Source: Congress Proceedings, 61st EOQ Congress 2017, *Success in the digital era, Quality as a key driver*, Beld, Slovenia, 2017, p. 123.

Effective Waste Management As Part of the Concept of Circular Economy

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Abstract:

Production process needs natural material resources. The level of development depends on the level of technology because those material resources are not always sufficiently exploited. More effective waste management or better kind of exploitation may bring environmental benefits. At the same time that means economic benefits, too. Better management of these resources in the liberal competitiveness market may be an advantage that makes a difference. Economy, since the primitive capital accumulation and industrial revolution, has been growing on the principle: "take, make, consume, discard" and presenting the so called "linear model". The transition process from "linear" to "circular" economy is complex because it requires fulfilment of a series of assumptions: corresponding institutional framework, awareness, scientific approach and a new view of the economic reality and future. The EU has concluded that the concept of "linear economy" endangers competitiveness of the EU. Better material resource use is possible and this can significantly contribute to competitiveness of the EU economy. Transition from "linear" to the concept of "circular economy" is essential for realization of the program for successful exploitation of material resources in the framework of the Europe 2020 strategy. Model of "optimal waste management" means further improvement of the "circular" economy concept. In this paper the author researches the *effective waste management as part of the "circular" economy concept.*

Key words: *waste management, linear model, concept of circular economy, optimal waste management model.*

1. INTRODUCTION

Waste, defined as "any substance or object which the holder discards or intends or is required to discard", potentially represents an enormous loss of resources in the form of both materials and energy.[1]

„In addition, the management and disposal of waste can have serious environmental impacts. Landfill, for example, takes up land space and may cause air, water and soil pollution, while incineration may result in emissions of air pollutants. EU waste management policies therefore aim to reduce the environmental and health impacts of waste and to improve the EU's resource efficiency. The long-term aim of these policies is to reduce the amount of waste generated and when waste generation is unavoidable to promote it as a resource and achieve higher levels of recycling and the safe disposal of waste."[2]

[1] Directive 2008/98/EC of the European Parliament and of the Council, 19. November 2008, Article 3(1).
[2] EUROSTAT.

2. GLOBAL ECOLOGICAL FOOTPRINT

"Ecological resources are at the core of every country's long-term wealth. Yet population growth and consumption patterns are putting more pressure on these critical assets."[3]

Ecological Deficit Date – EDD[4] marks the date when the nation's demand for ecological resources and services in a given year exceeds what the nation's ecosystems can regenerate in that year. A national deficit day is the equivalent of Earth Overshoot Day – EOD at the national level.[5]

In the last twenty years, since 1997, this date shifted from the end of September to the 2nd of August in 2017. If the whole humanity is taken into account, at the moment resources are used 1.7 times faster than the planet is able to regenerate.[6] Such behaviour has led to numerous problems of the today's humanity.

"Today, the majority of countries in the world are running ecological deficits, using more resources than ecosystems within their borders can regenerate. Others depend heavily on resources from elsewhere, which are under increasing pressure. In some areas of the world, the implications of ecological deficits can be devastating, leading to resource loss, ecosystem collapse, debt, poverty, famine and war."[7]

„World biodiversity reduces at a shocking rate, endangering survival of other species and our future. The latest issue of the WWF Living Planet Report shows how difficult the situation is and how it can start improving. The Living Planet Index – LPI reveals that global population of fish, birds, mammals, amphibian and reptiles has declined by for 58% in abundance between 1970 and 2012. In the period from 1970 to 2020 we could witness a decrease exceeding two thirds, unless we act immediately. We must change our nutrition and energy systems and fulfil global obligations relating to coping with climate changes, biodiversity protection and supporting sustainable development."[8]

GFN data are measured in global hectares (gha), meaning that they present a unit for measuring requirements of the humanity on the planet Earth (demand) on the one part and the capacity (supply) of the planet Earth to satisfy such demand on the other part.[9] „Total biocapacity of Earth in 2012 was 12.2 billion gha (or 1.7 gha per person), and the ecological footprint was 20.1 billion gha (or 2.8 gha per person). The ecological footprint is not uniformly distributed and citizens of richer countries put an unproportional pressure on the nature by using

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[3] GFN – **Global Footprint Network:** The Ecological Footprint is a resource accounting tool that helps countries understand their ecological budget and gives them the data necessary to manage their resources and build a secure, resilient future." http://www.footprintnetwork.org/countries/

[4] Ibid.

[5] EOD – **Earth Overshoot Day** "…marks the date when humanity's demand for ecological resources and services in a given year exceeds what Earth can regenerate in that year. We maintain this deficit by liquidating stocks of ecological resources and accumulating waste, primarily carbon dioxide in the atmosphere. EOD is hosted and calculated by Global Footprint Network, an international think tank that coordinates research, develops methodological standards and provides decision-makers with a menu of tools to help the human economy operate within Earth's ecological limits." http://www.overshootday.org/about-earth-overshoot-day/

[6] WWF – The **World Wide Fund for Nature** is an international non-governmental organization founded in 1961, working in the field of the wilderness preservation, and the reduction of humanity's footprint on the environment. It was formerly named the **World Wildlife Fund**, which remains its official name in Canada and the United States. The living planet report is published every two years by WWF since 1998, it is based on living planet index and ecological footprint calculation.

[7] GFN.

[8] WWF. http://croatia.panda.org/lpr_2016/

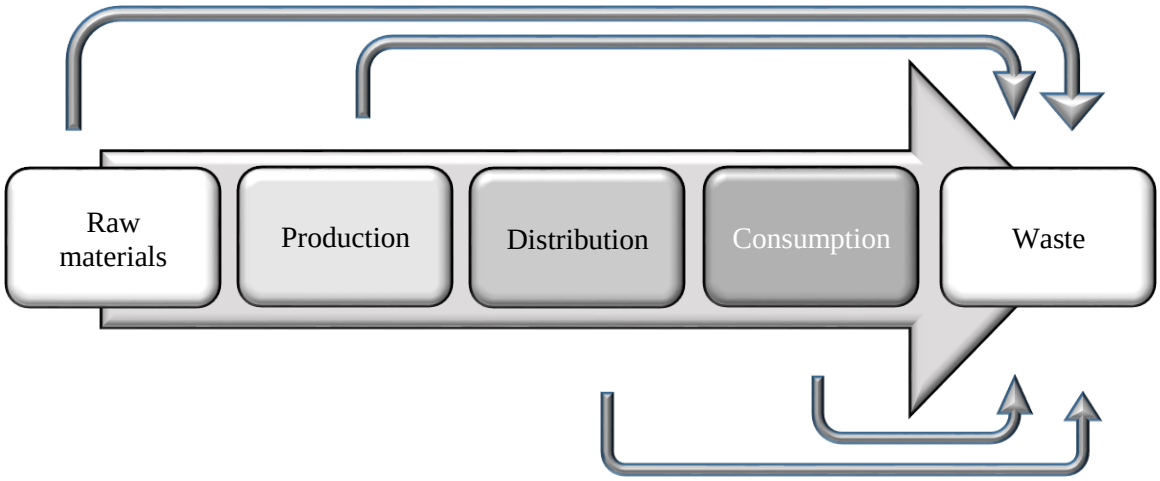
[9] **Global hectares** are hectares of biologically productive land and sea area with world average bioproductivity. Both biocapacity and the Ecological Footprint are measured in global hectares. (A hectare contains 10,000 square meters and corresponds to about 2.47 acres).
http://www.overshootday.org/lesson-what-day-is-earth-overshootday-2017/

resources of Earth more than they actually need. On the other side of the scale are some of the poorest countries in the world which barely have enough for basic needs.“[10]

3. CONCEPT OF LINEAR ECONOMY

It is characteristic for the Concept of Linear Economy – CLE to consider waste as an inevitable side effect of the process within the Supply Chain. Another characteristic of the concept is its functioning under the principle: “take, make, consume, discard”, leading to the conclusion that it thinks about the planet Earth as a limitless source of easily available material resources (Figure 1).

Figure 1 Phases of the CLE model



Source: Author according to: Milan Krišto, „Kružna ekonomija za brži razvoj“, Gospodarstvo i okoliš, Hrvatski poslovni savjet za održivi razvoj, Vol., No. 41, 2015, p. 11.

Earth as a planet has limited resources. This means that unlimited growth is not possible, while the tendency of the world population growth and the tendency of industrial growth cause constantly increasing demand for material resources.

CLE is also characterized by the fact that waste appears as a result of all Supply Chain segments: Row materials, Production, Distribution, Consumption (Formula 1).

$$TwqL = RMwq + Pwq + Dwq + Cwq \quad (1)$$

where the symbols have the following meaning:

TwqL – Total waste quantity – Linear economy concept
RMwq – Raw Materials waste quantity
Pwq – Production waste quantity
Dwq – Distribution waste quantity
Cwq – Consumption waste quantity.

[10] Ibid. http://croatia.panda.org/lpr_2016/ekoloski_otisak/

"Currently, world cities generate about 1.3 billion tonnes of solid waste per year. This volume is expected to increase to 2.2 billion tonnes by 2025. Waste generation rates will more than double over the next twenty years in lower income countries. Globally, solid waste management costs will increase from today's annual $205.4 billion to about $375.5 billion in 2025. Cost increases will be most severe in low income countries (more than 5-fold increases) and lower-middle income countries (more than 4-fold increases)."[11]

As might be expected, the overall amount of waste generated is related to some extent to the population and economic size of a country. The smallest EU Member States generally reported the lowest levels of waste generation and the larger ones the highest. Nevertheless, relatively high quantities of waste were generated in Bulgaria and Romania and a relatively low quantity in Italy.

Table 1 Waste treatment, 2014 (thousand tons)

Total	Recycling	Energy recovery	Backfilling	Incineration	Landfill
2.319.500	839.659	109.017	236.589	34.792	1.099.443
100,00%	36,20%	4,70%	10,20%	1,50%	47,40%

Source: EUROSTAT, YB 2014-1.png

The data in Table 1 show that the EU-28 member states generated the total of 2.319.500 t waste in 2014, with the following use percentages: Recycling 36.20% (839.659 t), Energy recovery 4.70% (109.017 t), Backfilling 10.20% (236.589 t), Incineration 1.50% 34.792 t) and Landfill 47.40% (1.099.443 t).

Table 2 Waste generation by economic activities and households, 2014 (thousand tons)

Total	Construction and demolition	Mining and quarrying	Manufacturing	Households	Energy	Other economic activities
2.319.500	804.866	654.099	236.589	192.518	85.823	345.605
100,00%	34,70%	28,20%	10,20%	8,30%	3,70%	14,90%

Source: EUROSTAT, YB 2014-1.png

The share of different economic activities and of households in total waste generation in 2014 is presented in Table 2. In the EU-28, construction contributed 34.70% (804.866 t) of the total in 2014 and was followed by mining and quarrying 28.20% (654.09 t), manufacturing 10.20% (236.589 t), households 8.30% (192.518 t); energy 3.70% (85.823 t) the remaining 14.90% (345.605 t) was waste generated from other economic activities.[12]

In 2010 the share of hazardous waste (97.490 t) in the total waste quantity (2.362.840 t) was 4.12%. Compared to 2010, in 2012 the EU-28 generated 2.20% more non-hazardous waste and 3.30% more hazardous waste, meaning that the quantity of the latter increased from 97.5 to 100.7 million tons. The share of hazardous waste in 2012 in the overall quantity of generated waste in the EU-28 was 4.19% on average and was below 10.00% in all member states except Estonia, where it amounted to 41.60% of the overall waste, and Ireland, where the share was

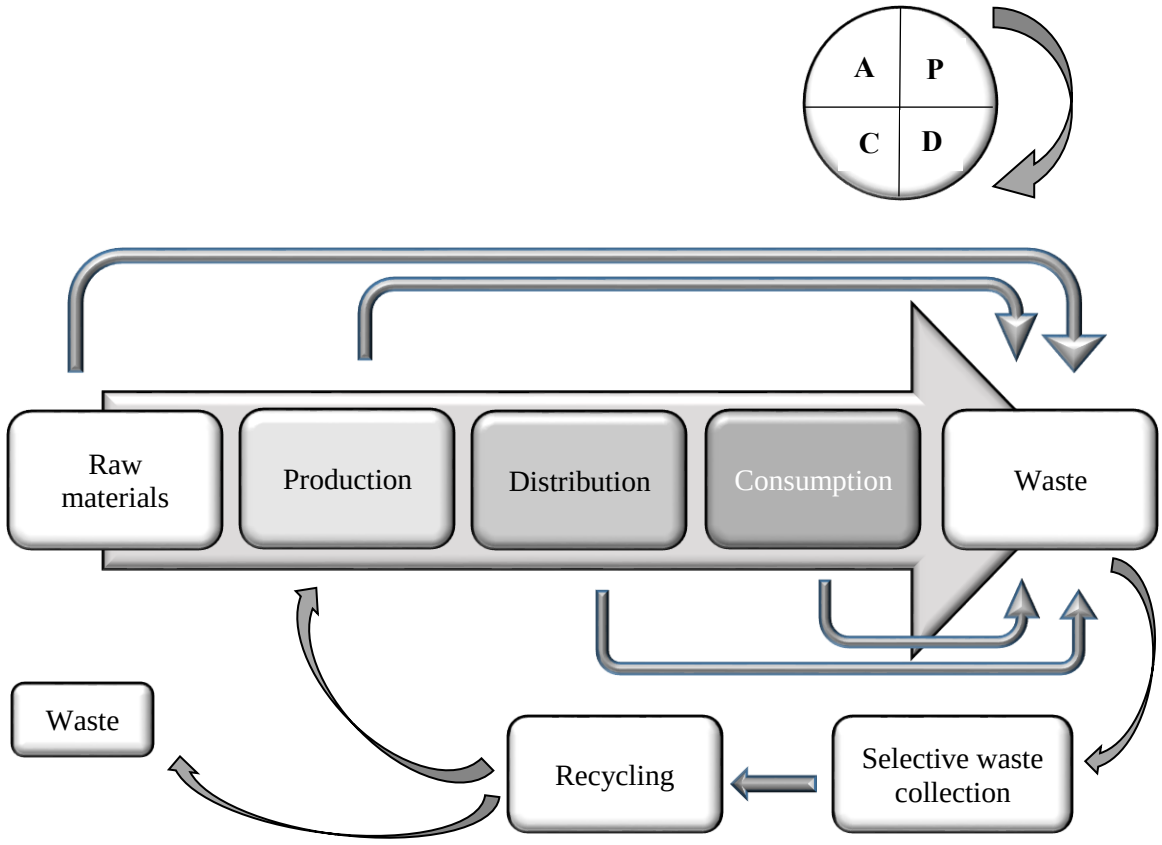
[11] Daniel Hoornweg and Perinaz Bhada-Tata, *What a waste, A Global Review of Solid Waste Management*, The World Bank, 2012, p. 9.
[12] EUROSTAT.

10.30%. The very high share of hazardous waste in Estonia was generated primarily by production of energy from oil shale. Among non-member countries, the biggest share of hazardous waste in the overall quantity of generated waste was recorded in Serbia (26.30%) due to intensive activities of mining industry and quarrying, followed by Bosnia and Herzegovina (21.20%) and Norway (12.70%).[13]

4. CONCEPT OF CIRCULAR ECONOMY

Despite domination of the neoliberal concept prevailing in the world economy and „ ... the neoliberal economic doctrine appearing in the economic theory in the last thirty years of the 20th century, as an answer and a possible practical solution for the that time world economic stagnation occurring after over two decades of economic growth within the framework of the Keynesian and Neo-Keynesian state capitalism and in the theory of the dominating neoclassical synthesis, ...“[14] it can be noticed in the last years that awareness and understanding of the need to replace the liberal economy concept with a concept that would manage resources on the planet more efficiently, including waste.

Figure 2 Phases of the Concept of Circular Economy



Source: Own research.

[13] Ibid.
[14] Milovan Jovanović i Ivo Eškinja, „Neki aspekti neoliberalizma u svjetskom gospodarstvu,“ Zbornik Pravnog fakulteta Sveučilišta u Rijeci, Vol. 29, No. 2, Rijeka, 2008, str. 941-958.

$$TwqC = (RMwq + Pwq + Dwq + Cwq) – RCwq \quad (2)$$

where the symbols have the following meaning:

TwqC – Total waste quantity – Circular economy concept
RMwq – Raw Materials waste quantity
Pwq – Production waste quantity
Dwq – Distribution waste quantity
Cwq – Consumption waste quantity
RCwq – Recycled waste quantity.

According to the Concept of Circular Economy – CCE, (Figure 2) waste generated during operation of processes within the Supply Chain is not discarded into the environment but is collected in the selective waste collection system, so that waste can be recycled, and a part of the recycled waste afterwards re-enters the production as raw material, reducing by this quantity the need for new ore extraction. The smaller part not suitable for recycling is safely disposed, in compliance with regulations.

One of the main characteristics of the CCE is establishing a feedback through the selective waste collection and recycling process. In this way, as shown by Formula 2, the total waste quantity may be reduced and contribute significantly to environmental protection, presenting the application of the Sustainable development principles.[15]

This process is repeated continuously, in cycles, based on the principles of the Shewhart cycle (P-Plan; D-Do; C-Check; A-Act).[16] In this way waste is managed by applying the continuous improvement methodology.

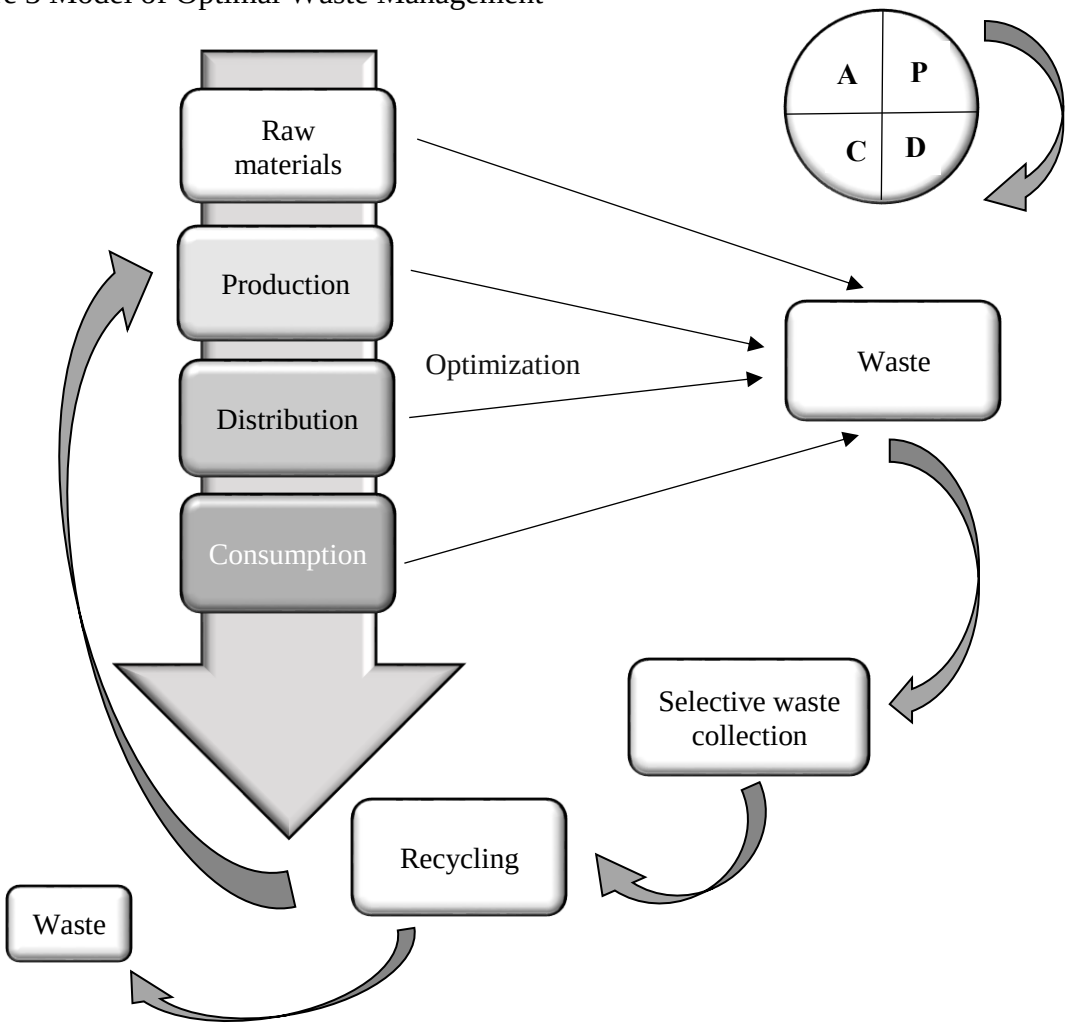
„It is estimated that by 2030 the need for material use could be reduced for noteworthy 17-24% in the whole value chain, by improving the use of material resources, and that a better use of resources could result in annual savings of 630 billion in the European industry. Results of researches directed to the needs of companies and based on shaping a model at the product level show significant possibilities in the EU industry for saving material resources thanks to the concept of circular economy, as well as a potential for the EU GDP increase of up to 3.9%.“[17]

5. MODEL OF OPTIMAL WASTE MANAGEMENT

Obviously, it is a long term problem. Such demand for resources exceeding the supply of the planet Earth at the annual level and significantly moving the EDD towards the middle of the calendar year inevitably produces a growing quantity of waste, which puts additional pressure on the environment. In such situation the CLE proves insufficient for solving the problem. It generates growing costs, increases environmental pollution and negatively affects quality of life of people.

[15] Miroslav Drljača, „Koncept kružne ekonomije,“ Kvalitet & izvrsnost, Vol. IV, No. 9-10, Fondacija za kulturu kvaliteta i izvrsnost, Beograd, 2015, str.18-22 i 99.
[16] Methodology of continuous improvement based on Walter Andrew Shewhart (1891.-1967.) principle popularised by William Edwards Deming (1900.-1993.) and worldwide well known as a Deming cycle (PDCA cycle).
[17] Cf. *Towards the Circular Economy: Economic and business rationale for an accelerated transition,* Ellen MacArthur Foundation, 2012.

Figure 3 Model of Optimal Waste Management



Source: Own research.

$$TwqO = (RMwq - Owq) + (Pwq - Owq) + (Dwq - Owq) + (Cwq - Owq) \quad (3)$$

$$TwqL > TwqC > TwqO$$

$$CEC = (TwqL - TwqC) - (TwqC - TwqO) \text{ or}$$

$$TwqL - TwqO$$

where the symbols have the following meaning:

TwqO – Total optimized waste quantity
CEC – Circular Economy Contribution.

Raw materials waste optimization can be achieved by a more rational use of raw materials during extraction in mines, meaning by applying more advanced technologies for separation of useful material from spoils.

Production waste optimization can be achieved by applying advanced technologies in the production process, which result in larger degree of raw material usability and reduction of the quantity of waste.

Distribution waste optimization can be achieved by high quality planning of transport flows and delivery of products from manufacturers to distribution centres, warehouses and

points of sale. Care should be taken not to damage products during distribution process so that they need not be removed and disposed of as waste even before delivered to the customer, or before use. Equally, attention should be paid to packaging so that original packaging remains undamaged and requires no replacement. The aspect of toxic gas emissions by transport vehicles is also a significant aspect, which should similarly be optimized by the most suitable planning and vehicle fleet management.

Consumption waste management is done in several ways. First of all, only necessary products should be procured for end use, in order not to needlessly create surplus which will later be discarded as waste due to useful life expiry or other reasons. Further on, waste should be collected selectively after consumption in order to facilitate further handling and waste recycling process, or its final disposal in a safe way.

In all parts of the supply chain it is possible to contribute to the process of optimization of waste also within the CCE, by applying adequate measures and procedures and acting in the Supply Chain Waste Management System. In this way the total quantity of waste decreases and burdens the environment to a smaller extent and we can talk about improvement of the CCE in the Concept of Optimal Waste Management (OWM).

The aim of the Waste Management System (WMS) is: 1) reduction of waste quantity; 2) sorting of waste; 3) recycling of waste and its return to the production process and 4) safe disposal of waste which cannot be recycled. Figure 3 shows the OWM model. Since waste is generated in all parts of the Supply Chain, from exploitation of raw materials needed for production, over production, distribution and consumption, the OWM model relates to all mentioned parts of the Supply Chain. In order to optimize the waste quantity in all parts of the supply chain it is necessary to:

- provide financial means;
- establish the environmental management system;
- train people;
- ensure modern technology;
- perform control during process operation.

The OWM model (Figure 3) in the Supply Chain ensures generation of a smaller quantity of waste in all parts of the Supply Chain, and eventually this means a smaller total quantity of waste. Waste should be collected separately according to types in order to ensure a good quality recycling procedure enabling a portion of waste to be used again as raw material in the production process; this reduces the total need for exploitation of natural resources for the purpose of providing resources for production, meaning also a smaller quantity of waste in the part of the Supply Chain where raw material is exploited. A small quantity of waste which will still remain after recycling, the waste that cannot be recycled in an acceptable way, will be safely disposed of by approved organizations. This process also repeats in cycles, continuously, under the principles of the Shewhart cycle (P-Plan; D-Do; C-Check; A-Act).

6. CONCLUSION

The CLE is based on acting under the principle: „take, make, consume, discard“. It does not take care of the fact that the planet Earth is limited and that overuse of resources causes permanent damages to the planet. Such behaviour has led to the fact that the planet Earth cannot any more absorb pollution by waste generated by the humanity, so that in the last twenty years, from 1997, the EDD has moved from the end of September to the 2nd of August in 2017. In efforts to significantly change the situation for the better and contribute to the preservation of the planet Earth, the CCE has been designed, a concept which contains all elements of the CLE,

but adds a vital change, and it is feedback relating to waste, in a way in which waste does not move in one direction and is discarded in the nature, but is selectively collected and recycled, this results in return of the recycled waste into the production process, and only a small portion of waste that cannot be recycled is permanently disposed of in a safe way. The EUROPE 2010 strategy is based on this concept. By such improvement of material resources use in the whole Supply Chain the need for material use could be reduced for 17-24% by 2030, and an annual saving of 630 billion EUR could be achieved in the European industry by better use of resources. The concept could be also applied to the rest of the world. However, since the CLE concept shows that waste is generated in all phases of the Supply Chain, the CLE concept does not present the peak of the waste quantity reduction. Improvements in waste management at the global level are achieved by optimizing waste generation in each phase of the Supply Chain. Therefore the author proposes, on the basis of the results of the research shown in this paper, the OWM model, which contains the CLE improved by feedback within the framework of the CCE, and further improved by a process of waste generation optimization in all phases of the Supply Chain. Pollution of the environment is a global problem and requires global solutions for the purpose of effective waste management. This involves establishment of a Waste Management System (WMS) at the global, but also at national, regional and local levels.

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