bags is also dependent on the individual customers (or shops and sellers), who can be influenced by concerning campaigns. The authorities may also take actions, for example, banning, extra fees or taxes on plastic bags [60]. In terms of circular economy, the European Union set goals for 2030, in order to reduce plastic wastes, e.g., all plastic packages on the EU markets have to be either reusable or cost-effectively recyclable [61].

2.3. Economic Sustainability of Short Supply Chains

In terms of economic sustainability, in optimal cases, short trade chains can support local and regional development and contribute to the consumers' food quality [9] and job creation [13,62]. Experiences from several case studies show that SSC channels are mostly used by relatively small farms [63–65] (or are most profitable for them). They integrate supply chain functions in this way, but they also need to connect horizontally [66]. In many cases, producers' participation in SFSC is motivated by interdependence, self-employment [13], or by selling directly to the consumer at better prices, avoiding retail and wholesale trade [67]. In this way, they can receive a higher return on the value of the products [68]. Short chains have the opportunity to offer more value-added from producers [9]. Non-financial motivations of participating can be preserving tradition, establishing and maintaining relationships with customers, protecting local, values, and environmental factors (such as sustainability and the natural or cultural environment) [69]. Limited local demand and seasonality of production mean drawbacks. According to Zhang et al. (2019) [70], in a wieder sense, SSCs can have a positive impact on local economic regeneration. Income generated by SSC participants may remain in the local economy [68]. In the case of the (orgainc) farms examined by Al Shamsi et al. (2018) [71], there was a strong correlation between the producers' preference of local markets and high performance in terms of sustainability.

The positives mentioned above come into being in the "ideal case" of course. Reduction of distances and the numbers of intermediaries may increase production earnings in short food chains, but in itself, it does not secure a long-term position in the food market [59]. The economic efficiency of the short supply chains depends on the particular situation and is highly dependent on the presence of solvent demand. There are consumers who are fully committed to local foods, but the numbers of such consumers are probably low. Other consumer groups are willing to give preference to local food, but only in a case of reasonable prices [72]. On a verbal level, there are many statements that certain forms of circular economy and short supply chains can play an important role in sustainable rural development, but on the other hand, these systems hardly exist in the newly acceded EU Member States (joined in 2004). In these new Member States, the relatively low willingness to pay for local products hampers the development opportunities for short supply chains [33]. Schupp (2016) [73] examined the location of producers' markets in the United States. According to his experiences, producers' markets are unlikely to appear in rural areas. As his results show, producers' markets affect almost exclusively the middle and upper classes, and they occur very rarely in areas with below-average socio-economic status. Also, in the American study of Low and Vogel (2011) [64], local food trade provided opportunity for economic development mostly in urban areas.

2.4. Connections between Short Chains, Sustainability, and Healthy Eating, Consumers' Well-Being

Unhealthy eating habits often develop during childhood and also persist in adulthood. Many young people do not have sufficient daily quantities of vegetables and fruits, as determined by the United States Department of Agriculture (USDA) [74].

Nutrition habits are based on complex decisions and have a significant impact on the environment and society [75]. From a consumers' perspective, several studies on SSC highlight aspects of freshness and "healthy eating" generally and specifically regarding fruit and vegetable trade (e.g., [76]). One of the main reasons for the preference of short chains is that consumers who choose SSCs perceive that small producers' wares are fresh, healthy, and of good quality. (e.g., [11]). Also, in the case of organic products' SSC-trade, healthy eating is the most motivating factor [77]. Ethical factors, such as traceability or environmental impact, can also have a significant influence on consumers' purchasing habits [78]. According to Leglise and Smolski (2017) [79], it is important for customers who prefer SFSCs to produce these goods with the best environmental practices, specific techniques, without agri-chemicals or industrial methods. In this way, product quality is also an attraction for customers [34]. At the same time, reliability, reputation, and respect of a (bio) producer may have a greater influence on consumers' behavior than the perceived bio-classifications on food [80]. In the traditional multi-actor chains, it is difficult to make good consumers' decisions regarding sustainability. Consumers are unaware of the entire food chain and its factors [7]. Consumers can be motivated or influenced by various campaigns to raise awareness of food waste and its environmental impact [53,81]. Del Giudice et al. (2016) [56] noted that by providing information on the carbon footprint of the given bread production, it was possible to motivate consumers to buy lower-carbon-footprint bread [53,56].

In the case of short chains, consumers are more aware of the place of foods' origin, the mode of production, and the identity of producers [70]. In the study of Giampietri et al. (2016) [82] where Italian students were surveyed, aspects like sustainability, and local development (as well as comfort) played a key role in short-chain shopping. Consumers who are spreading health awareness, expect healthy, fresh products. After harvesting, the quality of the products deteriorates continuously [83]. This is very much related to the time between harvesting and getting to the table [55]. Stahlbrand (2015) [84] describes the food sector as a sector of "relentless deadlines". Food is perishable, and consumers demand "immediate service".

It is assumed that consumers attributing high value and good quality to producers' goods behave more consciously, and do not accumulate unnecessary surplusses that become waste later.

However, empirically, it is difficult to substantiate that local food would universally surpass non-local or imported food in terms of its impact on the environment or consumers' health. According to Edward-Jones (2010) [85], there is no known (or there was no known) publication examining the nutritional differences between local and non-local products or the health effects of a completely local diet. The positives attributed to SSC products can be attributed to the transport and storage characteristics that are different from conventional (multi-actor) sales channels. The quality and content of the products change differently compared to long delivery. Based on the study of Verraes et al. (2015) [86], SSC-products may have different microbiological quality parameters and different food safety aspects than food traded in conventional chains. According to their research on dairy products, SSCs are slightly more exposed to food safety concerns. This opinion is supported by the results of Jancsó et al. (2017) [87], who examined the quality of raw bovine milk sold directly to consumers in Hungary.

2.5. Environmental Aspects of Short Supply Chains

The idea of the circular economy can be interpreted in the food systems, as reducing losses, wastes, and avoidable environmental damage caused by the food chains [55].

The topic of sustainability has been gaining relevance in land use studies. The bibliometric analysis (of articles from the period 1988–2017) by Aznar-Sánchez et al. (2019, p. 13) [88] shows that research on sustainable development and land use "focuses on a new form of agrarian management, such as organic farming, permaculture, and multifunctional systems." The authors suggest that future lines should address the development of circular economic systems in agriculture.

Furthermore, extensive production methods may affect nutrition and (in this way) human health. For example, organic products of plant origin are grown without chemical-synthetic pesticides or without readily soluble mineral fertilisers or sewage sludge and waste compost. It is widely believed that organic foods are healthier than conventionally produced ones. (Absence of pesticide residues has great importance in this term.) However, the actual effect of agricultural techniques on nutrient composition is still not clear according to Gennaro and Qualia (2003) [89]. It is difficult to give a final answer due to uncontrollable factors (like rainfall and sunlight that have influence on nutrient content.) According to Popa et al. (2019) [90] (still) more research is needed to draw unwavering conclusions about the superiority of organic food (compared to conventional ones.) Relatively more environmentally sustainable production methods may be associated with SSCs, resulting in less input use, including pesticides, synthetic fertilizers, animal feed, water, and energy [10]. Applying a shorter supply chain can, in financial terms, facilitate the application of more sustainable practices. Such practices may include feeding the farm-animals by local feed or grazing, using organic, or biodynamic cultivation methods, or using on-farm production of renewable energy [68].

The lower negative environmental impact attributed to short supply chains (e.g., [9]) can be explained by the reduction of the food-miles (distances between the place of production and consumption) due to lower CO_2 emissions or noise pollution [67].

However, in itself, the food mile as an indicator is not sufficient to asses the environmental impacts of food chains [14,91]. It is not enough to measure transport emissions because it is difficult to assign certain kilometers to particular foods. Furthermore, different modes of transport, equipment, and different types of fuel also should be taken into account [25]. Some authors equate shorter transportation with less energy use, while others consider that short chains basically have poor energy performance.

Many consumers seek to reduce harmful environmental effects by consuming locally produced foods [92]. However, the benefits of "eating locally" and energy use are being challenged in several studies [93], and for the right judgment, the effectiveness of SSC distribution and the distances travelled by consumers for purchasing, must be examined. According to Weber és Matthews (2008) [94], the "buying local" behavior of an average American household could reduce greenhouse gas emissions proportionally only by 4–5%, since the majority of gas emissions occur during the food production phase.

From a consumers' perspective, the more the consumers have to drive for purchasing, the greater their environmental impact and CO_2 emissions [34]. Local food means an opportunity for sustainability if production, distribution, and consumers' shopping trips are sufficiently energy- and cost-effective [57]. Mancini et al. (2018) [34] suggest that buying in a specialized dairy shop (investigated by them) is less environmentally effective than going to a larger grocery store, where a wide variety of foods can be found. On the other hand, one of the drawbacks of SFSC-s in terms of logistics is the less concentrated transport, which also results in lower efficiency (small freights, that are time and money demanding, especially for longer distances, and to less populated areas with specific delivery conditions) [95]. This suggests that energy- and cost-effective mass delivery systems can be even more sustainable than local production and distribution [6,57]. However, sustainability cannot be measured with a single indicator (travelled distance, or greenhouse gas emission). Energy efficiency is not the only measure of sustainability [93].

Industrially produced meat consumption in Western nutrition is a critical factor for sustainability in food consumption [7]. Van Huis and Oonincx (2017) [96] state that due to the growing population, growing consumer demands, and limited land-areas, there is an increasing need to replace traditional meat products. Changing over to a more plant-based diet is a possible solution [7]. Small farmers selling in SSC can play a role in this process. A very important product category for short supply chain trade is the purchase of vegetables and fruits from producers. Vegetarianism, as a consumer choice, is often associated with its positive environmental effects. A vegetarian meal has a less environmental impact than a pork-based meal (with about 40% lower emission) [56]. In the case of livestock rearers, regional (local) feed supply can also have a positive environmental impact, but it can also significantly increase the consumers' price of meat and dairy products. The socio-ecological impact of price increases can be significant; on the one hand, it can contribute to the change of dietary habits, for example by switching to plant-based foods; however low-income consumers may not be able to effectively change their buying habits [97].

It is difficult to draw a comprehensive conclusion on the sustainability of SSCs because the farms involved and the production methods they use are very different. Truly sustainable food systems should have a low environmental impact and, according to Al Shasmi et al. (2018) [71], organic production is one of the best ways to achieve this. However, even SSC-trade and organic farming are not automatically considered environmentally friendly [30], nor can it be generalized that conventional supply chain farming systems would in all cases be environmentally more intensive than SSC-oriented ones [98]. Sustainability and product quality performance of SFSC-s are closely linked to the local context and market situation in which they operate [28]. Organic farming and integrated farming are often described as they can reduce the environmental impact, but for the production of various vegetables (such as salads and leaves), there is just a little scientific evidence on the relative environmental impact of such alternative production methods [99].

Local food systems using organic methods increase worldwide, but little is known about their carbon footprint. Vitali et al. (2018) [100] examined the production of greenhouse gases in short supply chains related to the marketing and sale of organic beef. They found that farm activities and home consumption had the greatest global warming potential in the product path. As a conclusion, the environmental impact of SSC transport was considered to be relatively low, compared to production and consumption.

Based on "arbitrary rules" [85], it can be said that in the case of seasonal fresh products, such as fruits and vegetables, the carbon footprint is lower, or at least comparable to non-local fruits and vegetables. The short travelled distance and the avoidance of intermediary actors and quality preserving processes mean shorter shelf-life and freshness [28]. But, for example, if fresh products are stored and consumed out of season, the above-mentioned "arbitrary rules" may fail [85]. According to Frankowska et al. (2019) [101], green vegetables imported to England produced in unheated greenhouses have a lower environmental impact than vegetables produced locally in heated greenhouses in England (despite the transport). Operations during the processing phase like freezing, pasteurisation, baking, use of added materials (e.g., oil), also result in high(er) environmental impacts. Because of agro-ecological and socio-ecological differences, it is not certain that the environmental impact of local food is lower, for example, if a given production site is more suitable for producing a certain type of food, compared to other (closer) areas [102]. Because of these facts, in agreement with the words of Depperman et al. (2019) [97], one has to be very careful about statements that call local food equal to sustainable food. Consuming local food is not always an environmentally beneficial option. It also should be noted that many products cannot be raised or produced in local systems because of climatic conditions [103]. In this way, consumers have to purchase them in conventional trade chains, regardless of sustainability considerations.

According to Gatimbu et al. (2018) [104], the relationship between environmental and economic performance is not clear. Both positive, negative, and insignificant examples can be found in the literature. According to their [104] research with small-scale tea factories in Kenya, environmental efficiency reduced the economic efficiency of business. According to Lehtinen (2011) [25], cost-effectiveness is not necessarily opposed to sustainability, and local food systems are not necessarily sustainable, but there are several facts that support the view that local foods can be more sustainable than other alternatives.

2.6. Social Sustainability of Short Supply Chains

Regarding the sustainability of supply chains, research on social aspects is still underrepresented, and this fact offers further research opportunities for the future [105]. Examining societal aspect may be recommended directly in the field of Circular Economy too [106]. According to Taghikhah et al. (2019) [107], it is impossible to talk about sustainability without extending the supply chain to consumers' behavior itself and its impact on system performance. In their work, they show how a supply chain can increase its socio-environmental and economic performance by motivating consumers towards green consumption, and how consumers motivate producers (and suppliers) to change the way they operate in this regard. Consumers' campaigns [81] may be able to reduce consumers' waste production by highlighting harmful environmental impacts.

Production ways and methods can greatly influence consumers' decisions [56]. Supporting local producers can be an important motivating factor for consumers' participation in SSCs (besides their various attitudes towards food quality) [77,108]. Producers with strong consumer relationships can be greatly supported by the community [109]. The sustainable operation of SSCs strongly depends on the (producer and consumer) community that operates it. The success of farmers' work depends on the support of the community [110]. The long-term viability of SSC-channels such as CSA (Community Supported Agriculture) is highly dependent on customer satisfaction [111] because if producers establish long-term relationships with consumers, CSA can operate cost-effectively and optimally [11]. The social and environmental side of farming can also be a motivation factor for consumers. Promoting and sustaining other people's well-being is in line with the basic goals of short supply chains [112]. Even antipathy to the dominant consumer culture can motivate customers to buy in SSCs [113]. The visibility of food production and its natural and seasonal limitations may encourage customers to a sparing and responsible handling of food [12].

In general, determining the market price of new "green products" related to the circular economy is an important optimization problem. Substitute—and possibly cheaper—products on the market, make it difficult to develop optimal pricing and advertising strategies [114]. Customers generally have a positive attitude towards the locality of production, but this does not mean in itself that they are able and willing to pay premium prices for local products [30]. Local food is usually more expensive than conventional chain products due to low production volume and high (specific) transport costs [25].

In the case of premium-priced products, consumer willingness to pay is a major issue. D'amico et al. (2014) [115] investigated consumer habits in Italy, in the directly sold wine market. According to their results, prices did not have a decisive role in the selection of local products. Based on the results of Carpio and Isengildina-Massa (2009) [116], it was found that the willingness to pay was higher among responders who attributed a higher quality to local products (than to products from outside South Carolina, where the research happened). Consumers were willing to pay an average surplus of 27% for local products. However, it should be noted that the willingness to pay for local products may vary in space and time. Results from other studies may draw attention to a lower willingness to pay. It is worthy to emphasise the possible demand-stimulating effects of tourism. Local-, agro- or gastro tourism may have positive effects on local community and economy. (Local) food has an important role in (gastro)tourism, and according to an older research on American tourists [117,118], up to 25% of total tourist expenditure is accounted for by food. Agrotourism can play also an important role in protecting and preserving the environment [119].

On the topic of local communities, it is worth mentioning that according to Bavec et al. (2017) [120], the current literature on SSCs has not yet paid sufficient attention to the economical organisation of SSCs. They were not studied extensively from a business perspective [121]. The importance of trust and community awareness also comes to the fore in the organisation of short chains, because according to Van Oers et al. (2018) [65], they are essential for a high level of acceptance of organisational activities (e.g., in the cases of CSA-s). Trust between producers and consumers is based on the personal relationship of the participants [66], and their relationships have a mutual role [122] in community building. Loyalty and trust can contribute to the progressive development of SFSC-s [123]. They can create community bonds, but not under all circumstances [109]. Consumers of SFSC-s may also require that (local) products be associated with a local (cultural) identity [79,124]. Demartini et al. (2017) [30] also drew attention to the possible drawbacks of producer-buyer relationships, that direct contacts with consumers do not necessarily lead to higher profits or "fair" transactions. A profiteering farmer may exploit the consumers' confidence.

3. Materials and Methods

Very significant literary works have been created before in the term of circular economy, for example, the bibliometric network and survey analysis of Türkeli et al. (2018) [106], or the bibliometric analysis of 743 articles made by Ruiz-Real et al. (2018) [125] Sustainability and short supply chains are also widely researched topics. In this article, we relied on our experiences we gained from the articles of a literature review.

To systematize the information material, we selected aspects, expressions, and factors from the literature that were most decisive for the content of our article, in a brainstorming manner way. These terms or topics were examined in the reviewed articles on short supply chains. Fifty-three terms were collected in this manner (Appendix A). The purpose of this collection was to select factors related to the circular economy and sustainability aspect of short supply chains in terms of environmental, economic, social and consumer welfare (based on Lehtinen (2011) [25]), in a comprehensive way. All of these terms are connected to each other in a broad sense, to a certain extent. We endeavored to explore the more important relations based on the above-mentioned terms.

The 55 aspects we selected that are closely related to those "50 most common words" were collected by Tseng et al. (2019) [126], from articles on the subject of green supply chain management. According to our subjective judgment, our list covers approximately 70% of the 50 most common words in the content, while the word-for-word or close-to-word ratio is approx. 38%. The differences come from the fact that short supply chains differ in some characteristics from conventional trading chains, so some features, such as "management" or "technology" were not used in our analysis, while others (such as "trust", "employment") were used.

Takács and Takács-György (2019) [127] presented a list of the most mentioned terms of English language articles published in the "Annals of the Polish Association of Agricultural and Agribusiness

Economists" between 2009 and 2019 (It is one of the most important Polish scientific journals in the field of agricultural economics). From the 17 terms, eight occur in our list in an almost literal match, and 14 overlap in content.

4. Results

The 55 sustainability, circular economy aspects we collected were grouped according to four conceptual classes. They relate to the categories identified by Lehtinen (2012) [25], which cover the sustainability aspects of food chains. These are the "ecological", "economic", "social", and "consumer" dimensions. Then, we searched for relationships between the four dimensions formed in this way. This is how "Environmentally Conscious, Sustainable Production" and "Lifestyle; good community and healthy eating" dimensions arose (Figure 1) (A list of the identified aspects and the system of their connection can be found in the Appendices A–C, and in Figure A1).

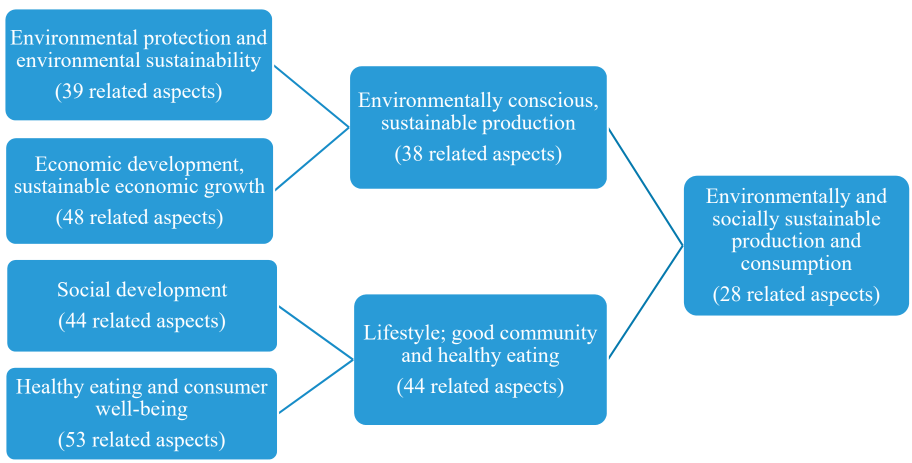

Figure 1. Grouping of the aspects of short supply chains related to sustainability and the circular economy (based on 55 concepts/aspects). Source: own editing, connected to Lehtinen (2012) [25], Tseng et al. (2019) [126] and "Appendices A–C".

Finally, we identified the general dimension which is related to both of the environmental, economic, social and consumer dimensions: "Environmentally and socially sustainable production and consumption". Among the concepts underlying the grouping, the following were comprehensively related to the "Environmentally and socially sustainable production and consumption": Carbon (-emission, -foodprint); circular economy; consumer (purchasing); cooperation; cost (producers'); education (producer and/or consumer); environment; environment friendly production; health; marketing/advertisement; package/packaging; policymakers/government; pollution; producer; price (consumers') rural; rural development; social/social embeddedness; sustainability; tourism/tourism destination; urban; waste; wellbeing (Appendix C).

From a sustainability perspective, these conceptual classes imply that people's well-being and (physical and mental) health is closely linked to the state, cleanness or pollution of their environment, home and to the quality of the food they consume, and their relationship with their community. The basic aim of the circular economic model is to use resources sparingly and considerately and to reduce the environmental burden in this way. Its successful operation requires the right attitude of producers, and shifting consumers' food purchasing habits towards sustainability, for example, by favoring low carbon footprint or food mile distance products, with a conscious behavior to avoid food waste and reduce waste generation.

By this means, the circular economy (waste reduction) and sustainability aspects of short supply chains form a close link with the environment, economy, and society. In Figure 2, we systematized our experiences, creating an "ideal, model-like" system where all of the presented aspects contribute positively to the goals of sustainability and the circular economy. It is "ideal" and "model-like" because—as we presented in the "Literature review", these aspects may also have their lacks and downsides, and their positive impacts cannot always be realized. It can be said that they are dependent on the given situations, for example, when the production methods used by small producers are not environmentally friendly, or if SSC-logistics is not efficient enough, or consumers' willingness to pay is low, or their behavior is not environmentally conscious (in greater detail, see the Literature Review chapter).

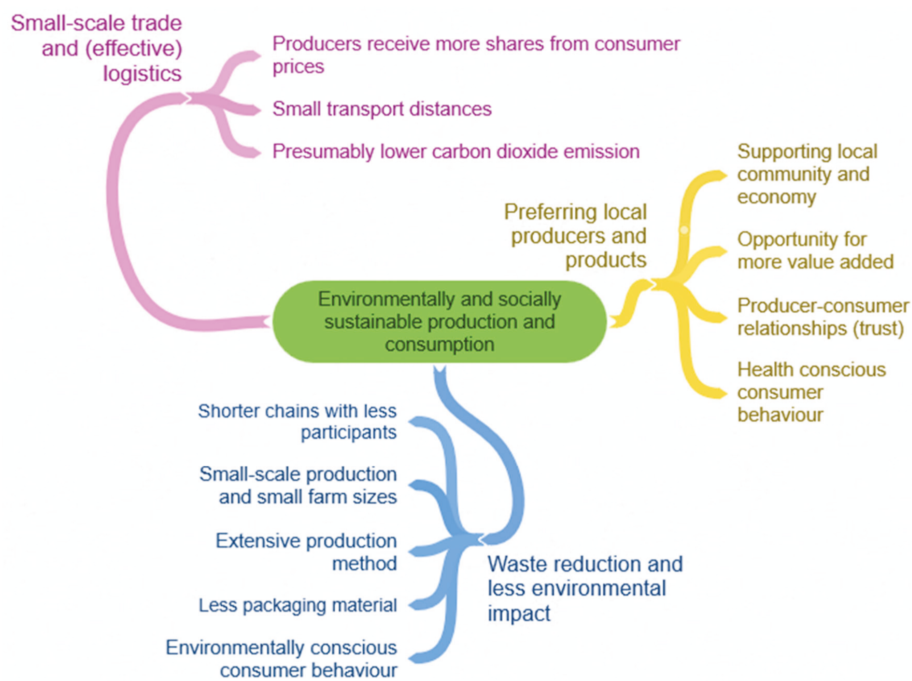

Figure 2. Possible positive effects of short supply chains on the circular economy and sustainability goals. Source: Own editing (used "coggle.it"), based on the literature review

5. Discussion and Conclusions

In our article, we reviewed the sustainability and circular economy aspects of short supply chains (SSCs) through a literature review.

The sustainability of food chains is linked to the dimensions of the environment, economy, society, and consumers' welfare [25]. We collected 55 concepts or factors that well describe the sustainability and circular economy implications of short supply chains along these four dimensions. On their base, the cross-section of the four dimensions is the "environmentally and socially sustainable production and consumption". This term indicates that, in our experience, supply chains generally can be brought into connection with sustainable production and consumption by the aspects of health, well-being, community, producers and consumer behavior, reduced waste and pollutant emission. Furthermore, the organisation and efficiency of short chains can be fundamentally affected by governmental support or regulatory policies. The effective operation of circular economic aspects requires the supporting behavior of producers and individual consumers.

The principles of the circular economy regarding food chains include minimising waste and surplus, reusing food, nutrient recycling, and promoting more varied and effective dietary patterns [5]. Although the concept of short supply chains is not based on waste reduction, in our experience, they can contribute to the prevention of food waste, and in this way, to the objectives of the circular economy. The trade of fresh products, with shorter shelf-lives, moderate packaging usage, flexible package sizes, and possibly more conscious customer behavior may contribute to the waste reduction. However, it should be mentioned that, as the role of SSCs in modern trade is very limited, these aspects have a less important role in large-scale waste reduction.

Reduced carbon emissions from short transport distances is an important fact for assessing the environmental impact of SSCs. Furthermore, food goes through fewer processing steps, with less or zero packaging, and the small-sized producers are likely to use extensive production methods. However, these findings are depending on the given situation: it is not regular that small producers always use extensive production methods and SSC transport may be less (environmentally) efficient due to its possible deconcentration (with numerous small freights [95], and greater distances travelled by customers.) Besides, the distance of transport and food miles—as indicators, in themselves—are not sufficient to assess the environmental impacts of food chains [91].

It is undisputed that there are many potentials for sustainability in short supply chains—provided that they meet the appropriate economic, environmental, and social conditions. However, following Born and Purcell [128], we agree that "local traps" should be avoided, which means local systems should not be automatically declared as "good practices", based solely on proximity. As Depperman et al. (2019) [97] suggested, one has to be very careful with statements that call "local food" equal to "sustainable food".

Finally, we need to mention the limitations of our research. We have endeavoured to collect a sufficient amount and quality of the literature as a sample, but it is more than likely that there is information that our research does not cover. We studied English-language journal articles, and this excludes the presentation of case studies and experiences from non-English journals. Assessing the sustainability of short supply chains and their role in a circular economy can be a more complex and multi-faceted task, to which our article sought to contribute.

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Appendix A

"Aspects describe the relation of short supply chains and sustainability and circular economy"

Accessibility; bio/organic; carbon (-emission); child; circular economy; consumer; cooperation; cost (producers'); delivery; education; employment; energy consumption; environment; environment friendly production; fairness; fair trade; family; food safety; food security; food quality; food-mile; handmade products (small amount); health; income; marketing/advertisment; nutrition/nutritional value; package/packaging; policymaker/governemnt; pollution; poverty; price; process/processing; producer; producer-consumer relationship; rural development; rural; social/social embeddeddnes;

supplying with food; sustainability; traceability; tourism/tourism destination; transport; trust; urban; waste; wellbeing; zero-kilometres (-distance -products).

Appendix A.1 Environmental Protection and Environmental Sustainability

Bio/organic carbon (-emission); circular economy; consumer; cooperation;cost (producers'); delivery; education; energy consumption; environment; environment friendly production; food-mile; handmade products (small amount); health; marketing/advertisment; package/packaging; policymaker/governemn; pollution; price; process/processing; producer; rural development; rural; social/social embeddeddnes; sustainability; traceability; tourism/tourism destination; transport; urban; waste; wellbeing; zero-kilometres (-distance -products).

Appendix A.2 Economic Development, Sustainable Economic Growth

Accessibility; bio/organic; carbon (-emission); circular economy; consumer; cooperation; cost (producers'); delivery; education;employment; energy consumption; environment; environment friendly production; fairness; fair trade; food quality; food-mile; health; income; marketing/advertisment; package/packaging; policymaker/governemnt; pollution; poverty; price; process/processing; producer; producer-consumer relationship; rural development; rural; social/social embeddeddnes; supplying with food; sustainability; traceability; tourism/tourism destination; transport; trust; urban; waste; wellbeing; zero-kilometres (-distance -products).

Appendix A.3 Social Development

Carbon (-emission); child; circular economy; consumer; cooperation; cost (producers'); education; employment; environment; environment friendly production; fairness; fair trade; family;food safety; food security; food quality; handmade products (small amount); health; income; marketing/advertisment; nutrition/nutritional value; package/packaging; policymaker/governemnt; pollution; poverty; price; producer; producer-consumer relationship; rural development; rural; social/social embeddeddnes; supplying with food; sustainability; tourism/tourism destination; trust; urban; waste; wellbeing.

Appendix A.4 Healthy Eating and Consumer Well-Being

Accessibility; bio/organic; carbon (-emission); child; circular economy; consumer; cooperation; cost (producers'); delivery; education;employment;environment; environment friendly production; fairness; fair trade; family; food safety; food security; food quality; food-mile; handmade products (small amount); health; income; marketing/advertisment; nutrition/nutritional value; package/packaging; policymaker/governemnt; pollution; poverty; price; process/processing; producer; producer-consumer relationship; rural development; rural;social/social embeddeddnes; supplying with food; sustainability; traceability; tourism/tourism destination; trust; urban; waste; wellbeing; zero-kilometres (-distance -products).

Appendix B

Appendix B.1 Environmentally Conscious, Sustainable Production

Bio/organic; carbon (-emission); circular economy; consumer; cooperation; cost (producers'); delivery; education; energy consumption; environment; environment friendly production; food-mile; health; marketing/advertisment; package/packaging; policymaker/governemnt; pollution; price; process/processing; producer; rural development; rural; social/social embeddeddnes; sustainability; traceability; tourism/tourism destination; transport; urban; waste; wellbeing; zero-kilometres (-distance -products).

Appendix B.2 Lifestyle; Good Community and Healthy Eating

Carbon (-emission); child; circular economy; consumer; cooperation; cost (producers'); education; employment; environment; environment friendly production; fairness; fair trade; family; food safety; food security; food quality; handmade products (small amount); health; income; marketing/advertisment; nutrition/nutritional value; package/packaging; policymaker/governemnt; pollution; poverty; price; producer; producer-consumer relationship; rural development; rural; social/social embeddeddnes; supplying with food; sustainability; tourism/tourism destination; trust; urban; waste; wellbeing.

Appendix C

Appendix C.1 Environmentally and Socially Sustainable Production and Consumption

Carbon (-emission); circular economy; consumer; cooperation; cost (producers'); education; environment; environment friendly production; health; marketing/advertisment; package/packaging; policymaker/governemnt; pollution; price; producer; rural development; rural; social/social embeddeddnes; sustainability; tourism/tourism destination; urban; waste; wellbeing.

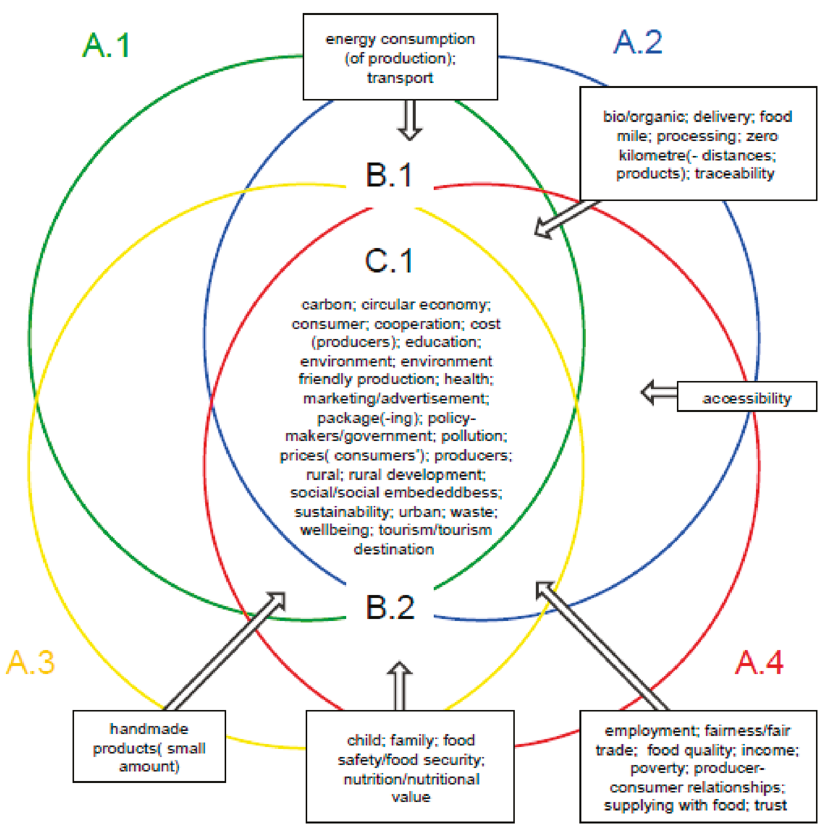

Figure A1. "Aspects describe the relation of short supply chains and sustainability and circular economy, and they possible*way of connections". Source: Own editing, (used "gliffy.com"). All of these terms are connected to each other to a certain extent, but this system focuses on supply chains, and reflects the opinions of the authors.

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resources

Project Report

Improving the Efficiency of Pyrolysis and Increasing the Quality of Gas Production through Optimization of Prototype Systems

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Abstract: Pyrolysis is a thermochemical process that consists of the degradation of organic polymers and biomass minerals in lignocellulose materials. At low pyrolysis temperature (300–400 °C), primarily carbon is produced during the reaction time. Rapid pyrolysis takes place at temperatures between 500 and 650 °C. If the temperature is higher than 700 °C, the final product is methane, also known as biogas. The pyrolysis generator can be combined with a small power plant (CHP), which is a promising technology because the unit can be installed directly near the biomass production, and electricity can be fed de-centrally to the public utility network, while there are several possibilities for using waste heat in local systems. Carbonaceous ash can be utilized well in the agricultural field, because, in areas with intensive farming, the soil suffers from carbon and mineral deficiencies, and the phenomenon of material defect can be reduced by a proper level of implementation. This study describes the technical content of the biochar pilot project, and then, through a detailed presentation of the experimental results, we interpret the new scientific results. Our aim is to improve the quality of the produced gas by increasing the efficiency of the pyrolysis generator. In order for the pyrolysis unit to operate continuously, with proper efficiency and good gas quality, it is necessary to optimize the operation process. Our review reveals that the use of vibration may be advantageous during pyrolysis, which affects the mass of the pyrolysis carbon in a plane. Accordingly, the application of vibration to the input section of the funnel might enhance the quality of the gas, as well. The study concludes that more accurate dimensioning of the main parts of the gas reactor and a more convenient design of the oxidation and reduction zones enhance the good-quality gas output.

Keywords: fixed bed pyrolysis; oxidation-reduction zone; reduction of tar in gas; the significance of biomass particle size; carbon cycle

1. Description of the Developed System within the Project

Pyrolysis systems were designed based on the results of available technical resources and the authors' experience and suggestions. We refer to previous results about the design and measurement on several occasions in order to highlight the specific reasons for this solution [1–4]. Oxidation and reduction are important processes for gas quality [4]. Noncombustible gases in the pyrolysis space, as well as carbon dioxide and water, pass through the oxide field and on the glowing charcoal in the lower layer, which reduces them during further chemical reactions [5–12]. In the quality zone, the endothermic process takes place, removing heat from the environment. If you do not use a favorable temperature of 750 to 1000 °C, you will deteriorate the quality of the gas produced [13]. The release of hydrocarbons occurs around 800 °C, with the secondary air entry into the fibered, and the gases are burned with a visible flame. The chemical processes and corresponding energy changes can be represented as follows:

$$C + CO_2 \rightarrow 2CO\ (-164.9\ MJ/kg\ mol)$$

$$C + H_2O \rightarrow CO + H_2\ (-122.6\ MJ/kg\ mol)$$

$$CO + H_2O \rightarrow CO_2 + H_2\ (+42\ MJ/kg\ mol)$$

$$C + 2H_2 \rightarrow CH_4\ (+75MJ/kg\ mol)$$

$$CO_2 + H_2 \rightarrow CO + H_2O\ (-42.3MJ/kg\ mol)$$

The proposed system differs in many respects from what is known in the literature, mainly because of the simplifications of top-fed and bottom-fed solutions [14–16].

2. Flowchart and Structure of the Developed System

The incoming biomass is transported from the site (yard) storage space to the preinstallation storage space, where it is dried to the desired moisture content. The hot gas interacting in the gas–air heat exchanger (presented in Figure 1 and Table 1) provides the heat needed for this. The direction of the processes is indicated by arrows. The air entering the oxidation space is also preheated by the air passing through a said heat exchanger. So, on the other side of this heat exchanger, the air is preheated, and then the water is injected into this airstream. This process is already taking place in the reactor space. The pressure in the total space of the reactor (from the gas discharge side) is smaller than the atmospheric pressure (due to connected vacuum pump), which also determines the direction of gas flow.

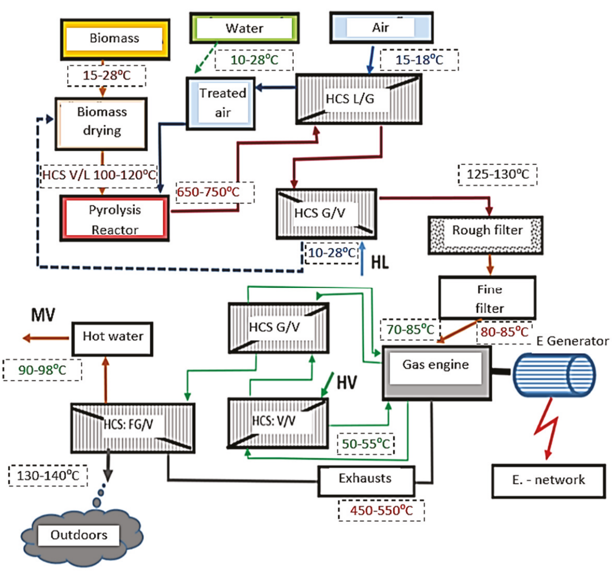

Figure 1. The flowchart of the system, with each measured temperature values (edited and designed by the authors).

The gas discharged from the lower part of the generator cools through the heat exchange, and the cooler gas enters the dust filter, where the powder is coarsely separated, and, from here, it moves on to pass through a safety filter, to get completely tar-free gas into the system [17,18]. This allows the engine to be protected from deposits in the combustion chamber. Waste heat from the engine is presented by water/water heat exchanger. The heat exchangers serve to preheat domestic hot water.

The final temperature of the domestic hot water is practically made by the high-temperature flue gas flowing out of the engine [19,20]. As a result, a clean and low-temperature flue gas is released into the environment. This is achieved by the complex system at its best efficiency. The system is illustrated in more detail in Figure 2, by marking each unit (Figure 2 and Table 2).

Table 1. The symbols and names of each part of the system (edited and designed by the authors).

Sign	Name of Each Part	Sign	Name of Each Part
HCS	Exchanger	L	Air
FG	Flue gas (Exhausts)	MV	Hot water
V	Water	HL	Cold air
G	Gas	HV	Cold water

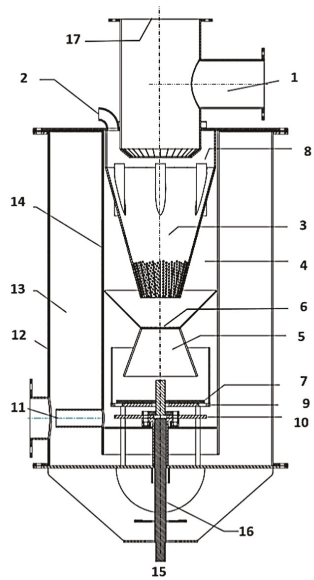

Figure 2. Schematic figure of a pyrolysis generator (edited and designed by the authors).

Items No. 3, 4, 5, and 7 were basically the subjects of the investigation, since the process of decomposition, its quality, and the performance of the equipment also depend on them. The oxidation air, as well as the recirculated gas mixture and the vapor phase, were introduced at site 2. The heated air in the heat exchanger is fed with water through a high-frequency valve, which is due to the high temperature; it is then converted into steam and fed into the oxidation/reduction zone through the nozzle No. 8.

The composition of the investigated substances, fast and slow degradation, and the effects of heating rate have already been described in detail in a previous article about this research program [21]. In the part of the equipment where the air is introduced, a certain part of the pyrolysis products is oxidized. The energy obtained here covers the heat demand of the thermal decomposition in endothermic processes. An important feature of the further zones is the decomposition of tar and its conversion into smaller molecules, which is very important for the operation of the Gary motors [22,23]. The goal was that the tar should not cross the oxidation zone. This cannot occur here at a lower temperature [24–26]. In the fixed-bed zone of the reactor model, the roasting progress takes place in the parabolic cone [27].

Table 2. Sign and names of Figure 2 (source: authors own research).

Numbers	Names of Each Part of the System
1	Fuel Feeder (Screw)
2	Preheated air, gasification aid
3	Carbonation zone (pyrolysis cone)
4	Oxidation chamber
5	Reduction zone (reduction cone)
6	Cross-section part
7	Rotating blade (scraper blade)
8	Pyrolysis gas exhaust gas pump
9	Grate
10	Rotary excavator
11	Drainage of gas
12	Gas closure outer jacket
13	Thermal insulation
14	Gas and solid baffle inner heat resistant jacket
15	Drive motor
16	Driveshaft
17	Closure cover for repair and assembly

Thus, the geometry of the oxidation zone is a fundamental and critical design factor. The thickening of the throat helps to concentrate the heat, so the airflow should be such that an equally high-temperature zone is formed throughout the cross-section (Figure 3). The complete cross-section of the incoming air (air–steam mixture) up to the wall must be filled (space 3 in Figure 3). The volume of gas flowing through the solid bed is then determined by the particle size and the upper opening of the drying space [28]. Between the upper and lower portions of the inlet portion, the inlet cross-section ratio at or near 3:2 is favorable (presented by Figures 4 and 5). The angle of the cone formed by the constriction influences the friction of the material and the downward movement thereof. The axial movement velocity of the flow of carbon and gases, i.e., the residence time in space, should be such that the maximum conversion is achieved [29,30].

In the transient double cone, the indicated narrowing is usually appropriate, but the actual dimensions depend on the particle size and size of the particles, since particle friction processes play an important role in the reduction [8,15,31–33]. It is preferred that, at the introduction of the material to be gasified, the opening between the opening and the wall is at least as wide as 10 large particles (i.e., 300–500 mm for "G50" material).

The amount of material above the pharynx increases the interaction between the surface and the particles, i.e., the friction between the sidewall and the particles. If the wall exerts a greater frictional force than the weight of the layer on a particle layer of thickness, the pressure will not increase further. The maximum pressure (in (Pa)) is calculated with Equations (1) and (2):

$$p_{max} = \frac{r\,\rho\,g}{2\mu^*} \tag{1}$$

$$P_{mv} = p_{max}\,r^2\pi = \frac{r^3\,\pi\,\rho\,g}{2\mu^*} \tag{2}$$

where r = diameter of the orifice (m), P_{mv} = downward force (N), ρ = density of the substance (kg/m^3), and μ^* = coefficient of friction between particles (varies with particle size).

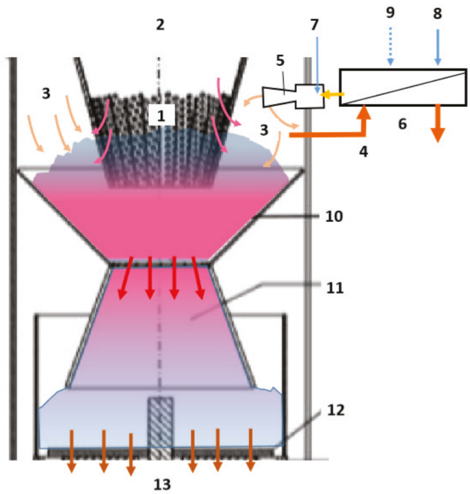

Figure 3. Functional characterization of the generator (edited and designed by the authors). Name of the numbered parts of the generator: 1—Carbonization, pyrolysis space; 2—Drying zone; 3—Oxidation chamber; 4—Primary gas; 5—Injector; 6—Exchanger; 7—Air from biomass (external pressure); 8—Heated air; 9—Water injection (from vibrating pump); 10—Double cone (reduction flow); 11—Reduction zone; 12—Rotating blade and grille; 13—Hot gas, ash, soot, carbon particles.

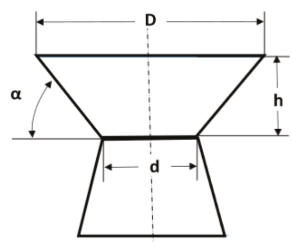

Figure 4. Double cone between oxidation and reduction zones (edited and designed by the authors).

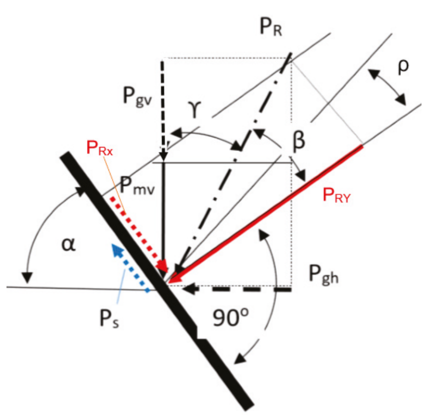

Figure 5. The cone angle and the developing force relations ($\alpha = \beta + \Upsilon$) (edited and designed by the authors).

3. The Aperture and Angle of the Reduction Cone

A practical question is whether the storage tanks are gravitationally drained or vibration is required. For example, if the radius and height of a cylindrical container are the same. When particulate material is introduced into the container, the pressure acting on the bottom of the container initially increases similarly to the hydrostatic pressure of liquids. However, the amount of material poured in increases the interaction between the sidewall and the granules, and, with it, the friction between the sidewall and the granules increases [34]. If the wall exerts a greater frictional force than the weight of the layer on a particle layer of thickness, the pressure will not increase further. Part of the weight of the cast material is supported by the sidewall, which is also subject to vertical resulting forces (presented by Figure 5). The tension in the material and the arches that block the outflow occur. The extent of this is significantly related to the quality of grinding, i.e., longer fiber residues can also be inhibitory causes [35,36]. From this point of view, the simplest experimental study of their statics is the measurement of the slope. The cast materials do not spill out; instead, they form a more or less regular cone. The angle of the cone component with the horizontal is the slope. The extent of the slope, which depends on the size, shape, and material quality of the particles, is also influenced by other operating forces besides the construction. In the present case, the gas flowing between the particles, which cause their displacement, but also the shredding knife on the lower part of the reduction basket, which also acts on the vertical force, plays a role.

The angle of the upper cone is represented by Equation (3):

$$tg\alpha = \frac{D - d}{2\,h} \tag{3}$$

where D = diameter of the oxidation zone (300 mm), d = diameter of the transition (stenosis) (100 mm), and h = height of the upper cone of the reduction zone (170 mm).

In terms of static state, a runoff occurs when the following occurs (Equation (4)):

$$P_s < P_{RX} \tag{4}$$

So, the thrust is greater than the friction (Equation (5)):

$$P_{RY}\, tg\rho < \; P_{RY}\, tg\beta \tag{5}$$

$$tg\rho < tg\beta$$

$$\alpha = \beta + \Upsilon$$

If α is reduced to P_S, the P_{RX} thrust will be greater, so the flow will be faster. But when α is high, the P_{RX} decreases against the frictional force (P_S), and the ability to pass is impaired. After all, the drive compression force must be greater. In an existing system, this can only be achieved by increasing the pressure difference (increasing the vacuum) [37,38].

Ultimately, P_{GV} (differential gas pressure in vacuum) = oxidation chamber pressure – vacuum at the exhaust outlet.

The friction hemispherical angle ($t_g\rho$) decreases the possibility of flow to the free outlet value in the case of a 60° inclined funnel. Above 60° for steel and carbon, ρ is already less than 8°–9°, which is less than the internal friction value, thus the tendency for arching is moderate (negligible). In practice, the resulting reaction force is overcome by the effect of differential pressure [39,40]. Flow is safe at the calculated and measured flow rate (velocity). Therefore, the cone angle was chosen to be 60°.

Model measurements with planar carbon particles (~1.0–8.0 mm) show that the runoff intensity is stable in the range of ~40°–60° (presented by Figure 6), which is advantageous for the smooth operation of the system.

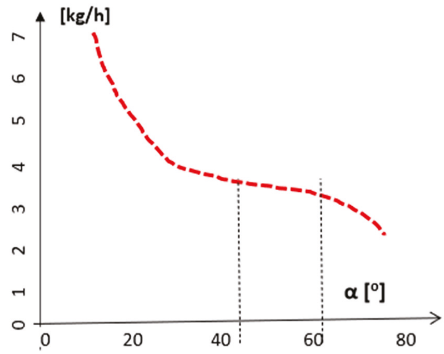

Figure 6. Mass flow as a function of α (edited and designed by the authors).

4. The Effect of Porosity

The position (porosity) of the various particles of the material, the size of the gaps (presented by Figure 7), and the "compactness" of the material determine the gas permeability of the set and thus influence the rate of reactions [41–43].

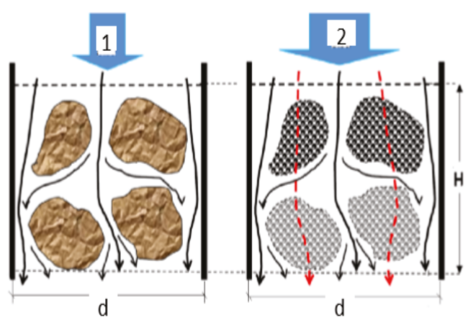

Figure 7. Typical system diagrams (1—wood granules; 2—carbon granules) (edited and designed by the authors).

Volumes and/or densities should be measured to determine porosity. The relative void volume is the value of the intergranular void volume relative to the total volume (Equation (6)):

$$\varepsilon = \frac{V_h}{V + V_h} \tag{6}$$

where V = material volume (m^3), and V_h = the so-called. gap volume (m^3).

The porosity can also be calculated from the bulk density, in which case, in addition to the volume of the particles, the volume between the particles, filled with air, must also be taken into account (Equation (7)):

$$\rho_t = \frac{m}{V + V_h} \tag{7}$$

where m = mass of the substance (kg).

The porosity with Equation (7) could be Equation (8):

$$\varepsilon = 1 - \frac{\rho_t}{\rho} \tag{8}$$

where ρ = density of original material (kg/m^3).

During pyrolysis, air or particles between the particles are removed. The product gas is flowing. The flow rate of gas through the granular medium is proportional to the pressure gradient of the system (Darcy's Law). That is the homogeneous gradient, the difference between the pressure of the gas at the upper (p_o) and lower (p_k) levels divided by the distance of the measuring points (q_g) (Equation (9)):

$$q_h = \frac{\Delta p}{h} \tag{9}$$

where Δp = ($p_k - p_o$) = difference in gas pressure (P_a), and h = distance between measuring points (m).

In the discharge of gas through the grain gap, the properties of the particulate set and gas must also be taken into account (κ factor) (Equation (10)):

$$\kappa = \frac{\varepsilon\, \rho\, g}{\mu} \tag{10}$$

where ε = porosity of the particulate set, ρ = density of the gas (kg/m^3), μ = dynamic viscosity of the gas (Pa/s), and g = gravity constant (m/s^2).

The κ factor could also be called the gas conductivity of the set. Carbon from biomass is highly porous. The porosity of the inner part is generally nonuniform, typically having a small anisotropic structure, and the pores forming on the outer parts expand. The pores could be open, closed, or connected shapes. Researches show significant changes due to higher temperatures [44].

5. Effect of Adding Water and Air

The tar-reduction methods can be divided into five main groups: mechanical, system modification, thermal cracking, catalyst cracking, and plasma process. According to Phuphuakrat T. et al. [45], water and air (water vapor) have a strong influence on the tar decomposition reaction. The weight loss of gravimetric tar was 78% for thermal cracking and 77%–92% for water vapor and air intake. According to other sources, the introduction of air and H_2O in the process of pyrolysis of biomass and catalytic gasification has a significant beneficial effect [25]. During their conversion, the proportion of tar compounds is reduced during the conversion to gaseous compounds [46].

In gasification reactions above 900 °C, all effects are present [47]. The temperature of the gas produced alone should be heated to 1200 °C, to reduce the tar content to 15–20 mg/Nm^3. According to the literature, the highest cold-gas efficiency can be achieved with a carbon-dioxide-containing atmosphere. For any dosing or administration, it reduces the tar content to below the limit for engines due to gas remixing and oxidation [48].

Our aim was to improve the performance of the system, without major modifications, while keeping the gas to its permitted purity [39]. Several sources of literature have referred to this possibility. It was emphasized that the introduction of water and air into the oxidation or reduction space changes the composition of the gas and reduces the tar content. By injecting water, the water (water vapor) flowing into the open pores of the carbon particles (presented by Figure 8) dissociates into hydrogen and carbon monoxide. This also changes the composition, flammability, and energy content of the gas.

To check this, different amounts of water were injected into the system through the aforementioned injectors through the adjustability of the oscillating valves (dosing frequency). Water entering the valve was added to the pyrolysis feed air. A significant part of the water vapor/air mixture was delivered directly to the oxidation and reduction space. The results of these studies are presented in Table 3. The diagrams drawn from these illustrate the changes in the process (presented by Figures 9–11). The effect of the system temperature on the gas composition is of decisive importance, but it also influences the temperature of the reduction space when introducing the water/air mixture, but it is important to maintain the proper temperature for degradation. To achieve this, the reduction double funnel-shaped transition below the oxidation space requires the correct choice of mouth size. Proper design is important because of the residence time required for the reaction and the flow of sufficient material. The biomass feed should match the mass flow of the glowing carbon passing through the double cone. The experiments were performed at a constant value of the output power of the equipment.

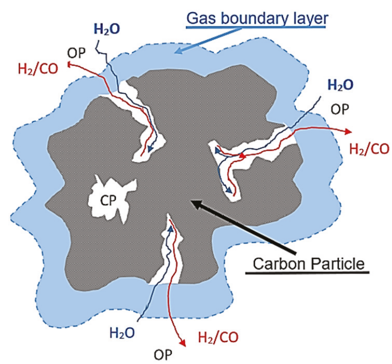

Figure 8. Conversion of water entering the pores of a high-carbon particle (edited and designed by the authors).

Table 3. Measured data after water injection (authors own research).

Performance (KW)	Air Supply (m^3/h)	Time (s)	Oxidation Temperature (°C)	Mass Flow of Water (kg/h)
5	11.25	83.2	1165	0.43
5	10.50	69.2	1150	0.52
5	10.00	55.4	1140	0.65
5	9.75	43.4	1136	0.83
5	9.25	35.6	1128	1.01
5	8.75	30.6	1116	1.18
5	8.50	26.8	1080	1.34
5	8.50	23.8	1048	1.51
5	8.50	21,2	1021	1.70
5	8.25	19.2	1010	1.88
5	8.12	17.8	1000	2.02
5	8.25	16.8	1000	2.14

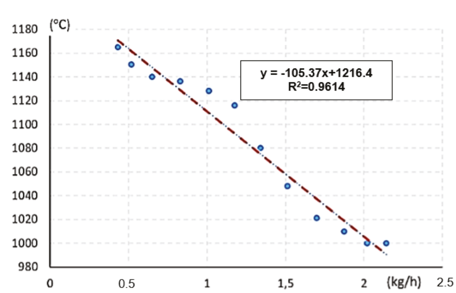

Figure 9. The effect of water intake on the temperature of the reduction space (edited and designed by the authors).

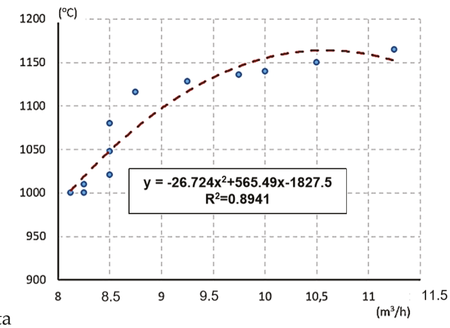

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Figure 10. Effect of air supply on the temperature of the reduction space (edited and designed by the authors).

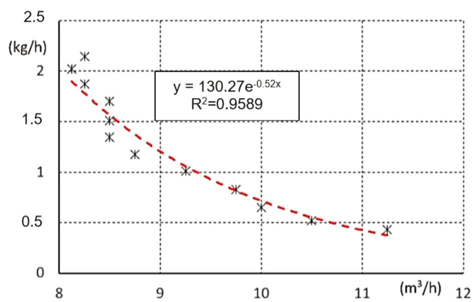

Figure 11. Relationship between air and water intake (in linear case: $y = -0.5373x + 6.1759$ and $R^2 = 0.8542$) (edited and designed by the authors).

As a result of the amount of water introduced into the vibrating valve (indicated by the frequency of vibration), the temperature of the reduction space decreased (Figure 9). From the results, it can be seen that it is not advisable to add more than 1.5 kg/h of water to the present apparatus, so that the temperature in the reduction space does not fall below 950–1000 °C. The introduction of air also has an effect on the temperature of the reduction space [49]. Given that more oxygen is introduced into the air, the combustion improves its temperature-increasing effect. The introduction of more than 9.0 to 9.5 m^3/h air volume for the reported equipment is not justified, as it would already reduce the temperature of the reduction space. It follows from the two relationships that the relationship between water and air dosing is exponentially decreasing (almost linear). It follows that, when increasing air, the amount of water should be reduced.

However, the introduction of water increases the amount of hydrogen in the gas, which is very favorable for the energy content of the gas. The amount of water intake should be used with caution since larger amounts of water reduce the temperature of the reduction space, which results in a reduction in tar degradation. In contrast, because of the air supply, the temperature of the reduction pond increases, so the optimum should be sought for the two values.

The favorable values for this unit are ~9.5 m^3/h airflow and ~1.1 kg/h water flow. This is also illustrated in Figure 11.

The literature also points out that the effect of water and air intake, as well as the remixing of the primary gas, results in a change in the composition of the gas that can be used, possibly increasing its energy content. Our experiments with the prototype equipment showed that the changes in the gas composition of this medium-sized hardwood biomass chip were significant. Because the throat diameter of the reduction cone determines the mass flow rate of the “material” to be transmitted, the flow rate could only be adjusted to the feed materials by vibrating the mass of material in and below the cone, to aid flow. The composition of the gas, according to the final gas components, was measured with a VISIT 03H gas analyzer (Table 4).

Table 4. Water (H_2O), air (Ai), and air and gas (RG + Ai) effect of recirculation on gas composition (authors own research).

Gas Components	H_2O (%)	Ai (%)	RG + Ai (%)
C_xH_y *	1.91	1.37	1.89
H_2O	2.00	12.10	15.20
H_2	39.80	29.44	24.50
CH_4	8.47	6.01	7.44
CO	22.00	37.98	43.20
CO_2	25.83	13.10	7.76

Note: * 0.1%–0.3% of this is tar (~15–35 mg/m^3).

Due to the high temperature of the oxidation and reduction zone, the other hydrocarbon content is less than 2%. It has a tar content of 0.1%–0.3% based on the gas recovered, 15–35 mg/m^3, which does not affect the operation of the gas engines. For the production of 1.0 Nm^3 gas, 1.42–1.48 kg of air-dried hardwood (biomass) was needed.

6. Conclusions

Tests on prototype equipment have shown that fixed bed equipment produces quality biogas that is suitable for gas engines to produce fuel and CHP heat and electricity. The quality of the pyrolysis gas is fundamentally influenced by the design of the equipment, in particular, the size and shape of the reduction and oxidation spaces, and the introduction of various additives into these spaces. In order to obtain a good product, the temperature in these spaces should not change significantly. It is harmful to engine operation if the gas contains tar. When temperatures drop, the tar is not completely decomposed. Furthermore, the addition of water/air mixture changes the composition of the gas. The water supply increases the hydrogen content, but recirculation of some of the primary gas increases the CO content, and, as a result, the gas purifies less CO_2 emissions. In order for the unit to operate continuously, with sufficient efficiency, and to maintain a good gas quality, the carbonated material must be moved in the reduction space. The application of vibration to the entire system is advantageous, as it reduces the space by the use of a suitable scraper for the ash design, which exerts a planar effect on the carbon mass above it. The drive shaft of this scraper must be extended to the throat of the transitional space, the funnel.

The test prototype device may be suitable for serial production, taking into account the measured parameters. Our main goal was to improve system performance without major changes, while maintaining or increasing the purity of the gas produced. In the literature, we have found technology variants that work toward improving the purity of the gas. Introducing water and air into the oxidation or reduction space generally improves the composition of the gas and reduces the tar content. By injecting water, water (vapor) flowing into the open pores of the carbon particles dissociates into hydrogen and carbon monoxide. This changes the composition, flammability, and energy content of the gas. Measurements show that the relationship between water and air supply reduced exponentially (almost linear). It follows that, when the air is increasing, the amount of water must be reduced. In the literature, it has been pointed out that the effect of water and air intake and the remixing of the primary gas changes the composition of the usable gas and increases its energy content. Our experiments with the prototype equipment showed that the changes in the gas composition of these medium-sized hardwood biomass shavings were significant. The new result, that the mass flow of the "material" to be conveyed is determined by the throat diameter of the reducing cone, and the flow rate on the base materials can only be adjusted by vibrating the mass of the material in and below the cone, to facilitate flow.

Author Contributions: L.T. and C.F. had the initial idea for the manuscript; C.F., D.C.F, and M.C. designed the manuscript; C.F. and M.C. researched the literature; C.F. and L.T. developed the methods and integrated the literature; L.T. and C.F. wrote the manuscript; M.C. and D.C.F. supervised the project. All authors provided critical feedback and helped shape the result.

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