STUDY OF CORRELATIONS OF STATISTICAL PARAMETERS WITH COLLECTED MUNICIPAL SOLID WASTE IN CROATIA IN PERIOD 2009-2013

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ABSTRACT

Croatia is currently increasing the recycling rates in order to meet the requirements of the European environmental policy, though the efforts do not result in target values. If striving for higher recycling rates, it is advisable to avoid higher environmental costs related to the introduction of changes in the relating methods and technology. This could be achieved through careful, knowledge-based planning and assessments. The complexity of the task to increase the recycling rates while avoiding an increase in the environmental costs becomes evident when one takes into consideration the heterogeneity of Croatia’s characteristics such as climate, terrain, and urban and rural population distribution. In addition, there are differences in the income, employment rate and economic activities dictated by the climate and terrain (tourism or agriculture).

In this paper, we research the MSW generation mechanism – how the country’s statistical parameters are correlated with generated MSW, enabling the prediction of the response in MSW generation to changes in country’s statistics. In addition, we inspect the correlations among the statistical parameters used in research.

Here presented study relies on county’s specific data, which enable the grouping of the counties by similarity and gives results better adjusted to counties’ specifics. Analysis groups are whole country, country without capital Zagreb, continental and coastal group of counties. The time scope of the analysis is five-year period 2009-2013.

Keywords: MSW, municipal solid waste, correlations, statistical analysis

1. INTRODUCTION

As a member of EU, Croatia is currently increasing the recycling rates in order to meet the requirements of the European environmental policy, though the efforts do not result in target values. If striving for higher recycling rates, it is advisable to avoid higher environmental costs related to the introduction of changes in the relating methods and technology. This could be achieved through careful, knowledge-based planning and assessments.

The complexity of the task to increase the recycling rates while avoiding an increase in the environmental costs becomes evident when one takes into consideration the heterogeneity of Croatia’s characteristics such as climate, terrain, and urban and rural population distribution. Croatia is dominated by two main climatic zones – the Mediterranean and the continental one, four types of terrain – coast, mountains, hills and plains [1], and a few highly-urbanized and densely populated areas, with rural areas being most often poorly populated and leaning on a number of small urban areas in their vicinity. In addition, there are differences in the income, employment rate and economic activities dictated by the climate and terrain (tourism or agriculture).

The objective to achieve higher waste recycling rates represents a burden for the government, which then puts pressure on waste collectors and households. Insufficient knowledge in the system and the urgency to achieve higher recycling rates could result in introduction of the solutions at hand and embracement of solutions that work in different conditions or, simply, in irrational investment that would burden the tax payers and the environment. For example, introduction of separate waste bins could be accompanied with the use of new trucks for separate waste collection or increased exploitation
of existing trucks and more driving (and fuel) and thus with higher costs for the utilities and consequently, for the households. Due to increased costs of waste management, households could require introduction of a new billing model with regard to waste collection, e.g. per quantity of produced waste, and abolition of the current billing model (per number of household members, regardless of the waste volume in the bin). If the “pay per quantity” principle is introduced and if it results in higher costs for households, the households could be tempted to lower the quantity of waste by disposing it differently (burning, disposal in the nature). Increased fuel consumption per ton of waste as well as increased emissions in the environment could diminish the benefits of increased recycling rates. Illegal dumping could potentially take place in poorly populated areas near riverbanks and the sea, which could lead to pollution of the natural environment, potable water and fisheries.

Having in mind the potential negative consequences of changes in the waste management system, the initial idea in the research was to identify the waste generation mechanisms, the main correlations with the country’s statistical parameters and to learn what the obtained data and deduced correlations would suggest. Part of the research presented herein was performed as a preparatory work in 2014 [2].

2. MATERIAL AND METHODS

To begin with, some assumptions are made. Municipal solid waste is generated in households and enterprises as a result of everyday human consumption (packages of various consumer goods, food waste etc.). The next assumption is that the quantity (volume) of municipal solid waste depends on the number of consumers, i.e. population. Everyday consumption and thus waste generation depend on a consumer’s financial status (consumers’ available money to spend) – more money available to spend, more waste is generated from increased consumption. In addition, on the waste generated the impact could have the consumers’ ability to produce their own food, to feed the domestic animals with food residue, and to compost with no especial efforts or costs. Considering those features, the authors regard households (total, with and without land) as an important indicator. The number of households without land in this context depicts urban population. In return, land-owning households are more related to suburban and rural areas. Another assumption is that land in use would as well reflect the possibility to make compost and hence produce less waste.

Regarding the financial ability of consumers, there are not sufficient data on how much money consumers spend on goods per year and county. However, it is assumed that the number of employees and their average monthly pay per county could reflect the income of the county and money available to spend. Those indicators helped us derive one indicator representing the total annual wages in a county. In popular tourist destinations, tourists also participate in everyday consumption, so it is important to include tourists in this research as well. As an indicator that would reflect not only tourist arrivals, but also the duration of their stay, we choose the nights spent at tourist accommodation (e.g. one tourist one day).

There is also an intention to inspect whether some facts, such as population density, road length, the number of towns, municipalities and populated places, can be used as indicators and whether they correlate with waste generation and diesel consumption.

Here is a short list of the indicators used in the research:

- number of towns, municipalities, populated areas,
- total number of inhabitants and number of inhabitants per area, also
- total length of roads and length of roads per area,
- agricultural land used,
- total number of households, with and without land,
- average monthly wages, number of employees and total annual income per county
- tourist nights per county.

The questions to which this research aims to respond are following:

- Which of the selected indicators strongly correlate with MSW generation?
- Do those properties correlate between each other?
- What is the nature of the calculated correlations with respect to the function graph (linear, non-linear)?
- Are there important differences in the MSW generation with respect to regional specificities?
- What general conclusions can be drawn from the analysis? What recommendations for the policy makers could be drawn from the analysis?

2.1. The sources of data
The sources of data are as follows:
- Croatian Environment Agency waste registry and reports: AZO (2009-2014) [17-22]
- Croatian Bureau of Statistics website (census data and annual reports: DZS 2010a-2014c) [23-40]
- County Road Administration

2.2. Data quality
The quality of the MSW data may vary due to the fact that the method of MSW quantity assessment varies between counties and companies. Some rely on weighting while others have no weighting devices and rely on estimates. The indicator ”nights spent at tourist accommodation” shows the number of registered guests. Yet, it is difficult to estimate how close that number is to the real number of guests and the time they spend at a certain destination; how many tourist arrivals and nights spent are not registered is also a dubious issue.

2.3. Statistical Analysis
The data processing in MS Excel and the analysis in StatSoft’s Statistica were conducted first. The detailed input tables are incorporated into Appendix A of the Study that will be available online after the conference (supplementary material).

After inspecting data and detecting some abnormalities in the distribution, the status without the abnormalities was examined. The first group (population of data) was named 21C, which is short for 21 counties, the total number of counties in Croatia. Considering the fact that the Zagreb County is in many aspects different from all the other counties (due to extreme population density and the fact that the city itself is a county, with no other towns, municipalities nor populated places), the former county was excluded from the second group which was named 20C (i.e. 20 counties). Further inspection of the data took us to structuring of two subgroups based on the variable ”tourist nights”. In the end, a correlation analysis was carried out. The table below (table 1) demonstrates the structure of the analysis.

The correlation analysis was conducted between all the variables and collected data. The idea behind this step was twofold: firstly, to inspect the relations between the variables as a preparatory action for regression analysis and secondly, to determine which variables correlate best with waste generation.

<table>
<thead>
<tr>
<th>Data set</th>
<th>Descriptive statistics / Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>21 counties (all)</td>
</tr>
<tr>
<td></td>
<td>Predictor variables</td>
</tr>
<tr>
<td></td>
<td>All predictor variables vs. MSW (2009-2013)</td>
</tr>
<tr>
<td>II</td>
<td>20 counties</td>
</tr>
<tr>
<td></td>
<td>Predictor variables</td>
</tr>
<tr>
<td></td>
<td>All predictor variables vs. MSW (2009-2013)</td>
</tr>
<tr>
<td>III</td>
<td>Group 1 (Continental)</td>
</tr>
<tr>
<td></td>
<td>Predictor variables</td>
</tr>
<tr>
<td></td>
<td>All predictor variables vs. MSW (2009-2013)</td>
</tr>
<tr>
<td>IV</td>
<td>Group 2 (Coastal)</td>
</tr>
<tr>
<td></td>
<td>Predictor variables</td>
</tr>
<tr>
<td></td>
<td>All predictor variables vs. MSW (2009-2013)</td>
</tr>
</tbody>
</table>

3. RESULTS

3.1. Correlation Coefficients
This chapter provides the results of the correlation analysis at the 95 % confidence level (p<0.05).
Table 2 presents the correlation result for the MSW collected in four analysis groups, sorted in descending order per strength and confidence level of a correlation coefficient. Fig. 3-1 discloses the correlation coefficient results at the p<0.05 confidence level. In supplementary material, Appendix B includes the scatterplots for visual inspection of the correlations whereas Appendix C involves a table of all correlations, including those between the predictor variables for each analysed group.

Table 2. Correlations of the variables with the MSW (t) generation ranked per absolute value (strength) of correlation factor r (correlations at the >95% confidence level are marked red)

<table>
<thead>
<tr>
<th>Variables (Units)</th>
<th>21 County</th>
<th>20 Counties</th>
<th>Continental</th>
<th>Coastal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>0.94</td>
<td>0.90</td>
<td>0.80</td>
<td>0.99</td>
</tr>
<tr>
<td>Households without land</td>
<td>0.94</td>
<td>0.89</td>
<td>0.79</td>
<td>0.99</td>
</tr>
<tr>
<td>Population registered</td>
<td>0.94</td>
<td>0.88</td>
<td>0.75</td>
<td>0.98</td>
</tr>
<tr>
<td>Population</td>
<td>0.94</td>
<td>0.87</td>
<td>0.72</td>
<td>0.97</td>
</tr>
<tr>
<td>Employees in legal entities</td>
<td>0.90</td>
<td>0.86</td>
<td>0.72</td>
<td>0.96</td>
</tr>
<tr>
<td>Annual income (Mil. HRK)</td>
<td>0.88</td>
<td>0.85</td>
<td>0.71</td>
<td>0.95</td>
</tr>
<tr>
<td>Roads (km)</td>
<td>0.86</td>
<td>0.85</td>
<td>0.68</td>
<td>0.94</td>
</tr>
<tr>
<td>Net wages (HRK), monthly</td>
<td>0.77</td>
<td>0.70</td>
<td>0.66</td>
<td>0.93</td>
</tr>
<tr>
<td>Population per km²</td>
<td>0.75</td>
<td>0.68</td>
<td>0.58</td>
<td>0.89</td>
</tr>
<tr>
<td>Land owning households</td>
<td>0.43</td>
<td>0.63</td>
<td>0.51</td>
<td>0.89</td>
</tr>
<tr>
<td>Tourist nights (x1000)</td>
<td>0.40</td>
<td>0.55</td>
<td>0.49</td>
<td>0.69</td>
</tr>
<tr>
<td>Towns</td>
<td>0.31</td>
<td>0.52</td>
<td>0.42</td>
<td>0.57</td>
</tr>
<tr>
<td>Used agricultural land (ha)</td>
<td>0.22</td>
<td>0.47</td>
<td>0.40</td>
<td>0.47</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>0.06</td>
<td>0.34</td>
<td>0.32</td>
<td>0.43</td>
</tr>
<tr>
<td>Populated area</td>
<td>-0.02</td>
<td>0.12</td>
<td>-0.12</td>
<td>0.13</td>
</tr>
</tbody>
</table>

In four analysed groups the “MSW generated” have shown correlations characterized by the >95% confidence level in the following way:
- In group 21C: with all variables except the municipalities, populated area and area; specifically, with: population, population density, roads, households, households without land, land owning households, used agricultural land (negative), population registered, employees in legal entities, net wages, annual income, tourist nights)
In group 20C: with all variables except the population density and used agricultural land (towns, municipalities, populated area, area, population, roads, households, households without land, land owning households, population registered, employees in legal entities, net wages, annual income, tourist nights)

In group continental counties: with all variables except the population density and tourist nights (towns, municipalities, populated area, area, population, roads, households, households without land, land owning households, used agricultural land, population registered, employees in legal entities, net wages, annual income)

In group coastal counties: with all variables except the area and net wages (towns, municipalities, populated area, population, population density, roads, households, households without land, land owning households, used agricultural land, population registered, employees in legal entities, annual income, tourist nights)

Figure 1. Correlation coefficients at p<0.05 for Municipal solid waste

4. DISCUSSION
This chapter encompasses comments and a discussion about the results presented in the previous chapter.

4.1. Specificities of analysed groups with respect to input data
When reviewing the 2011 census data for groups 21 C and 20C as well as for subgroups continental counties and coastal counties, one can observe some differences which are especially evident with
respect to the subgroups. Continental counties are generally smaller in size (area) and accordingly, inferior regarding the total road length and population. However, these counties are featured by more kilometres of roads per area as well as by higher population density than coastal counties. The former counties include much more land-owning households and more agricultural land in use than the latter counties do.

Population increase equivalent shows in some coastal counties, the resident population increase equivalent exceeding 50,000 or as much as 25% of the resident population. However, the season is at its peak in summer months (from June to the end of August), i.e. one quarter of the year, resulting in a fourfold 25% resident population increase, roughly a 100% population increase in summer months. Having in mind the aforementioned and considering the year-over-year increasing tourism activity, one can imagine how challenging can be to dimension the collection and waste management system, to meet the demand for service and to operate efficiently through both extremes of MSW generation. In terms of MSW collected (Appendix A), while in continental counties, this parameter ranges from 170 to 420 kg per capita, coastal counties collect from 400 to 620 kg of municipal waste per capita – and that is the annual average. At the peak of the season, this value is higher, while out of the peak season, it drops almost to the Croatian average (20 C).

4.2. Differences in strength of correlations in analysed groups

Analysing the strength of correlations in different groups, the 21 county group have shown strong positive correlations of the MSW collected with: population, population density, roads, households, households without land, employees, average monthly wages and annual income. In the 20 county group, in perspective comes another strong positive correlation – correlation with the number of towns. In the subgroups the results differ a bit. The continental counties subgroup is characterized by a strong positive correlation of the MSW generation with the area of the county, population, households, households without land and annual income, while in the coastal counties subgroup, there is a correlation with the following variables: towns, municipalities, population, population per area, households, households without land, land owning households, employees and annual income.

Regarding the positive and medium correlations in the 21 county group, the MSW generation correlates with the towns, land owning households and tourist nights. What is typical for the 20 county group is a correlation of the MSW generation with the municipalities and populated area number, area of the county, roads, land owning households, net wages and tourist nights. The continental subgroup is featured by a medium positive correlation with almost every variable category, excluding those with a high correlation coefficient mentioned hereinabove as well as the population density and tourist nights which disclose no significant correlation with the MSW generation. The coastal counties subgroup has revealed a medium positive correlation of the MSW generation with the populated area, roads, used agricultural land, and tourist nights.

The MSW generation has shown a weak negative correlation with used agricultural land in the 21 counties group.

4.3. Similarities and differences of the analysed groups in light of calculated correlations

The MSW generation positively correlates with the number of towns in all four analysis groups, meaning – more towns more MSW.

The correlations of the MSW generation with the variables ’’municipalities’’ and ’’populated areas’’ are positive in three groups while the Zagreb County was eliminated from the analysis. It is logical to expect a positive correlation of the MSW generation with the number of places to live. There is a positive correlation of the MSW generation with the size of a county in the 20 counties and continental counties groups.

In all four groups, there is a positive correlation of the MSW generation with the population variable, but a correlation with the population density exists only in the 20 counties and coastal counties groups. With respect to roads and the correlation of their length with the MSW generation, there is a positive correlation in all groups, but a specifically strong correlation has been detected in group 21C and it is due to the city of Zagreb which has already been identified as an extreme in our set of data.
The MSW generation positively correlates with the variables ’’households’’ and ’’households without land’’ in all groups. The same applies to households with land, though the respective correlation is medium, except in the coastal part where it remains strong. The correlation of the MSW generation and the used agricultural land variable is negative in the 21 county group. In the 20 counties group, no such correlation exists. Concerning the continental and coastal counties subgroups, there is a correlation between the above variables and it is positive. To find out why it is so, requires further research.

“Population registered” was more precise than the population number taken from Census 2011. However, there were no significant changes in population due to proximity of census, and the correlations were similar as for the population indicator. The variables ’’employees in legal entities’’ and ’’annual income’’ correlate with the MSW generation in all groups. However, there is no correlation with net wages in the coastal group. The MSW generation correlates with tourist nights in all groups except in the continental counties group where this activity is minor.

4.4. Waste Generation Mechanism
The obvious assumption that the quantity (mass) of municipal solid waste depends on the number of consumers, i.e. population, has been confirmed. However, both the number of households and the number of households without land have shown a solid correlation with waste generation, which is in some groups more evident than the one with the population. The quantity of waste generated per household could be tolerable to small differences in number of persons per household. In such cases, it could be deemed true that the quantity of waste correlates better with available bins (space) and the frequency of waste collection than with the number of consumers/waste producers. Of course, there is a certain minimum quantity of MSW produced per person or household, but it could be interesting to define this quantity and to examine how the quantity of waste correlates with the size of bins and the frequency of waste collection.

Everyday consumption and thus waste generation depend on a consumer’s financial status, but at the same time they also depend on whether waste producers-households produce their own food or not, if they have animals to feed with food residue and if they are able to convert their waste into compost with no especial efforts or incurred costs. Our results have shown that households without land correlate with MSW generation very strongly, much stronger than households with land (land owners).

The size of owned land is ignored on purpose. It is because composting and food growing for personal use, to our knowledge, do not require much space. What is also avoided is the deception that the land of all landowners is located in the proximity of their homes and that they use it for everyday food production and consumption. It could be of further interest to research how the proximity of land and its size per household correlate with MSW generation.

The size of agricultural land used per county is incorporated in the research and although it has been established that the size of land used negatively correlates with waste generation, the intensity of the correlation is weak and not always at a high confidence level. This indicator should be expressed in a better way, e.g. relatively to other input variables, or by means of a percentage. However, we can agree that the land owning households and households without land indicators are better presenting whether the population grows food or buys food predominantly. Those indicators could be used as predictors of increased waste generation in households in situations in which food production does not meet the expectations due to flood, drought, plant disease or other catastrophes.

Regarding the financial status of consumers, there are no sufficient data on how much money consumers spend on goods by year and by county. Nevertheless, it is assumed that this variable depends mainly on the number of employees and their average monthly pay. Those indicators have helped us derive one indicator representing the total annual wages in a county. The results have shown that our assumption is correct, that more employees and more money available for everyday consumption per county lead to more waste per county. That could be related to the fact that the employment rate is higher in towns, i.e. that employees primarily represent urban population (no land owning), and that employees have less time to grow food. However, in the event of additional income and waste generation elements (such as tourists and the tourism industry), the average wage is not a good indicator of the consumption rate.
Tourist nights spent (nights spent at tourist accommodation) have turned out to be a good indicator. Still, more information would be useful in this light. It would be very beneficial if for the analysed timeframe, there were information on household-related waste and tourism-related waste respectively. However, we should not ignore the fact that in continental counties with an extremely low touristic activity, an average person generates approximately 200 kg of MSW annually while in coastal counties, the annual volume of MSW per capita exceeds 500 kg.

Regarding other variables (such as population density, total road length, number of towns, municipalities and populated places), which have undergone our analysis with no special expectations; the variable ’roads’ seems to correlate with MSW generation surprisingly well. It is maybe because this variable correlates well with other indicators of urbanisation and development. The variable ’towns’ correlates better with MSW generation than the variable ’populated places (villages)’, which is no surprise and confirms our assumption on the MSW generation mechanism.

4.5. Implications and suggestions
Our results suggest that in Continental Croatia, it would be worthwhile to study the collection of MSW free of organic matter from households with land. With proper preparatory action, such a collection policy could be probably implemented. The waste free of biodegradable matter is easy to separate in a recycling centre. It would be useful to calculate whether the environmental costs and funds invested in the waste separation in recycling centres is more favourable than separate collection of MSW components in the context of large road infrastructure and low population density.

In Coastal Croatia, there could be a problem with waste management due to a large volume of MSW collected, which could result, in some circumstances, with pollution of the natural and human environment. Year to year increasing tourism activity accompanied with annual peaks in waste generation would require appropriate response in waste management system. It would be worthy to consider some advanced technological solutions in terms of transport, but also in terms of waste recycling and treatment.

5. CONCLUSION
The variables that strongly correlate with MSW generation at the country level are households (total and without land) and population (0.94). They are followed by employees (0.90), annual income (0.88), roads (0.86), net wages (0.77), population per area (0.75), land-owning households (0.43), tourist nights (0.40) and towns (0.31). All those variables have revealed a positive correlation with MSW generation, and consequently, those characterized by the strongest correlation have the biggest impact on MSW generation.

Used agricultural land (-0.22) is the only variable in this group that has disclosed a negative correlation with MSW generation. This correlation is weak and explains why the intensity of the correlation of land-owning households with MSW generation is lower than the one referring to households without land. Financial status (ie. employment, wages, and annual income) positively correlates with MSW generation. A higher employment rate positively correlates with towns and households without land, implying that urban population generates more waste than people living in rural areas do. Wages and employment do not represent a very good indicator of financial status if there are other sources of income.

With respect to geographical differences and regional specificities, the counties in the proximity of the Adriatic Sea generate more waste than the other counties do. The reason for that refers, for the most part, to tourism and life in urban areas. The increasing tourism activity in that part of Croatia is expected to further increase the work volume of waste collectors and complicate the waste management system and achievement of balanced operation throughout the whole year. It would be worthy to consider some advanced technological solutions in terms of transport, but also in terms of waste recycling and treatment.

It would be useful to calculate whether the environmental costs and funds invested in the waste separation in recycling centres is more favourable than separate collection of MSW components in the context of large road infrastructure and low population density.
Acknowledgements
This research has not been funded by any entity belonging to the public, commercial, or not-for-profit sectors. We give thanks to the Croatian Environmental Protection Agency for the provided Excel files on waste collection.

6. REFERENCES


