

## CIRCULAR CONCEPTS OF RESEARCH ROBOTICS FOR SMALL SCALE BENCHMARKS IN AUTOMATION ENGINEERING OF SMART CITIES

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**Annotation:** The standardisation of the parts and the usage of the 3D printing are considered as the concepts allowing to develop the research robotics prototypes for benchmarks of engineering automation's solutions to implement in support smart cities applications. It allows to provide the Reduce and Reuse principles of the circular economy at present, but implementations of the Recycle principle required complementary technologies not fully accessed at present. Small scales of the robotics prototypes decrease exploitative energy consumptions during the researches, so that the related carbon emissions are decreased.

**Key words:** circular economy, smart cities, automation benchmarks, robotics prototype.

**RELEVANCE.** Implementations of green and digital technologies are assumed to be crucial to provide sustainable prosperity and competitiveness of the EU next decades [1], and any support of smart cities initiatives is in full agreement with it. So, the relevance of this research is due to directions to circular concepts to develop research robotics required to benchmarks of green and digital automation engineering solutions for smart cities' applications.

Automation technologies are crucial for smart cities applications, as it is highlighted in a lot of published researches like in [2] for an example. Substantiations and illustrations of the engineering automation solutions are important to develop the reliable automated control systems for smart cities, and the suitable prototypes are required to do it, as it is discussed in the research [3] for an example. The importance is due to the necessity of the checking for novel automation engineering's solutions having no direct analogues and prototypes, including for the checking of the proposed mathematical models and related results predicted theoretically such as for an example in the research [4] based on the computer simulations only. The difficulties of benchmarks for automation engineering's solutions are related with developments of suitable real-world prototypes allowing to represent fully properties inherent exactly for the considered automation object, because it requires correspondent funding, and it is accompanied with energy, material consumptions leading to carbon emissions and solid wastes accumulations polluting the environment. The purpose of this research is in implementations of circular economy principles to develop research robotics for benchmarks of automation engineering's solutions directed to improve controls of smart cities infrastructures. Such a formulated purpose is in agreement with the EU visions, that the circular economy transition is one crucial way to achieve the sustainable prosperity and competitiveness of the EU next decades as it is highlighted in the political agenda [1].

**RESULTS.** It is possible to give different classifications of economic systems, but due to the global problems related with the pollution of the environment the directions of resources' flows are considered as the economics classification feature. The linear economics has the unidirectional flow of resources from the raw materials to the wastes, which are emitted to the environment, but the circular economy has the loop returning part of the wastes to the productions as raw materials after the recycling, so that it allows decreasing emissions of wastes to the environment. Of course, it is impossible to recycle all the wastes, but the degree of the possible recycling is defined by the design of products. Besides, reuse of the products and reducing the wastes after utilisations of products also lead to decrease emissions to the environment, but such possibilities are defined significantly by the design of products. So, the basic principles of the circular economy are formulated as 3R, which represents Reduce, Reuse, Recycle actions. It is assumed that implementations of these principles allow minimising emissions of wastes to the environment, but it is possible only if these principles

are applied for the most of products, including for the prototypes developed to benchmarks of automation engineering's solutions in smart cities applications.

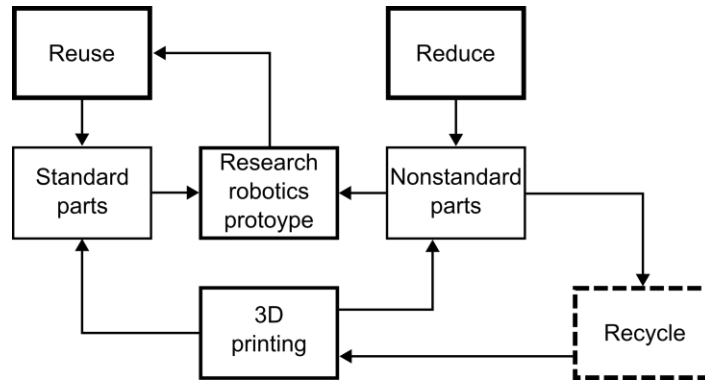


Figure 1 – Circular economy principles in developments of research robotics

The careful standardisation of the parts and the usage of the 3D printing usage are proposed as the principal pillars (Figure 1) for implementations of circular economy principles to develop the research robotics prototypes for benchmarks of automation engineering's solutions supporting smart cities applications. Indeed, the standardisation allows to reuse the same parts in different developed prototypes, and it allows to reduce the necessity of developments and productions of nonstandard parts (Figure 1). Usage of the 3D printing allow to have the least power consumptions comparing with metallic parts, and it allows to do decrease the time from the designing to the obtaining of produced parts. Besides, the plastics can be recycled by means the higher temperatures and used further to produce new parts. At the same time, it is necessary to highlight, that technologies providing recycling of the part printed by 3D printers are not fully accessible at present. The small scales of the developed robotics prototypes allow decreasing exploitative energy consumptions. The reduction of materials' flows and energy consumptions due to implementations of the proposed concepts lead to decrease direct and indirect carbon emissions in the environment.

**CONCLUSIONS.** The standardisation of the parts and the usage of the 3D printing allow to implement the circular economy principles to development of research robotics prototypes required for benchmarks of automation engineering's solutions supporting smart cities applications. It allows to provide the Reuse and Reduce principles of the circular economy at present, but to provide the Recycle principle, it is required the technologies, whose are not fully accessible at present. Small scales of the robotics prototypes allow decreasing exploitative energy consumptions during the researches, so that the related carbon emissions are decreased.

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