A Forecast Model for Projecting the Amount of Hazardous Waste

J. Vilgerts, L. Timma, and D. Blumberga

***Abstract*—The objective of the paper is to develop the forecast model for the HW flows. The methodology of the research included 6 modules: historical data, assumptions, choose of indicators, data processing, and data analysis with STATGRAPHICS, and forecast models. The proposed methodology was validated for the case study for Latvia. Hypothesis on the changes in HW for time period of 2010-2020 have been developed and mathematically described with confidence level of 95.0% and 50.0%. Sensitivity analysis for the analyzed scenarios was done. The results show that the growth of GDP affects the total amount of HW in the country. The total amount of the HW is projected to be within the corridor of – 27.7% in the optimistic scenario up to +87.8% in the pessimistic scenario with confidence level of 50.0% for period of 2010-2020. The optimistic scenario has shown to be the least flexible to the changes in the GDP growth.**

***Keywords*—Forecast models, hazardous waste management, sustainable development, waste management indicators.**

I. INTRODUCTION

THE industrial and petrochemical revolutions, followed by exponential growth in population and consumerism, have increased the hazardous waste (HW) flows worldwide [1]. Such a rapid development has a negative footprint, resulting in serious problems of waste, also hazardous, disposal [2]. On the European Union level the amount of HW had increase by 46% within 8 year time (2000-2008). About 77 million tonnes of HW were produced in year 2009. Nevertheless, the increase in HW generation per capita is forecasted to grow further – from 154kg of HW per capita in 2009 up to 198 – in 2010 [3]. The report by the European Environmental Agency (EEA) states that targets on waste prevention defined within the 6th European Action Program (EAP) were not reached [4]. Thus the European Union works on sticker inspections, enforcement of the regulation and future legislative measures for the HW sector [3].

In the past researchers have shown that waste generation trends and economic activity are strongly related [5]-[8]. The report by EEA [4] states that depending on the type of waste analysed the amount of waste is stabilizing or continues to grow, but at lower rate than the gross domestic product (GDP). The 6th EAP defines that use of resources and waste

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generation should be decoupled from economic growth. The Directive 2008/98/EC on waste [9] sets the objectives for the proposed targets.

The relationship between the amount of HW and economic activity in countries and regions is pointed out in the report by the European Commission [3] and by Duan et al. [10] on situation in China. Nevertheless, few authors have been analysed particularly the HW flows dependence from the economic activity.

The research by Court [11] has been done on the relationship between industrial HW economy and economic activity. The author points out, that understanding of relations between the HW flows and economic activity should be studied in more detail and excelled in order to obtain desired results for HW management strategies. For the model Court [11] used the indicative value – specific generation of HW per output of industry. The results of the research showed that six out of the sixty-two industries generated around 98% of the total HW amount in the United States of America.

The forecast model for the HW flows has been performed by Sjöström and Östblom [5]. The forecast model was based on the Computable General Equilibrium model developed for the economy of Sweden by Sjöström and Östblom [12]. While the amount of non-hazardous waste showed decoupling for 11 out of 17 cases, the total amount of the HW was predicted to grow faster than GDP.

Third order regression model between the generation of industrial solid wastes and GDP per capita was developed by Yanrong, Cuili and Han [13] with $R^2 = 0.99$.

Economic performance still plays main role for the managing of construction and demolition waste in China has been reviewed by Wang et al. [14]. Development of cost effective waste management plan for construction and demolition waste was done by Yuan [15].

Lilja and Liukkonen [16] analysed the goals of the National Waste Plan of Finland. The authors concluded that no decoupling of HW generation form the economic activity was observed for time period of 1992 to 2005.

Based on the European Commission report [17] a weak quality of forecast made for waste sector in Latvia, have led to the inadequate capacity of waste management facilities. At the same time the forecasts on HW generation published within the Waste Management Plan for Latvia 2013-2020 [18] predicts the increase of 25 % from 2010 until 2010.

Therefore the objective of the paper is to develop the forecast model for the HW flows. The developed model is then applied for the case study of Latvia. The results from the

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model are compared to the forecast made within the Waste Management Plan for Latvia 2013-2020. The sensitivity analysis for the proposed scenarios is carried out.

II. HYPOTHESIS FOR CHANGES IN THE AMOUNTS OF HAZARDOUS WASTE

Until 2020 the total amount of HW in the country is projected to change. The scenarios can develop at least in three different ways:

1) Pessimistic scenario – the total amount of HW in country is increasing. The pessimistic scenario can develop in the various cases. For example, in case of development of utilities and companies with high intensity of HW production. Increase in production rate and in the amount of supplied services. In case of stricter legislation measures. The amount of HW can increase also with higher public awareness for need of proper HW waste management strategy. Expansion and development of new HW collection facilities will make collection of HW more accessible. Development within the HW classification and research on properties of various materials and substances can lead to new classes of HW. Technological development will also play role for HW increase, since better HW detection and extraction methods will be available.

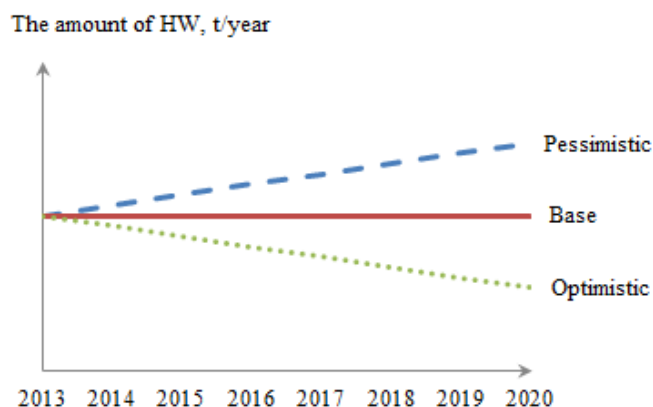Fig. 1 visually shows hypothesis for presented scenarios.

Fig. 1 The hypothesis for changes in the amount of HW

2) Optimistic scenario – the total amount of HW in country declines. The optimistic scenario can be triggered in various cases, by the same mechanisms already mentioned for the pessimistic scenario. For example, stricter legislation measures on HW can lead to situation when manufactured decides to substitute or reduce hazardous materials within the manufacturing process. Technological development can help to recycle HW more effectively or reuse hazardous substances within closed-loop manufacturing processes. Research on HW properties can lead to some new materials where HW is used as the raw material. Public awareness and increasing demand for consumer good without impact on the environment will force manufactures to supply the market with products, which does not contain hazardous materials. Enforcement of the legislation on cleaner production, integrated pollution control, ecodesign, etc. will reduce the amount of HW intensive processes, products and services. Last but not least, the increase of HW management costs will force, especially manufacturing sector, to reduce HW intensity.

3) Base scenario – the total amount of HW in country fluctuates around the constant value. The scenario is possible if pessimistic and optimistic cases are in the balance.

In reality variation of all three possible scenarios are possible.

III. METHODOLOGY

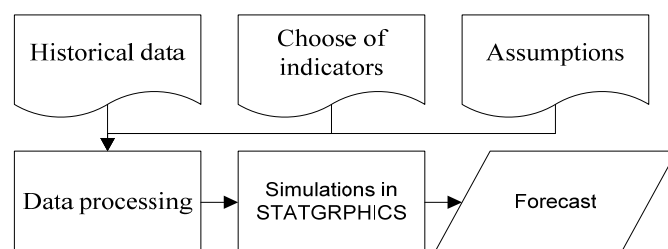The methodology consists of 6 modules; see Fig. 2

Fig. 2 The algorithm of the methodology [19]

The source of historical data is the State limited Liability Company "Latvia Environment, Geology and Meteorology Centre" database Nr.3-Waste [20]. The information available in the database is divided by sectors based on the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2) [21] classification. Choose of indicators are based on the literature review in the paper by Vilgerts, Timma and Blumberga [19].

The main assumption is that all HW flows are collected and properly managed. The amount of generated HW within NACE Rev. 2 sectors is subtracted from the total amount of HW and the difference is assumed to be generated by the households [19].

The data about the total amount of HW was divided by the amount of GDP for each individual sector and households, so the HW intensity indicators were obtained. The indicative values were calculated for the period of eight year (2003-2010) [19].

From the interactive statistical data analysis tool STATGRAPHICS Centurion 16.1.15 the forecast models were obtained. The confidence level of the models is set to 95.0%. 13 possible forecast models have been analysis [19]. For example, the simulation module has forecasted the future values of NACE Rev. 2 Sector C (manufacturing), to be expressed by an autoregressive integrated moving average (ARIMA) (1, 2, 1) model [19].

The general model of ARIMA is (p, d, q). Where p is

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number of non-seasonal autoregressive terms, d is non-seasonal differences, and q is lagged forecast errors in the prediction equation. The mathematical expression of ARIMA (1, 2, 1) is given in (1).

$$ARIMA\ (1,2,1) = \hat{Y}(t) = 2Y(t-1) + Y(t-2) + \\ + \phi[Y(t-1) - Y(t-2)] - \theta e(t-1) \tag{1}$$

where $\hat{Y}(t)$ is the result for the times series, ϕ is non-seasonal differencing and θ is non-seasonal lagged forecast error, and $(t-1)$ and $(t-2)$ are time periods. More detailed description of the methodology can be found in [19].

Further the GDP prognosis for Latvia are compared from various sources, including the International Monetary Fund [22], European Commission staff working document "Assessment of the 2012 national reform programme and convergence programme for Latvia" [23], Ministry of Economics, Republic of Latvia, Economic development of Latvia [24] and Waste Management Plan for Latvia 2013-2020 [18], see Table I.

TABLE I
PROGNOSIS OF GROSS DOMESTIC PRODUCT FOR LATVIA

Year	Source [22]	Source [23]	Source [24]	Source [18]	Taken for the model
2013	3.456	3.6	3.7	5.0	3.456
2014	4.155	4.0	3-5	5.0	4.155
2015	4.164	4.0	3-5	5.0	4.164
2016	4.014	-	3-5	5.0	4.014
2017	4.044	-	-	4.5	4.044
2018	-	-	-	4.5	4.000*
2019	-	-	-	4.0	4.000*
2020	-	-	-	4.0	4.000*

* Assumption

The GDP prognosis differs depending from the source, see Table I. The most optimistic prognosis of GDP increase is made by Latvian government. For the forecast model data from the International Monetary Fund are taken for time period 2013-2017. The GDP data for the period of 2018-2020 are assumed to be constant: + 4.0 %.

IV. RESULTS

The summary of the results from the forecast model and historical data on the amount of HW are given in Fig. 3.
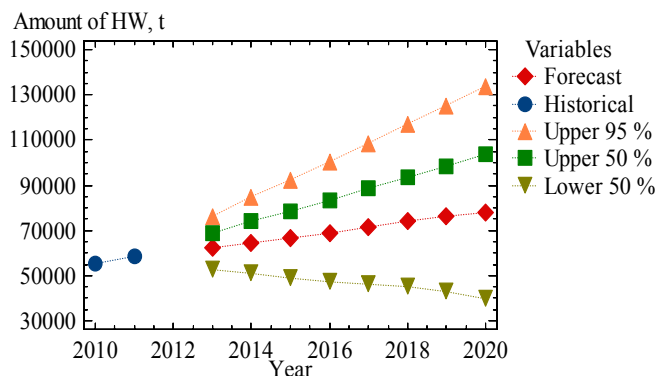

Fig. 3 The results from the forecast model and historical data for the HW amount

The total amount of the HW is projected to grow by 41.2% in the period of 2010-2020, which is higher increase than projected in the Waste Management Plan for Latvia 2013-2020. For the confidence level of lower 50.0% (see Fig. 3), which can be referred as the optimistic scenario (see Fig. 1), the amount of HW is projected to decrease by 27.7% from 2010 to 2020. For the confidence level of upper 50.0% (the pessimistic scenario) the increase of the amount of HW is 87.8%.

The sensitivity analysis of the GDP prognosis of the projected amount of the HW is shown in Fig. 4.
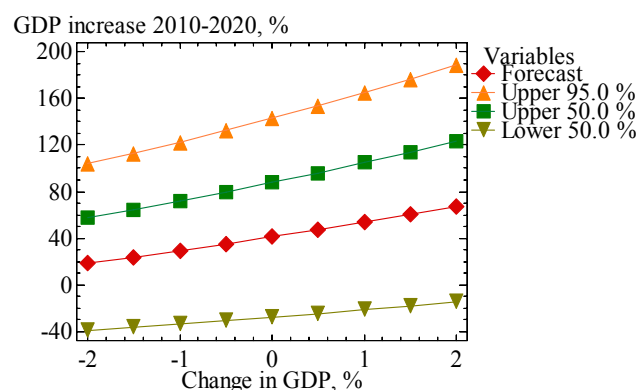

Fig. 4 Sensitivity analysis of the GDP prognosis on the projected HW amount

V. DISCUSSION

Economic and legislative developments within country are the main factors affecting the changes in the amount of HW. Nevertheless, vital role in the HW sector plays public awareness and participation in HW management system. The total amount of HW generated in households will change due to the better waste sorting and collection systems.

The highest influence of the GDP change on the amount of HW is observed for the forecast model with confidence level of upper 95.0% and upper 50.0%. The least flexible model to the change of GDP is obtained for the optimistic scenario (lower 50.0%).

The increasing amount of HW waste not always should be

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translated as negative tendency. Intensifying participation of households in HW management system, gives the example of the situation, when the increase of the total amount of HW cannot be directly classified as the harmful trend for the environment. Because the increase of HW from households can be referred to better HW collection systems, which lead to fewer hazardous substances gathered with municipal waste flows. For other sectors, for example small of medium sized manufactures, increasing amounts of HW can signal about the stricter enforcement of HW management legislation. The increasing potential of waste streams sorting can also increase the amount of HW.

In order to follow the optimistic scenario, following preconditions should be satisfied: the HW management system is restructured to be part of inside clean technology clusters, cleaner production measures are cost-effective solutions in comparison to the removal and storage of HW. Clean technology clusters are believed to encourage for HW utilization as the raw material for other processes.

VI. CONCLUSION

Economic development, in this case the growth of GDP, affects the total amount of HW in the country. The dependence of the amount of HW on the GDP values are identified and described by application of the developed forecast model.

In order to develop the forecast model, the methodology of 6 following modules: historical data, assumptions, choose of indicators, data processing, and data analysis has been applied.

The total amount of the HW is projected to be within the corridor of – 27.7% in the optimistic scenario up to +87.8% in the pessimistic scenario with confidence level of 50.0% for period of 2010-2020.

For the base scenario the increase in HW amount of 41.2% in the period of 2010-2020 is calculated with confidence level of 95.0%. The obtained projection for the base scenario is higher than the forecast given in the Waste Management Plan for Latvia 2013-2020.

The optimistic scenario has shown to be the least flexible to the changes in the GDP growth, since in optimistic case the HW intensity within country is declining.

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