

THE REHABILITATION AND PHYSICAL INDUSTRY IN THE CIRCULAR ECONOMY SYSTEM

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Abstract: *The rehabilitation and physical industry in the circular economy model is extremely relevant, especially in the context of sustainable development and resource optimization in healthcare. The circular economy is an economic model that strives to minimize waste and optimally use resources through reuse, recycling, repair, and extension of the product life cycle. Instead of the traditional linear „take-produce-dispose” model, the circular economy promotes sustainability and environmental responsibility. Benefits of recycling and reuse: Economic benefits - reducing the cost of purchasing new equipment and easier access to assistive devices for socially vulnerable groups; Environmental benefits - reducing waste and the carbon footprint and saving resources when producing new products; Social benefits - increasing accessibility to rehabilitation services and improving the quality of life of disadvantaged patients. The use of sustainable materials in the rehabilitation and physical industry not only protects the environment but also enhances accessibility, efficiency, and ethics in medical services. To realize this potential, cooperation between manufacturers, healthcare institutions and regulatory authorities is necessary, as well as increased awareness among patients and specialists. In the conditions of a circular economy, a basic principle is the maximum use of resources by extending the life cycle of products. This particularly applies to rehabilitation equipment, which is often costly, specialized, and difficult to replace. Innovations offer new solutions for repair, modernization and intelligent management of devices, thus saving resources, reducing waste and ensuring sustainability.*

Keywords: *circular economy, rehabilitation industry, physical industry, recycling.*

JEL classification: D21, H41, H75, I12.

РЕХАБИЛИТАЦИЯТА И ФИЗИЧЕСКАТА ИНДУСТРИЯ В СИСТЕМАТА НА КРЪГОВАТА ИКОНОМИКА

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Резюме: *Рехабилитационната и физическата индустрия в модела на кръговата икономика е изключително важна, особено в контекста на устойчивото развитие и оптимизацията на ресурсите в здравеопазването. Кръговата икономика е икономически модел, който се стреми да сведе до минимум отпадъците и да използва оптимално ресурсите чрез повторна употреба, рециклиране, ремонт и удължаване на жизнения цикъл на продуктите. Вместо традиционния линеен модел „взemi-произведи-изхвърли“, кръговата икономика насърчава устойчивостта и отговорността към околната среда. Предимства на рециклирането и повторното използване включват: икономически ползи – намаляване на разходите за закупуване на ново оборудване и по-лесен достъп до помощни средства за социално уязвимите групи; екологични ползи – намаляване на отпадъците и въглеродния отпечатък и спестяване на ресурси при производството на нови продукти; и социални ползи – увеличаване на достъпността до*

рехабилитационни услуги и подобряване на качеството на живот на пациентите в неравностойно положение. Използването на устойчиви материали в рехабилитационната и физическата индустрия не само защитава околната среда, но и подобрява достъпността, ефективността и етиката в медицинските услуги. За да се реализира този потенциал, е необходимо сътрудничество между производителите, здравните институции и регулаторните органи, както и повишаване на осведомеността сред пациентите и специалистите. В условията на кръгова икономика основен принцип е максималното използване на ресурсите чрез удължаване на жизнения цикъл на продуктите. Това важи особено за рехабилитационното оборудване, което често е скъпо, специализирано и трудно за подмяна. Иновациите предлагат нови решения за ремонт, модернизация и интелигентно управление на устройствата, като по този начин спестяват ресурси, намаляват отпадъците и осигуряват устойчивост.

Ключови думи: кръгова икономика, рехабилитационна индустрия, физическа индустрия, рециклиране.

JEL класификация: D21, H41, H75, I12.

Introduction

The rehabilitation and physical industry in the circular economy model is extremely relevant, especially in the context of sustainable development and resource optimization in healthcare. The circular economy is an economic model that strives to minimize waste and optimally use resources through reuse, recycling, repair, and extension of the product life cycle. Instead of the traditional linear „take-produce-dispose” model, the circular economy promotes sustainability and environmental responsibility [1].

Although healthcare is not a core component of the circular economy, the rehabilitation sector has significant potential to fit into this model.

I. Recycling and reuse of medical equipment

A variety of equipment is used in rehabilitation and physical medicine - from small aids to specialized therapy devices. Traditionally, when they wear out or fall out of use, this equipment is discarded, which leads to the accumulation of waste and inefficient use of resources. The circular economy seeks to extend the life cycle of these devices through repair, recycling and reuse [2].

1. Types of equipment that can be reused

A large part of the aids, such as: crutches, walkers, wheelchairs, anti-decubitus pillows, are reusable. Therapeutic equipment, such as electrostimulators, ultrasound devices, magnetic therapy devices and mechanical exercise equipment: exercise bikes, passive exercise benches, coordination and balance devices, are all reusable. Many orthoses and splints can be adapted for reuse after sterilization [3].

2. Benefits of recycling and reuse

2.1. Economic benefits:

- reducing the cost of purchasing new equipment;
- easier access to assistive devices for socially vulnerable groups.

2.2. Environmental benefits:

- reducing waste and the carbon footprint;
- saving resources when producing new products.

2.3. Social benefits:

- increasing accessibility to rehabilitation services;
- improving the quality of life of disadvantaged patients [4].

3. Practical mechanisms for implementing the recycling and reuse of medical equipment and aids

3.1. Establishment of recycling and reuse centers.

Organizations or healthcare institutions can collect used devices for repair, sterilization and re-distribution.

3.2. Establishment of “aid banks”:

“Aide bank” is an organization or service that collects, stores, repairs and re-rents medical and rehabilitation devices and appliances such as: wheelchairs, crutches, walkers, orthoses, hospital beds, therapeutic devices and others. These devices are provided temporarily or free of charge to patients in need – especially to people with low incomes or in crisis situations [5].

The creation of such “banks” reflects the basic principles of the circular economy:

- reuse of resources;
- repair and maintenance of existing devices;
- reduction of waste;
- optimization of available equipment.

The “Assistive Devices Bank” operates by:

- collecting donations from hospitals, private individuals, NGOs and manufacturers;
- purchasing new or used devices from social projects;
- assessment and repair;
- technical inspection, disinfection and, if necessary, repair;
- technical documentation and traceability

The distribution of assistive devices and medical equipment is done by:

- requests from patients, social workers or doctors;
- through platforms (website/mobile application) or on site.
- return and reuse is done through a temporary loan – after the patient recovers, the device is returned and used by another patient.

4. Advantages of the connection between the rehabilitation and physical industry and the circular economy model

4.1. Social:

– gives access to necessary equipment to people in disadvantaged situations, thus reducing economic inequality in access to rehabilitation.

4.2. Economic:

- save money for health institutions and patients;
- reduces the need to constantly buy new equipment.

4.3. Environmental:

- reduces the production and accumulation of waste;
- supports a longer life cycle of the devices [6], [7].

5. Challenges for the rehabilitation and physical industry in the circular economy model [8], [9], [10]

There are certain challenges for the rehabilitation and physical industry, such as:

- hygiene and safety – especially important for equipment that comes into contact with the skin or body fluids of patients;
- legislative restrictions – many countries have strict rules for the reuse of medical equipment;
- lack of infrastructure – lack of logistical and technical resources for collection and recycling;
- stereotypes and distrust – some patients and specialists prefer „new” equipment.

6. Successful examples of the rehabilitation and physical industry in the circular economy model

Scandinavian countries - well-developed system for the reuse of assistive devices through municipal services.

Netherlands - companies that collect and repair wheelchairs and resell them.

Bulgaria (in the initial stage) - non-governmental organizations and donation campaigns for the provision of assistive devices.

Recycling and reuse of medical equipment in the rehabilitation sector is a key step towards sustainable and accessible healthcare. With properly structured policies, technical support and public awareness, this practice can become the norm, not the exception. This would benefit not only the environment, but also the healthcare system and patients. Equipment such as walkers, wheelchairs, physiotherapy equipment and others can be recycled, refurbished, donated or re-provided, instead of being replaced with new ones.

II. Using secondary raw materials to produce new assistive devices

The rehabilitation industry relies on a variety of assistive devices - from wheelchairs and crutches to orthoses, splints and therapeutic devices. Most of them are made of plastic, aluminum, steel and textiles, which often remain unused, damaged or thrown away, although they could be restored or recycled. This is where secondary raw materials come into play - recycled materials that are used to create new, functional assistive devices. Secondary raw materials are materials extracted from already used products that have undergone a recycling, processing or restoration process, such as:

- metal – aluminum and steel from old wheelchairs and structures;
- plastic – recycled polymers from packaging or old devices;
- textiles and rubber – used in handles, seats, guards, etc.

The use of secondary raw materials in the production of assistive devices supports the basic principles of the circular economy such as: [12]

- reducing waste – using existing resources instead of extracting new ones;
- extended life cycle of materials;
- closed production cycle - old device → raw material → new product.

Many companies offer buyback and recycling of their products. This is a model in which manufacturers buy back used products from their customers, repair, recycle or refurbish them and either put them back on the market or use the parts for new production. This is a key part of the circular economy, as it extends the life of products and reduces waste.

This leads to sustainable use of resources, a reduction in carbon footprint and production costs, more affordable products for customers (including refurbished ones at a lower price), and incentives for returning old equipment (cash, discounts or donations).

III. Modular design – creating devices that can be disassembled and reused

Modular design is an engineering and design concept in which products are created from separate, interchangeable parts (modules) that: [14]

- can be easily disassembled, repaired, replaced or reused;
- allow adaptation and upgrading without requiring a completely new device.

In rehabilitation, this means that assistive devices – such as wheelchairs, crutches, prostheses and orthoses – can be adapted and updated over the years, without the need for disposal.

The modular approach is key to implementing the „design for reuse“ model and its connection to the circular economy [15] by:

- extending the life cycle of devices;

- allowing easier recycling of parts;
- reducing production and waste volume;
- facilitating local repair and maintenance.

The model is based on the idea outlined in the Ellen MacArthur Foundation's Butterfly diagram. [17]

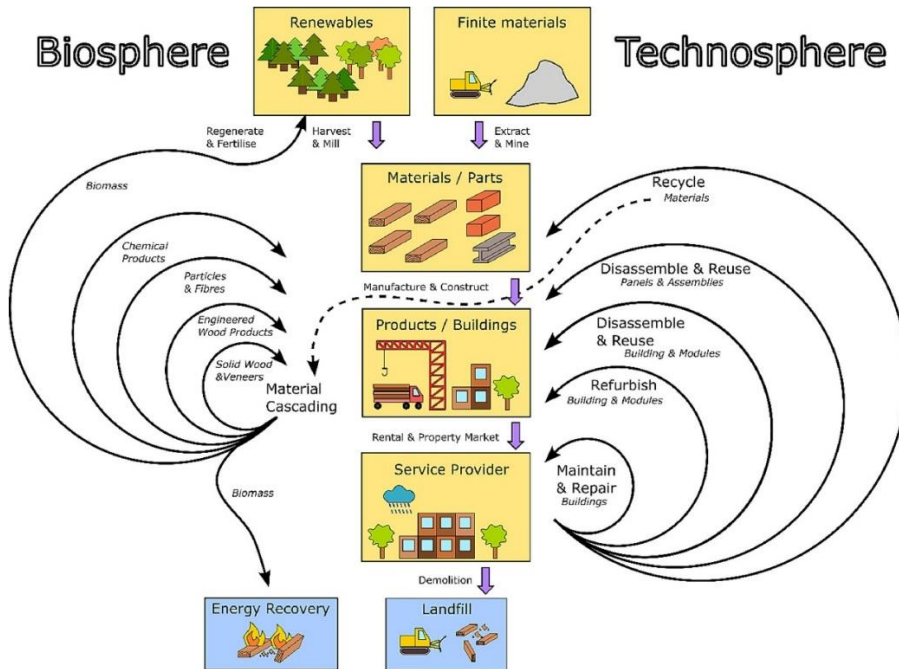


Diagram 1
Ellen MacArthur Foundation's Butterfly diagram

The Butterfly Diagram illustrates the core principles of the circular economy by showing how materials can flow in closed loops through biological and technical cycles, minimizing waste and maximizing resource efficiency.

Developed by the Ellen MacArthur Foundation, the Butterfly Diagram is a visual framework that explains how products and materials can be kept in circulation through restorative and regenerative processes. It's shaped like a butterfly, with two wings representing two distinct cycles:

a. Left Wing: The Biological Cycle

This side focuses on organic materials that can safely return to nature. Composting and anaerobic digestion return nutrients to the soil. Cascading use of biomass (e.g., wood, cotton) allows materials to be reused across multiple applications before final disposal. Regeneration of natural systems is emphasized, ensuring that biological resources are replenished.

b. Right Wing: The Technical Cycle

This side deals with non-biodegradable materials like metals, plastics, and electronics. Reuse, repair, refurbish, and remanufacture extend product lifespans. Recycling is the last resort, used when other options are exhausted. The goal is to retain value by keeping products and components in use as long as possible.

c. Central Flow: Circular Economy in Action

At the center of the diagram is the user, with flows moving outward toward either biological or technical recovery. The diagram emphasizes: Designing out waste and pollution; Keeping products and materials in use; and Regenerating natural systems.

1. Examples of modular design in the rehabilitation industry

Wheelchairs - the frame, wheels, armrests and backrests can be replaced individually, allowing adaptation as a child grows, needs change or damage occurs

Prostheses and orthoses - replaceable modules: ankle joints, legs, knee mechanisms. This facilitates adaptation to different levels of amputation and motor activity.

Electronic therapy devices - control, sensor and power modules are replaceable or compatible, allowing upgrades without replacing the entire device.

2. Benefits of the modular approach

Economic - saves costs for replacing the entire device; possibility of partial repair. Environmental - less waste, easier recycling of parts, reduced carbon footprint. Social - more affordable solutions through upgrades instead of replacement; support for decentralized services. Technological - the ability to integrate innovations without the need for a new device.

Within the scope of our study, Freitas, M., Tavares, S. Bragança, L., and Barbosa, S. focus on the Portuguese network project “Circular Economy as a Strategy for a More Sustainable Industry.” [16]. They pay special attention to the application of the circular economy in building renovation processes, urban planning, and the development of joint initiatives aimed at sustainable resource use. The authors emphasize that a successful transition from a linear to a circular economy requires adequate regulation and tax relief. Examples from different countries are presented to support this:

- In the United Kingdom, a 20% tax is imposed on new construction, while the renovation of existing buildings is exempt from VAT;
- In Sweden, lower VAT rates are applied to renovations aimed at preserving the building stock;
- In the Netherlands, the government encourages partnerships to create products based on the principles of the circular economy;
- „Circular Flanders” is an initiative of the Flemish administration responsible for waste, materials, and soil management policies.
- In Denmark, a step-by-step tool has been developed that describes the process of transitioning to a circular economy.
- In Porto, there is a material bank, as well as other similar initiatives.

Conclusion

Ultimately, we arrive at the following three important conclusions, namely:

First conclusion

Reusable design is the ability to develop new architectures and flexible technologies. It requires well-thought-out design processes, defined coding styles, and high-quality documentation. This approach includes integrating pre-built models, adding new elements to the reusable component base, modularity, parameterisation, and creating models focused on readability, adaptability, and reuse. Detailed documentation and effective communication between engineers and developers also play an important role.

Second conclusion

The use of sustainable materials in the rehabilitation and physical industry not only protects the environment but also enhances accessibility, efficiency, and ethics in medical

services. To realize this potential, cooperation between manufacturers, healthcare institutions and regulatory authorities is necessary, as well as increased awareness among patients and specialists.

Third conclusion

In the conditions of a circular economy, a basic principle is the maximum use of resources by extending the life cycle of products. This particularly applies to rehabilitation equipment, which is often costly, specialized, and difficult to replace. Innovations offer new solutions for repair, modernization and intelligent management of devices, thus saving resources, reducing waste and ensuring sustainability.

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