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MACROECONOMIC PREDICTOR FOR RECOVERY RATE OF CONSTRUCTION AND DEMOLITION WASTE. A NEURAL NETWORKS MODEL FOR ROMANIA

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Abstract

The common values of a circular economy are concentrated in decoupling economic growth from resource consumption; resource efficiency; waste management; sharing; reducing greenhouse gas emissions; lifecycle assessments and closing loops. With the increasing cost of natural resources as a real EU scenario, industries will significantly benefit from shifting towards a more circular approach. The aim of this paper is to analyses the waste management actions, especially for construction and demolition sector, in Romania in the EU-28 context by applying statistical methods and neural network modelling to find the best macroeconomic predictor for recovery rate of construction and demolition waste for period 2010 -2020.

Key words: waste management, neural networks, Romania, EU-28, constructions and demolition waste

1. Introduction

The world population is projected to increase from 7.7 billion to 9.7 billion people by 2050 [1]. As a result of the growing population, products consumption will also increase. Estimation shows that overall material use will reach around 90 billion tons by 2050, approximately twice the quantity observed in 2015. Construction industry is currently one of the largest global consumers of resources and raw materials. In 2017 for instance, in the United States (U.S.) alone, 569 million tons of construction and demolition waste was produced. It expected that, by 2025, 2.2 billion tons of construction and demolition waste will be generated worldwide [2]. Although, construction materials waste has a high potential for reuse and recycling, unfortunately, it is estimated that only around 40% of those waste is currently reused, recycled, or sent to waste to energy facilities [3], and the remaining 60% is diverted to landfills.

Construction, renovation, and deconstruction are key industry sectors related to the built environment. An increasing number of initiatives, government policies, and academic research have been focusing on the implementation of a *circular economy* in the built environment by better available techniques. This increasing trend addresses the rising pressures due to depleting natural resources, increasing a lot of waste production, and the rising cost of construction materials. Furthermore, the opportunities for implementing a circular economy in the built environment and related businesses are primarily recognized by different organizations. According to World Economic Forum, it estimates that the adoption of circular economy principles by the construction sector could result in over U.S. $100 billion a year in savings due to improved productivity [4].

In the case of Romania as part of European Union (EU-28), investigating the potential to reduce material use in this sector will significantly impact global raw material consumption and ultimately reduce the pressure on natural resources.

Regarding the EU-28 situation, in the Figure 1 is presented the recovery rate of construction and demolition waste for 2010-2020, according to the European Commission and it can observe that Romania has a rate under EU-28 average for all observed years [5].

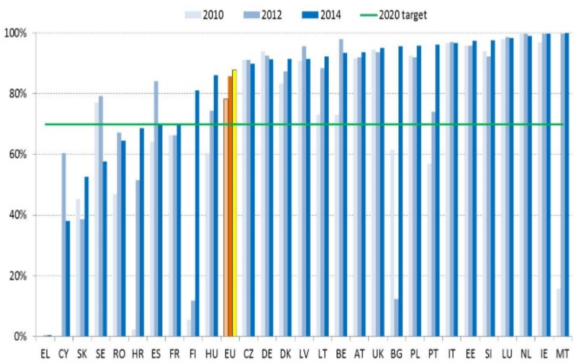

Fig. 1: Recovery rate of construction and demolition waste in EU-28 for 2010 - 2020

(Source: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018SC0017&rid=9)

The circular economy model is based on better management of resources by refusing, rethinking, and reducing unnecessary consumption patterns [6] that is, the model targets zero waste and pollution even if is not clear the way to achieve this ambitious target. [7]. Also, this model has the goal of retaining materials and resources circulating at their highest value within planetary boundaries, in a way that additional natural resources are unnecessary to produce goods, and the discarded materials are not viewed as waste [8]. In other words, the circular economy model is an alternative approach to a linear economy; it is focused on changing the traditional pattern of take-use-dispose and keeping resources in use for more extended periods by treating waste as useful inputs [9-10]. The common values of a circular economy are concentrated in decoupling economic growth from resource consumption; resource efficiency; waste management; sharing; reducing greenhouse gas emissions; lifecycle assessments (LCA); and closing loops [11]. With the increasing cost of natural resources as a real EU scenario, industries will significantly benefit from shifting towards a more circular approach. However, barriers such as insufficient knowledge regarding circular economy among stakeholders, inadequate funds for implementation, and uncertainties in the trade-offs, exist in the path towards circularity particularly in EU countries and Romania in particular [12].

The *aim* of this paper is to analyses the waste management actions, especially for construction and demolition sector, in Romania in the EU-28 context by applying statistical methods and neural network modelling to find the best macroeconomic predictor for recovery rate of construction and demolition waste for period 2010 -2020 by using Eurostat and United Nation Development Programme (UNDP) [13-18].

2. Materials and Methods

The variables used in this research are as follows:

- Recovery rate of construction and demolition waste (RRCDW);
- Human Development Index (HDI);
- GDP/capita;
- General government expenditure with environment protection (GGEEP) (mil. Euro);
- General government expenditure with environment protection (GGEEP) (% in GDP);
- People at risk of poverty or social exclusion (thousand persons);
- People at risk of poverty or social exclusion (%);
- Population by educational attainment level, sex and age (%)_Less than primary, primary and lower secondary education (levels 0-2).

Descriptive statistics were used for all variables for Romania and European Union 28 (EU-28) countries being presented in Table 1 as mean ± standard deviation.

Table 1: Descriptive statistics

Variables	Romania	EU - 28
Recovery rate of construction and demolition waste	67.6±8.80	71.23±32.58
HDI	0.81±0.008	0.85±0.03
GDP/capita	59.64±7.05	73.62±13.63
GGEEP (mil. Euro)	1234.63±219.9	586.2±707.6
GGEEP (% in GDP)	0.74±0.14	0.65±0.36
People at risk of poverty or social exclusion (thous persons)	7479.4±1006.9	2132.2± 2719.9
People at risk of poverty or social exclusion (%)	37.62±4.55	26.1±8.36
Population by educational	27.88±2.22	20.73±9.21

attainment level, sex and age %) Less than primary, primary and lower secondary education (levels 0-2)		

The statistical methods applied in our research are:

- *Spearman correlations* to find the statistically significant direction and power [19] of link between recovery rate of construction and demolition waste and macroeconomic variables;
- *One Sample Student test* [19] to test the statistically significant differences between variables means of the studies by comparing Romanian values with EU-28 averages;
- Neural networks [20-21] to find the best macroeconomic predictor for Romania and EU-28 for recovery rate of construction and demolition waste.

Data was collected for 2010 – 2020 and EU-28 is considered for the moment 1 January 2020. The analyze was performed with SPSS 23.0 licensed software and Microsoft Excel for the graphical representations of the heat maps of Pearson correlations.

3. Results and discussions

According to the results of *Spearman correlations* from Table 2 it can observed both positive (marked with blue color in the heat map) and negative (marked with red color in the heat map) correlations for Romania as follows:

- a direct (positive), medium to strong intensity and significantly statistic (p= 0.05) correlation (+0.664) between *recovery rate of construction and demolition waste* and *HDI*;
- a direct (positive) medium intensity and statistically significant (p=0.1) correlation (+0.523) between *recovery rate of construction and demolition waste* and GDP/capita;
- a inverse (negative) medium intensity and statistically significant (p=0.1) correlation (-0.540) between *recovery rate of construction and demolition waste* and *people at risk of poverty or social exclusion (thousand persons).*

Table 2: Heat map for Spearman correlations coefficients for Romania

	Recovery rate of construction & demolition waste	HDI	GDP/capita	GGEEP (mil. euro)	GGEEP (% in GDP)	PRPSE (thous pers)	PRPSE (%)	Population by educational level (0-2)
Recovery rate of construction & demolition waste	1.000	0.664*	.523	.067	-.221	-.540	-.486	-.342
HDI		1.000	0.826*	.292	-.373	-0.845**	-0.827**	-.545
GDP/capita			1.000	.108	-.465	-0.932**	-0.909**	-0.726**
GGEEP (mil. euro)				1.000	0.633*	-.287	-.273	.082
GGEEP (% in GDP)					1.000	.341	.383	0.696*
PRPSE (thous pers)						1.000	0.991**	0.664*
PRPSE (%)							1.000	0.682*
Population by educational level (0-2)								1.000

From Table 1 resulting that the average of recovery rate of constructions and demolition for Romania and EU-28 are closed and this aspect is confirmed by the results of *One Sample T-Test* from Table 3 with p-value = 0.201. Therefore, we cand conclude that Romania, for period 2010 -2020, has a good and close recovery rate of construction and demolition waste to EU-28 countries. There are statistically significant differences between Romania and EU-28 averages for all macroeconomic indicators from the study.

In Figure 2 we present the results of neural networks modeling for Romania and EU-28. We used the Multilayer Perceptron (MLP) algorithm. We choose this method due of advantages of flexibility and lack of distribution assumption.

Table 3: The results of One-Sample T-Test by comparing Romania and EU-28

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Recovery rate of construction and demolition waste	-1.367	10	.201	-3.63000	-9.5450	2.2850
Human Development Index	-16.321	10	*.000*	-.040400	-.04592	-.03488
GDP/capita	-6.583	10	*.000*	-13.98604	-18.7200	-9.2521
General government expenditure with environment protection (mil. Euro)	9.781	10	*.000*	648.47465	500.7436	796.2057
General government expenditure with environment protection (% in GDP)	2.275	10	*.046*	.09492	.0019	.1879
People at risk of poverty or social exclusion (thousand persons)	17.642	10	*.000*	5356.134	4679.67	6032.60
People at risk of poverty or social exclusion (%)	8.394	10	*.000*	11.5192	8.462	14.577
Population by educational attainment level, sex and age (%)_Less than primary, primary and lower secondary education (levels 0-2)	10.699	10	*.000*	7.14770	5.6591	8.6363

Also, having both the categorial (EU-28 or Romania) and continuous variables in the research (all the variables from Table 1), the neural networks can be used to predict both categorial and continuous outcomes [20-21].

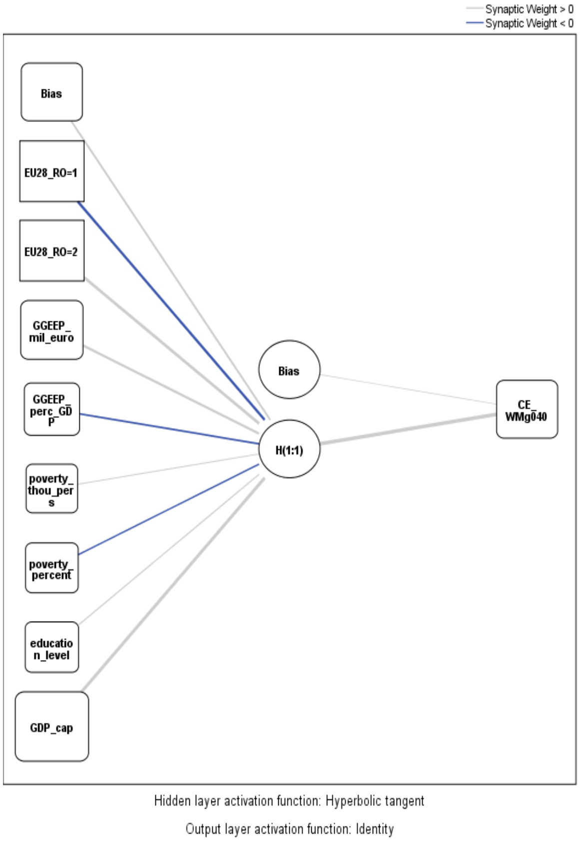

Fig. 2: Result of neural networks for Romania and EU-28

(Note: CE_WMg40 = Recovery rate of construction and demolition waste)

The *input layers* of neural networks were all the macroeconomic variables from table 1 and the categorial variable Romania or EU-28. The *output layer* was the recovery rate of construction and demolition waste. We opted as *model architecture* for one hidden layer and one node and to present the synaptic weights as well. The blue color of the synaptic weights in the Figure 2 indicates the weight is less than zero and the grey color indicate the weight exceed zero. Therefore, it is evident the contrast of comparison Romania (negative, blue synaptic weight) – EU-28 average (positive, grey synaptic weight).

The model returns one *hidden layer node H (1:1)* but the *synaptic weights* are different for Romania compared with EU-28 average, in Table 4 being presented the parameter estimates.

Table 4: Parameter Estimates

Predictor		Predicted: Hidden Layer 1 H(1:1)	Predicted: Output Layer RRCDW
Input Layer	(Bias)	.391	
	[RO]	-.556	
	[EU28]	.601	
	GGEEP (mil. euro)	.524	
	GGEEP (% GDP)	-.271	
	Poverty (thou pers)	.170	
	Poverty (%)	-.206	
	Education level	.184	
	GDP/capita	.757	
Hidden Layer 1	(Bias)		.036
	H(1:1)		.888

According to the results from Table 4 and Figure 2, the hidden layer H (1:1) includes (in order of independent variable importance (Figure 4):

- a positive contribution of GDP/capita (0.757)
- a positive contribution of *General government expenditure with environment protection (GGEEP) (mil. Euro)* (0.524) to H (1:1);
- a negative contribution of *General government expenditure with environment protection (GGEEP) (% in GDP)* (-0.271) to H (1:1);
- a positive continuation of *Population by educational attainment level, sex and age (%)_Less than primary, primary and lower secondary education (levels 0-2)* (+0.184) to H (1:1);
- a negative contribution to H (1:1) for *people at risk of poverty or social exclusion (%)* (-0.206);
- a positive contribution to H (1:1) for *people at risk of poverty or social exclusion (thousand persons)* (+0.170).

The Figure 3 indicate what macroeconomic variables affect (and the percentage of importance) more than other variables the outcome (recovery rate of construction and demolition waste). It can be seen that a total importance of GDP/capita level for Romania and EU-28, a statistically significant differences according to the One Sample T- Test results following by the *general government expenditure with environment protection (GGEEP) (mil. Euro).*

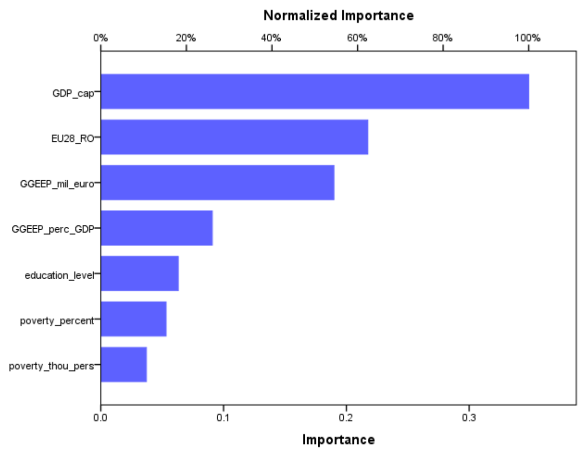

Fig. 3: The normalized importance of independent variables

Therefore, we can conclude that the best predictors and what are the macroeconomic indices that differentiate Romania from EU-28 average level are the GDP/capita and the general government expenditure with environment protection (GGEEP) (mil. Euro).

4. Conclusions

According to the European Union statistical data from Eurostat (Figure 1) and literature review [22-23] there are significant differences between member states regarding the construction and demolition waste generated [23]. The present results validate and confirm other research results for Romania that out country is still in transition towards sustainable construction and demolition waste management activities [22]. The countries that have specific legislation regarding construction and demolition waste have bigger recycling rates, their experience can be assimilated in the rest of European countries [23].

The rate of recycling and recovery of construction and demolition waste for the year 2020 is set at 70%. [18; 24-25]. The waste recovery level in our country the collected waste is mostly disposed of by storage in landfills, without any other recovery or reuse [24].

Construction and demolition activities in the European Union (EU) are responsible for generating 850 million tons of construction and demolition waste per year [25]. In the published scholar papers a little attention has been paid to investigate the causal and determinant relationship of construction and demolition waste arising with national economic, social and technological factors across different countries [25]. Therefore, our novel contribution emphasis an important aspect in this sense and pointed out that, for Romania, *GDP/capita* and *general government expenditure with environment protection (mil. Euro)* could be considered a good predictor for recovery rate of construction and demolition waste. A novel approach was adopted by using the neural networks modelling and by take into considerations both macroeconomic indicators which reflect the national economy and civic and awareness of the population.

The practical objective of this research is to analyse and highlight Romanian situation in terms of Waste management of construction materials deposited in urban areas without prior classification in the circular economy context. The evaluation through the macroeconomic predictors model will indicates how close or not Romania is developing instrument to achieve the ambitious EU objectives. The main conclusion of this research is that both education of citizens and governmental financial effort is important to increase the recovery rate of construction and demolition waste in Romania. For Romania is important to make the connections and synergies between industrial sector of economy to a better waste management and increase the productivity of resources use.

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