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TRENDS OF MUNICIPAL WASTE FLOWS, COMPOSITION, TREATMENT IN LITHUANIA AND ITS REGIONS

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Abstract. *Purpose* – to propose conceptual model for forecasting of waste trends and empirically implement the model based on the case of Lithuania and its regions.

Research methodology – 1) scientific literature analysis on circular economy, zero waste and waste management, 2) gathering of statistical data on waste flows, composition and treatment 3) creation of conceptual model of forecasting with Exponential Smoothing for prediction of waste-related trends based on literature review.

Findings – proposed conceptual model for prediction of waste-related trends is adequate for prognosis of waste flows, composition and treatment ways. The main forecasting results are that the total waste flows will increase in Lithuania, on a regional level, Alytus, Kaunas, Klaipėda, Telšiai, have a tendency of the increase in municipal waste flows. The results imply that in order to contribute to the reduction of waste, the active involvement on a regional level is necessary.

Research limitations – the research can be extended with statistical data on waste of other countries to check adequacy of the conceptual model for waste-related trends prognosis.

Practical implications – the findings of the research can be applied in planning and decision-making process of government bodies on national or local level. The results are also useful for the general public in educational purposes.

Originality/Value – the study provides original conceptual model for the forecasting of waste-related trends which provides robust results of predictions and can be replicated by different countries.

Keywords: circular economy, waste, municipal waste management, zero waste, trends, forecast, Exponential Smoothing.

JEL Classification: C53, Q53, R11.

Conference topic: Contemporary Financial Management.

Introduction

The dominance of linear economy over the past decades has stipulated the growth of municipal waste around the world. Also, changing economic conditions in different parts of the world have stipulated the movement of inhabitants moving from rural areas to cities, which also has an effect on the waste formation flows (Allam, 2018; Zaman, 2012; Zaman & Lehmann, 2013).

The emerging importance of the waste problems are now the major concern of citizens, companies, governments and policy makers. The number of studies has been carried out by academics to tackle waste problems and propose solutions such as shift to circular economy and adoption of zero waste principles. In turn, European Commission, United Nations, local governments have issued measures aimed to control the waste generation and, subsequently, to decrease the waste flows in the future.

However, projections of future waste generation doesn't indicate any improvement or reduction of waste flows (Allam, 2018; Zaman & Swapan, 2016). World Bank Group (Kaza et al., 2018) estimated that the world will produce 2.59 billion tonnes of municipal solid waste annually and this number is going to increase up to 3.4 billion tonnes by 2050, compared to 2.01 billion tonnes in 2016. This research also indicates that that high-income countries are subject to incremental increase of municipal solid waste, whereas low-income and lower-middle-income countries have a tendency of greatest increase in waste flows due to economic progression and raise of the population.

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Predictions of future waste trends play an important role in formation of waste management policies and waste treatment ways. According to the Ministry of Environment of the Republic (Lietuvos Respublikos aplinkos ministerija, 2021) of Lithuania, the long-term goals lay the groundwork for the waste management capacity planning – at least 65% municipal waste should be reused or recycled and no more than 5% of municipal waste can be disposed in landfills. Therefore, forecasting of waste flows can help policy makers to reach the goals by applying various control measures to deal with littering, food waste and disposal of biodegradable waste at landfills.

Academics apply various methods for the forecasting of various type of waste, such as artificial intelligence, machine learning, artificial neural networks, time series analysis and many others. The aim of this paper is to propose conceptual model for forecasting of waste trends and empirically implement the model based on the Lithuania's data.

The article follows the structure of four sections: the first section investigates the synergy of circular economy and zero waste concepts aimed to tackle waste challenges, the second section explains research methods and proposes conceptual model of forecasting waste, the third section introduces results and findings of the research and the fourth section provides conclusions and provides guidelines for further research and discussion.

1. Coherence of circular economy, zero waste city concept and municipal waste management

The importance of circular economy is growing nowadays and receives increased interest from citizens, companies, governments and policy makers (Corona et al., 2019; Cudečka-Puriņa et al., 2019; Haupt et al., 2019; Kirchherr et al., 2017; Lahti et al., 2018; Schroeder et al., 2019). Circular economy aims to foster responsible and circular use of resources (Moraga et al., 2019; Wilson, 2015), its principles can be compared to the processes happening in our nature, where the end of one process lays the groundwork for a new process (Allam, 2018; Hannon & Zaman, 2018).

Circular economy model is substantially different from linear economy as it oriented towards improvement of linear economy drawbacks (Doussoulin, 2020). Circular economy model is a long-term objective supported with a synergy of economic growth, zero waste and sustainability (Greyson, 2007). The successful long-term orientation towards circular economy can be achieved through the cooperation and interrelationship between society, businesses and governments (Sánchez-Ortiz et al., 2020). As a result of application of circular economy model, society, companies and governments can exercise increased employment opportunities, reduction of costs, increased productivity and innovation capabilities and effective use of resources (Schroeder et al., 2019).

One of supporting disciplines of circular economy is orientation towards zero waste. The main focus of a zero-waste concept is to tackle waste issues (Zaman, 2014, 2015; Zaman & Lehmann, 2013) with avoidance and prevention of waste instead of application of waste treatment methods (Hamid et al., 2020). Zero waste programs are beneficial from financial, economic, social and environmental standpoints (Pietzsch et al., 2017; Roetman & Daniels, 2011). At social level, zero waste programs contribute to reduction of health dangers and have a positive impact on societal lifestyle. Environment can benefit from reduced waste flows and increased environmental control. At financial and economic levels, zero waste programs contribute to symbiosis of cost reduction and amplification of profits supported by enhanced productivity, ameliorated product or service design and boosted competitiveness.

However, successful implementation of zero waste programmes include potential execution challenges arising from the micro and macroenvironment (Pietzsch et al., 2017). Typical microenvironmental challenges include increased need of political support on waste management policies, bear societal behavioural change and education requirements, stipulate the need of tax reforms and raised R&D budgets to contribute to the development of waste management technologies. Microenvironmental difficulties are usually related to the questions arising at a company-level, where businesses face ambiguities in understanding technical solutions of reaching zero waste goals at reasonable costs, along with implementation of waste management solutions into practice and improvement of products or services.

Increasing amounts of waste globally and the relatively low rates of recycled and composed waste is receiving increased interest from the policy makers world-wide. Waste Framework Directive 2008/98/EC (European Union Law, 2008; Scarlat et al., 2019) issued by the European Commission lays the groundwork for basic waste management principles such as waste management practices which exclude harm to environment or human beings, includes "polluter pays" and "increased producer responsibility" principles. The Directive also provides common waste management hierarchy, where prevention of waste is considered to be non-waste, while preparation of waste for re-use, recycling, recovery and disposal are attributed to waste. On the other hand, academics (Chen et al., 2020) evaluated the trends in world's municipal waste flows and suggested that European Commission's circular economy targets may be effortful to reach by 2030 if more channelled policies will not be introduced.

Scientists, policy makers, governments stress the importance of the education of citizens towards zero waste practices – increase in knowledge will have a positive effect on waste generation patters. Circular economy and zero waste models also include education of society on waste management problems and ways of involvement into waste reduction as one of the elements of successful municipal waste reduction. Academics (Minelgaitė & Liobikienė, 2019) analysed the difference between the intention of citizens of the European Union to reuse, recycle and recover and the actual behaviour based on Eurobarometer survey "Attitudes of Europeans towards waste management and resource efficiency" and concluded that countries seeking to minimise the generation of waste, should put an emphasis on the promotion of sustainable consumption and production practices. Furthermore, the academics found that waste-reducing behaviour can be stimulated by the increase in knowledge of global waste problems and how citizens individually can make a change in terms of waste reduction. The study suggests that to enhance waste-reusing behaviour, improvement of the quality and life span of products practices should take place, whereas, to promote recycling behaviour, improved in recycling facilities should be implemented with an emphasis that the waste from these facilities is recycled in an effective manner.

2. Research methods

Waste flows and waste formation trends receive increased interest from the academic communities, governments, policy makers and the public. As a result of need to forecast waste to carry out adequate policies and directives along with understanding of future trends, academics suggest diverse ways of forecasting waste flows.

The forecasting methods used for different types of waste predictions include machine learning (Kontokosta et al., 2018), small area estimation (Kontokosta et al., 2018), artificial neural networks (Akgül et al., 2020; Cubillos, 2020; Hao et al., 2019), regression analysis (Ghinea et al., 2016; Davidavičiene et al., 2012; Pavlas et al., 2020; Wei et al., 2013), ARIMA (Buhl et al., 2020; Ghinea et al., 2016; Ghomi & Marandi, 2016; Mwenda et al., 2014), artificial intelligence (Abbasi & Hanandeh, 2016), multivariate grey models (Intharathirat et al., 2015), Holt's double Exponential Smoothing (Islam & Huda, 2019), Holt–Winters Exponential Smoothing (Wąsik & Chmielowski, 2016), Winters multiplicative methods (Denafas et al., 2014).

Among the variety of methods, academics also use Exponential Smoothing (Buhl et al., 2020; Denafas et al., 2014; Wąsik & Chmielowski, 2016) and observe that the method is suitable for forecasting waste. However, other researchers (Akgül et al., 2020; Mwenda et al., 2014) argue that other methods like ARIMA provide more robust forecasting results.

The aim of this paper is to propose the conceptual model for the forecasting of municipal waste flows based on the application of Exponential Smoothing and validate the accuracy of the proposed model based on the Lithuania's data. The methodology for the prediction of the municipal waste formation flow in Lithuania's regions is depicted in Figure 1. The actual data on municipal waste formation flows is collected at the Environmental Protection Agency's web page. The data is grouped to summarise country-level variables and the amounts dedicated for 10 regions of Lithuania – Alytus, Kaunas, Klaipėda, Marijampolė, Panevėžys, Šiauliai, Tauragė, Telšiai, Utena, Vilnius. Thus, calculation of Exponential Smoothing in MS Office Excel is carried out with corresponding statistical measures of forecast accuracy.

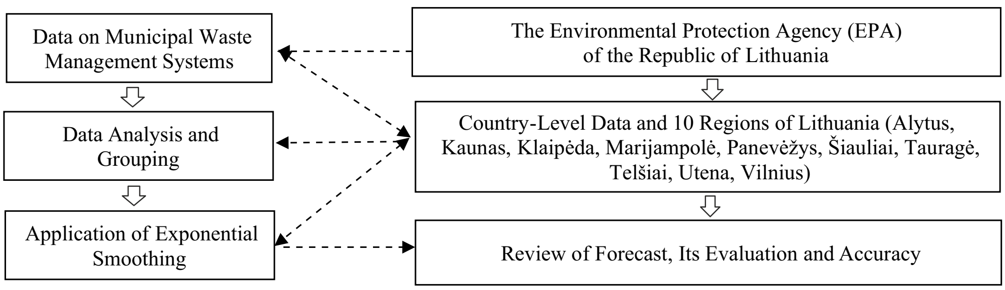

Figure 1. Conceptual model of forecasting waste
(source: compiled by authors)

Exponential Smoothing techniques have gained popularity among scientists and the business due to strong forecasting capabilities, reliable results and relatively straightforward application (Ariyanti et al., 2018; Cadenas et al., 2010; Corberán-Vallet et al., 2011; de Faria et al., 2009; Gardner, 2006; Snyder et al., 2004; J. Taylor, 2004; J. W. Taylor, 2003; Yager, 2013). The calculation of Exponential Smoothing is established on linear statistical models (Snyder et al., 2002), where the most recent actual values are assigned with more weights while former actual values receive decreasing weights (Ariyanti et al., 2018; de Oliveira & Cyrino Oliveira, 2018; Ferbar Tratar et al., 2016; Shim, 2009; J. Taylor, 2004). Therefore, Exponential Smoothing depends on the tree types of data: the latest actual data, the latest forecast, and a smoothing constant Alpha (Hoshmand, 2010; Ravinder, 2013), which varies from 0 to 1. When smoothing constant is close to 0, then the impact of smoothing is greater, and vice versa, when smoothing constant is close to 1, smoothing effect is weaker (Ariyanti et al., 2018).

Exponential Smoothing can be calculated using MS Office Excel Forecast Sheet option. Herein, forecast is created using Exponential Smoothing algorithm which is based on actual data. Forecasting of Exponential Smoothing using MS Office Excel Forecast Sheet option is relatively new concept among academics. This method was used to predict student absence (Dakhil et al., 2018), rainfall and ground water production of Deir El-Balah City in the Gaza Strip (Abuamra et al., 2020), salinity rates and levels of groundwater in Deir El-Balah (Abuamra et al., 2021), the number of COVID-19 cases in Chennai City (Ramasamy et al., 2020), analyse COVID-19 situation in Bengaluru (Ramasamy & Jayakumar, 2020).

3. Research results

The proposed conceptual model of forecasting waste provides predictions, denoted as F, of waste generation flows, waste treatment ways and waste composition (Table 1 and Table 2) for the year 2025 based on the actual country's data, denoted as A, based on the years 2018–2019 and depending on data availability. The results also include statical data of forecast accuracy such as Mean Absolute Scaled Error (MASE), Symmetric Mean Absolute Percentage Error (SMAPE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE) along with smoothing constants applied at Exponential Smoothing.

Results imply that the total waste generated in the country will be reduced by 1.36% at 2025 compared to 2019 (see Table 1). Waste treatment in landfill and waste burned without energy recovery will not take place. Forecast also shows increase in waste to energy, composed waste, processed waste and untreated waste amounts. MASE and SMAPE statistics indicate variations in accuracy of the forecast of waste generation flows is treatment ways, however, MAE and RMSE statistics indicate less robustness of the prediction.

According to the forecast (see Table 2), the considerable reduction in a composition of waste in Lithuania can be observed in green and wood waste, PET packaging, plastics, metals, glass, ceramics, concrete and stones. The increase in waste can be adhered to paper and paperboard, biodegradable food, textiles, other municipal biodegradable waste, combined packaging and other waste. MASE, SMAPE, MAE, RMSE indicate high prediction of the forecast.

The proposed conceptual model of forecasting waste provides predictions of waste generation flows, waste treatment ways and waste composition (Table 3 and Appendix), for the year 2025 based on the actual data of 10 regions of Lithuania. According to the forecast (see Table 3), the amount of waste will increase in four regions by 2025 – Alytus 22.60%, Kaunas 14.79%, Klaipėda 3.08%, Telšiai 31.74% increase. The decrease in generated waste can be observed in Marijampolė region (–67.86%), Panevėžys region (–39.71%), Šiauliai region (–19.53%), Tauragė region (–18.62%), Utena region (–16.91%), Vilnius region (–30.13%).

Statistics vary in the same manner on regional data. Prediction of waste generation flows on regional level shows variations in MASE and SMAPE indicating on reliability of the forecast, while MAE and RMSE statistics indicate less robustness of the prediction.

The results of the prognosis of waste composition and corresponding statistics of the 10 regions of Lithuania are depicted in Appendix. The research proposes that the highest reduction of paper and paperboard can be observed at Marijampolė region and increase in Klaipėda region. Green waste is going to be reduced in Tauragė region, while forecast of other regions shows increase in this type of waste. The highest decrease in wood waste is depicted in Panevėžys region, while the highest increase in Kaunas region. Other noticeable results – amounts of biodegradable foods will increase in seven regions, with slight reduction in Alytus, Vilnius and Utena. Also, metal waste reduces considerably except for Alytus and Klaipėda regions. Lastly, forecast proposes that Utena region will have reduced the amounts of green, wood, biodegradable waste, PET and combined packaging and ceramics, concrete and stones to a minimum. MASE, SMAPE, MAE, RMSE indicate high prediction of the forecast.

Table 1. Actual values, forecast and smoothing constants of waste generation flows and treatment ways of the Republic of Lithuania (source: compiled by authors)

Year	Generated municipal waste, tonnes	Waste removed in landfill, tonnes	Waste burned with energy recovery, tonnes	Waste burned without energy recovery, tonnes	Waste processed (with export for processing), tonnes	Waste composted, tonnes	Remaining untreated waste quantity due to temporary storage, tonnes
(A)	1318626	326161	179128	6	362745	289304	161288
(F)	1300682	0	338745	0	425853	634012	192090
Statistic							
Alpha	0.00	0.00	0.90	0.75	0.00	0.00	0.3
MASE	0.43	0.48	0.75	0.81	0.58	0.70	0.9
SMAPE	0.01	0.11	0.44	1.37	0.03	0.19	0.6
MAE	8951.66	48258.18	30903.29	250.40	8865.26	37351.86	35107.18
RMSE	13172.32	67187.71	44058.29	529.67	10936.69	45192.20	42898.99

Table 2. Actual values, forecast and smoothing constants of the waste composition of the Republic of Lithuania (source: compiled by authors)

Year	Paper and paperboard, avg. %	Green waste, avg. %	Wood, avg. %	Biodegradable food, avg. %	Textile, avg. %	Other municipal biodegradable waste, avg. %	Plastics, avg. %	PET packaging, avg. %	Combined packaging, avg. %	Metal, avg. %	Glass, avg. %	Ceramics, concrete, stones, avg. %	Other waste, avg. %
(A)	6.32	4.64	0.93	14.77	7.85	15.41	11.95	0.77	1.52	1.68	4.44	9.94	19.78
(F)	7.39	1.49	0.26	15.92	9.19	22.08	10.82	0.08	2.10	1.01	3.27	3.65	22.70
Statistic													
Alpha	0.25	0.25	0.13	0.25	0.10	0.25	0.10	0.25	0.25	0.10	0.25	0.10	0.10
MASE	0.69	0.74	0.46	0.71	0.49	0.77	0.47	0.76	0.58	0.48	0.55	0.36	0.31
SMAPE	0.04	0.13	0.14	0.05	0.02	0.10	0.03	0.27	0.19	0.05	0.05	0.07	0.01
MAE	0.28	0.66	0.12	0.72	0.13	1.45	0.32	0.21	0.22	0.08	0.24	0.81	0.14
RMSE	0.40	0.93	0.17	0.88	0.21	2.01	0.41	0.28	0.31	0.14	0.33	1.03	0.23

Table 3. Actual values, forecast and smoothing constants of waste generation flows and of the 10 regions of the Republic of Lithuania (source: compiled by authors)

Year	Alytus region, tonnes	Kaunas region, tonnes	Klaipėda region, tonnes	Marijampolė region, tonnes	Panevėžys region, tonnes	Šiauliai region, tonnes	Tauragė region, tonnes	Telšiai region, tonnes	Utena region, tonnes	Vilnius region, tonnes
(A)	72293	233878	145514	58557	79558	105115	38082	60605	45351	314732
(F)	88634	268476	149998	18823	47966	84590	30990	79845	37681	219909
Statistic										
Alpha	0.50	0.50	0.25	0.13	0.00	0.25	0.25	0.50	0.50	0.50
MASE	0.76	0.69	0.75	0.69	0.44	0.27	0.83	0.70	0.91	0.78
SMAPE	0.03	0.04	0.01	0.05	0.03	0.04	0.11	0.06	0.03	0.06
MAE	1732.02	9011.50	1576.50	3001.17	2237.92	4256.64	4315.27	3124.99	1271.49	19966.01
RMSE	2112.18	12408.42	1829.98	3925.01	3344.77	4988.16	5748.99	4123.95	1594.03	25575.17

Conclusions

Forecasting future waste trends play an important role in formation of waste management policies and planning of waste treatment ways. Among a variety of forecasting methods and techniques, it is important to distinguish methods applicable for waste prediction. The conceptual model of waste forecasting using Exponential Smoothing proposed in this research is empirically implemented on the country-level and regional data. Accuracy of the proposed conceptual model's results is evaluated and provides rationale that conceptual model is adequate for the prediction of waste trends.

The findings of the research show that total waste generated in the country will be reduced by 1.36% at 2025 compared to 2019. In 2025, the increase in waste in Lithuania can be attributed to paper and paperboard, biodegradable food, textiles, other municipal biodegradable waste, combined packaging and other waste. On a regional level, the amount of waste will increase in four regions by 2025 – Alytus, Kaunas, Klaipėda, Telšiai, wherease in other six regions, namely Marijampolė, Panevėžys, Šiauliai, Tauragė, Utena, Vilnius, amounts of waste are subject to decrease in 2025.

Supplementary analysis can be carried out to investigate the relationships between the trends of municipal waste flows and factors which have an effect on increase of decrease in waste. Results of such study would complement the policy and decision makers in selection process of waste control measures.

The further research can be extended by the application of statistical data on waste of other countries and cities to check adequacy of the conceptual model for waste-related trends prognosis. The conceptual model can be validated on the cities and corresponding countries depicted by Zero Waste Europe (Zero Waste Europe, 2020) as showing best zero waste practices implemented: Munich and Germany, Bruges and Belgium, Prelog and Croatia, etc. Also, conceptual model can be extended with application of other forecasting methods in order to increase the robustness of the forecast in combination with exponential Smoothing. Lastly, the conceptual model can be validated via application of other waste types, such as e-waste, in order to address the fastest-growing element of the world's domestic waste stream, according to the Global E-Waste Monitor Report (Forti et al., 2020).

Disclosure statement

The authors do not have any competing financial, professional, or personal interests from other parties.

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APPENDIX

Table A1. Actual values and the forecast of waste composition of the 10 regions of the Republic of Lithuania (source: compiled by authors)

Figures	Paper and paperboard, average %	Green waste, average %	Wood, average %	Biodegradable food, average %	Textile, average %	Other municipal biodegradable waste, average %	Plastics, average %	PET packaging, average %	Combined packaging, average %	Metal, average %	Glass, average %	Ceramics, concrete, stones, average %	Other waste, average %
Alytus region													
(A)	5.25	8.14	1.65	17.53	12.18	0.53	5.94	1.35	0.72	2.52	4.18	8.80	31.22
(F)	3.94	10.37	2.51	14.52	18.71	0.00	1.85	0.53	0.79	3.57	3.74	11.03	31.05
Kaunas region													
(A)	7.10	6.29	1.49	7.80	3.10	23.33	20.59	0.76	0.73	1.35	4.22	6.21	17.06
(F)	7.42	12.72	3.14	10.35	3.42	5.69	22.22	0.62	0.42	0.42	4.00	7.54	20.06
Klaipėda region													
(A)	10.00	2.35	1.00	9.82	6.33	0.00	16.74	0.48	0.70	3.29	6.32	26.43	16.57
(F)	15.58	0.00	0.69	11.07	7.66	0.00	23.77	0.21	0.87	6.12	8.19	8.56	23.90
Panevėžys region													
(A)	3.39	8.16	0.94	31.97	7.58	8.16	5.20	0.40	0.83	1.42	4.07	13.13	14.78
(F)	2.13	0.00	0.59	66.66	1.72	26.99	4.69	0.00	0.99	0.17	1.57	5.50	0.00
Šiauliai region													
(A)	6.49	6.71	0.97	21.75	8.47	0.66	21.35	0.47	0.53	1.44	3.69	16.51	10.97
(F)	6.40	8.80	0.00	29.22	10.62	1.60	25.06	0.00	0.21	0.00	2.71	2.86	17.36
Marijampolė region													
(A)	3.39	8.16	0.94	31.97	7.58	8.16	5.20	0.40	0.83	1.42	4.07	13.13	14.78
(F)	1.86	11.18	0.00	83.78	5.28	0.00	1.39	0.00	1.25	0.34	9.01	0.00	6.07
Vilnius region													
(A)	7.37	3.06	1.24	9.49	8.05	24.10	11.00	0.83	0.65	1.74	6.25	4.82	21.43
(F)	7.86	0.00	1.38	8.31	9.23	33.85	12.20	0.54	1.87	0.00	7.18	6.50	14.20
Tauragė region													
(A)	3.31	5.06	0.63	11.04	7.44	6.15	8.48	0.85	1.02	0.84	8.58	13.96	32.65
(F)	2.74	3.28	0.85	17.54	6.85	0.00	9.22	0.56	1.88	0.12	10.86	26.43	44.39
Utena region													
(A)	3.94	0.55	0.05	13.51	8.70	20.26	15.94	0.72	2.34	1.13	5.27	2.00	25.62
(F)	3.88	0.00	0.00	0.00	8.86	38.04	22.94	0.00	1.93	0.31	3.85	0.00	63.95
Telšiai region													
(A)	13.13	4.49	0.63	22.92	8.78	15.34	7.14	0.47	6.96	1.73	1.14	6.30	10.99
(F)	28.19	7.38	–1.84	29.17	17.37	12.62	–15.55	–0.71	9.77	2.59	–6.67	15.61	8.76

Table A2. Statistics and smoothing constants of waste composition of 10 regions of the Republic of Lithuania (source: compiled by authors)

Statistic	Paper and paperboard, avg. %	Green waste, avg. %	Wood, avg. %	Biodegradable food, avg. %	Textile, avg. %	Other municipal biodegradable waste, avg. %	Plastics, avg. %	PET packaging, avg. %	Combined packaging, avg. %	Metal, avg. %	Glass, avg. %	Ceramics, concrete, stones, avg. %	Other waste, avg. %
Alytus region													
Alpha	0.25	0.25	0.25	0.00	0.13	0.25	0.25	0.25	0.10	0.13	0.25	0.25	0.25
MASE	0.75	0.62	0.66	0.44	0.50	0.71	0.54	0.62	0.48	0.39	0.69	0.62	0.82
SMAPE	0.26	0.37	0.15	0.05	0.12	1.08	0.19	0.31	0.26	0.03	0.03	0.27	0.11
MAE	1.15	2.15	0.24	0.88	1.09	0.62	1.01	0.40	0.13	0.08	0.13	3.32	3.81
RMSE	1.40	3.00	0.36	1.25	1.54	0.78	1.27	0.59	0.22	0.10	0.16	4.13	4.72
Kaunas region													
Alpha	0.10	0.13	0.25	0.25	0.00	0.25	0.00	0.10	0.25	0.00	0.25	0.10	0.00
MASE	0.43	0.38	0.76	0.76	0.41	0.58	0.40	0.51	0.59	0.24	0.79	0.44	0.46

End of Table A2

Statistic	Paper and paperboard, avg. %	Green waste, avg. %	Wood, avg. %	Biodegradable food, avg. %	Textile, avg. %	Other municipal biodegradable waste, avg. %	Plastics, avg. %	PET packaging, avg. %	Combined packaging, avg. %	Metal, avg. %	Glass, avg. %	Ceramics, concrete, stones, avg. %	Other waste, avg. %
SMAPE	0.06	0.10	0.27	0.12	0.16	0.09	0.12	0.11	0.06	0.02	0.04	0.21	0.04
MAE	0.41	0.45	0.24	0.76	0.62	2.52	2.06	0.08	0.05	0.03	0.20	1.03	0.66
RMSE	0.56	0.63	0.29	0.93	0.82	3.22	2.51	0.13	0.06	0.06	0.24	1.66	0.81
Klaipėda region													
Alpha	0.10	0.10	0.00	0.10	0.00	–	0.25	0.25	0.10	0.10	0.10	0.25	0.25
MASE	0.62	0.33	0.42	0.38	0.38	–	0.63	0.42	0.44	0.32	0.59	0.64	0.45
SMAPE	0.12	0.15	0.39	0.01	0.05	–	0.16	0.04	0.08	0.09	0.04	0.09	0.06
MAE	1.14	0.59	0.27	0.09	0.31	–	2.65	0.02	0.06	0.18	0.22	2.64	0.83
RMSE	1.75	0.84	0.33	0.13	0.38	–	3.99	0.02	0.09	0.35	0.35	4.06	1.24
Panevėžys region													
Alpha	0.10	0.10	0.25	0.25	0.25	0.00	0.25	0.10	0.25	0.10	0.00	0.25	0.00
MASE	0.45	0.62	0.60	0.53	0.48	0.35	0.75	0.63	0.68	0.34	0.38	0.67	0.53
SMAPE	0.25	0.19	0.18	0.12	0.06	0.26	0.12	0.47	0.22	0.07	0.12	0.24	0.10
MAE	1.44	1.85	0.15	3.30	0.48	0.96	0.71	0.34	0.23	0.12	0.61	2.88	1.58
RMSE	2.58	2.82	0.18	4.00	0.60	1.14	0.89	0.51	0.28	0.23	0.74	3.48	1.88
Šiauliai region													
Alpha	0.25	0.25	0.10	0.00	0.10	0.10	0.10	0.10	0.25	0.10	0.10	0.10	0.10
MASE	0.76	0.73	0.21	0.46	0.37	0.33	0.56	0.63	0.71	0.15	0.45	0.52	0.45
SMAPE	0.03	0.33	0.05	0.05	0.03	0.13	0.09	0.46	0.13	0.02	0.08	0.06	0.04
MAE	0.19	1.52	0.06	1.09	0.21	0.05	2.10	0.27	0.07	0.04	0.36	1.09	0.40
RMSE	0.25	1.83	0.09	1.43	0.40	0.07	3.23	0.42	0.09	0.06	0.61	1.63	0.51
Marijampolė region													
Alpha	0.10	0.25	0.25	0.25	0.25	0.25	0.25	0.10	0.25	0.25	0.25	0.25	0.25
MASE	0.52	0.72	0.48	0.85	0.69	0.78	0.77	0.66	0.70	0.80	0.78	0.66	0.67
SMAPE	0.12	0.48	0.24	0.87	0.07	0.79	0.16	0.19	0.24	0.19	0.83	0.77	0.25
MAE	0.40	2.35	0.22	8.77	0.58	23.56	1.15	0.08	0.15	0.28	1.30	8.16	3.61
RMSE	0.69	2.85	0.28	10.67	0.72	28.55	1.40	0.13	0.18	0.36	1.57	9.88	5.16
Vilnius region													
Alpha	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.10	0.25	0.25	0.25
MASE	0.77	0.30	0.75	0.77	0.58	0.81	0.63	0.61	0.66	0.30	0.74	0.68	0.61
SMAPE	0.29	0.06	0.29	0.22	0.04	0.42	0.13	0.22	0.73	0.08	0.11	0.19	0.11
MAE	2.87	0.23	0.28	2.57	0.36	6.47	1.57	0.17	0.14	0.20	0.71	1.04	2.24
RMSE	3.49	0.28	0.35	3.22	0.44	7.83	1.94	0.26	0.17	0.29	0.87	1.25	2.71
Tauragė region													
Alpha	0.25	0.25	0.25	0.10	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
MASE	0.76	0.73	0.78	0.35	0.76	0.79	0.82	0.78	0.84	0.67	0.81	0.78	0.61
SMAPE	0.03	0.07	0.37	0.05	0.09	0.48	0.11	0.25	0.54	0.14	0.09	0.19	0.04
MAE	0.10	0.37	0.16	0.42	0.74	4.63	1.00	0.19	0.29	0.13	0.80	2.46	1.33
RMSE	0.15	0.54	0.19	0.64	0.93	6.57	1.25	0.23	0.35	0.16	1.04	3.28	2.01
Utena region													
Alpha	0.25	0.10	0.25	0.25	0.25	0.25	0.25	0.25	0.13	0.00	0.00	0.25	0.10
MASE	0.67	0.33	0.63	0.56	0.67	0.68	0.76	0.47	0.51	0.32	0.54	0.45	0.55
SMAPE	0.09	0.32	1.16	0.36	0.06	0.44	0.24	0.17	0.08	0.05	0.03	0.19	0.31
MAE	0.42	0.72	0.33	5.37	0.46	10.53	2.84	0.16	0.18	0.06	0.14	0.49	4.35
RMSE	0.51	1.10	0.43	6.48	0.56	14.74	3.48	0.19	0.25	0.08	0.17	0.59	5.80
Telšiai region													
Alpha	0.25	0.13	0.00	0.25	0.25	0.10	0.25	0.25	0.10	0.00	0.10	0.10	0.10
MASE	0.29	0.50	0.56	0.77	0.60	0.44	0.79	0.57	0.44	0.39	0.44	0.45	0.42
SMAPE	0.08	0.19	0.28	0.35	0.17	0.20	0.35	0.45	0.28	0.11	0.26	0.38	0.16
MAE	0.74	1.00	0.22	5.55	1.43	3.12	3.45	0.20	1.26	0.24	0.75	4.72	2.52
RMSE	0.91	1.37	0.27	6.69	1.73	4.17	4.91	0.24	2.25	0.39	1.14	7.25	4.92