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## **DYNAMICS OF THE NUMBER OF DUST-CARTS GROWTH IN UKRAINE**

*In the period of 2014 – 2020 the growth of the dust-carts fleet in Ukraine was 14 %. Determination of the regression dependence, describing the dynamics of the number of dust-carts growth in Ukraine is an important scientific-technical problem.*

*Objective of the study is determination of the regression dependence, describing the dynamics of the dust-carts growth in Ukraine and can be used for the prediction of the amount of the dust-carts. In the process of the study the method of regression analysis of the results of single-factor experiments and other paired dependences with the selection of the rational type of function from the sixteen most widely used variants by the criterion of the maximum value of the correlation coefficient has been used. Regression was performed on the base of the linearizing transformations, which enable to reduce the non-linear dependence to linear one. Determination of the coefficients of the regression equations was carried out, applying the method of the least squares by means of the developed computer program "RegAnaliz", protected by the Certificate of the State registration of the rights to the copyright object.*

*Adequate regression arch-tangential dependence, describing the dynamics of dust-carts quantity growth in Ukraine has been obtained, it can be used for the prediction of the number of dust-carts. Graphic dependence, describing the dynamics of the dust-carts number increase in Ukraine, allows to illustrate this dynamics and show the sufficient convergence of the theoretical results with actual data has been constructed. Using the obtained dependence, it is predicted that the number of the dust-carts in Ukraine, taking into account the existing rate of growth will reach 3873 units in 2030.*

**Key words:** *dust-cart, solid municipal waste, growth, dynamics, regression analysis, regression dependence.*

### **Introduction**

Unlike solid industrial waste, that can be recycled [1 – 5], solid municipal waste (SMW) in Ukraine are mainly buried at the landfills and dumpsite, polluting the environment, only minor portion of the waste is recycled and reused [6]. For the collection and transporting SMW to the places of further management the rigid body dust-carts are used in Ukraine, their total number is more than 3800 units, they are able to compact SMW, reducing the cost of the transportation and decreasing the area of the landfills [7]. In order to decrease the rate of the areas, needed for the SMW landfills, the waste is to be primary recycled during the loading into the dump-cart by means of compaction [8], dehydration [9] and grinding [10]. In the period of 2014 – 2020 the number of dust-carts in the municipal enterprises of Ukraine increased by 14 %.

### **Problem set up**

In the Law of Ukraine of February 28 2019 № 2697-VIII “On main strategy of state ecological policy of Ukraine for the period up to 2030” among the tasks of the strategy the return in the economic turnover the resource-valuable materials is indicated, also it is planned to 2030 to reduce up to 35 % of the total volume of the waste the share of the buried waste [11]. According to the Decree of the Cabinet of Ministers of Ukraine № 265 the provision of the usage of modern high efficient dust-carts is indicated among the priority directions of SMW management in Ukraine [12]. That is why, the determination of the regression dependence, describing the dynamics of the dust-carts growth in Ukraine, and can be used for the prediction of the amount of the dust-carts is actual scientific-technological task.

### Analysis of the recent studies and publications

For attaining the goal of the marketing research, aimed at determining the possibilities of the application of the marketing elements for the solution of the business-ecological problems of the Ukrainian regions on the example of the solution of the problem dealing with the disposal of SMW, carried out in the study [13], it is necessary, in particular, increase the number of the dust-carts, containers, employees at the enterprise, etc.

The paper [14] considers in existing methods of the dust-carts operation organization and walking accessibility to the primary collection points [PCP], classification of the dust-carts for further determination and analysis of the functional zones of PCP at different methods of SMW disposal. The author underlines that each municipal enterprise has own dust-carts fleet for servicing the territory, that is why, locating PCP the enterprise proceeds from technical characteristics and operating zone of the available dust-carts, neglecting in greater part of cases, requirements of the norms and creating discomfort environment for living. The technique of the operation process calculation when the body of the dust-cart is completely loaded, is provided. It is established that the needed number of the dust-carts depends on the volume of the transported solid municipal waste (SMW), frequency of the transportation and efficiency of the transport vehicle. The efficiency of the special transport vehicles operation is influenced by the method of loading and unloading of SMW, number of the serviced PCP, distance to the object of SMW disposal and operation speed of the transport vehicle. According to the rules [15] the following data are taken into account determining the needed quantity of the transport vehicles: information regarding the actual development of housing facilities and enterprises of non-production sphere, technical state of the motor vehicles, distance to the object of SMW disposal and other local conditions of the specific settlement.

In [16 – 18], applying regression analysis the dynamics of the dust-carts wear in Khmelnytskyi, Vinnytsia and Zhytomyr Regions of Ukraine was studied. Reduction of the dust-carts wear is explained by the purchase by the municipal enterprises new dust-carts, timely repair, replacement and restoration of their parts and units, removal out of operation the outdated models of the dust-carts and those vehicles which are beyond repair and restoration [17].

Among the basic components of the dust-carts with the lateral mode of loading of SMW the shortest service time (error-free running time) according to the studies [19] has the hydraulic system that promotes the increased wear of the dust-cart. According to the results of the observations, published by the author of the study [20], the structure and most frequent reasons of failures of the dust-cart hydraulic equipment is determined: hydraulic cylinders – 34.92 % (wear of collars, sealings, rod; breaking of the nut fixing piston to the rod; bending of the rod; mechanical damages), hydraulic pump – 16.40 % (pump body wear, gear wear, gland pressing out, body fractions), pipelines, hoses, pipes – 15.34 % (hoses breakage, pipelines wear), hydro distributors – 13.23 %, (sealing wear, gate valves wear; body fractions).

In the paper [21] it was established that electronic telematic navigation-monitoring motor vehicle control systems in the process of operation on the route allow to control the machine operation automatically and provide smooth motion of the levers, decrease their jerks and vibration during the unloading of the containers with SMW. These jerks and vibration realize negative impact on the motor vehicle. As a result of decreasing the negative impact the service life of the body and chassis increases and their wear decreases.

The studies [22 – 27] contain statistical data regarding SMW management in Ukraine, in particular, the increase of the number of the dust-carts in 2014 – 2020. However, as a result of the analysis of the known publications the author did not reveal any specific mathematical dependences, describing the dynamics of the number of dust-carts growth in Ukraine.

### Objective and tasks of the paper

**Objective of the given paper** is construction by means of the regression analysis the regression

dependence, describing the dynamics of the dust-carts number growth in Ukraine and can be used for the prediction of the number of the dust-carts.

### Methods and materials

For the determination of the regression dependence, describing the dynamics of dust-carts number increase in Ukraine, the following methods were used: regression analysis of the results of single-factor experiments and other paired dependences, computer simulation.

### Results of the studies

Table 1 shows the dynamics of the dust-carts number increase in Ukraine [22 – 27] in 2014 - 2020. On the base of the data of the Table 1 it was planned to obtain paired regression dependence, describing the dynamics of the dust-carts number increase in Ukraine. As the argument of the regression dependence is a year, the order of the values of which exceeds three times the order of the width of its change range, then in order to improve the accuracy of the regression dependence it is suggested to take the year preceding the start of the studied range ( $x = t - 2013$ ) as the beginning of the coordinates.

Table 1

**Number of dust-carts in Ukraine, units, in different years [22 – 27]**

Year	2014	2015	2016	2017	2019	2020
Number of dust -carts in Ukraine, units	3383	3405	3496	3795	3854	3862

Regression was performed on the base of the linearizing transformations, which enable to reduce the non-linear dependence into linear one. Determination of the coefficients of the regression equations was performed, applying the least square method by means of the developed computer program "RegAnaliz" [28], protected by the Certificate of the State Registration of the rights to the copyright object and is described in details in [29, 30].

Program "RegAnaliz" enables to perform regression analysis of the results of single factor experiments and other paired dependences with the selection of the rational type of function from sixteen most widely spread variants by the criterion of the maximum correlation coefficient and saving the results in MS Excel and Bitmap format.

Results of regression analysis are shown in Table 2, where the cells with maximum values of correlation coefficient  $R$  are marked with grey color.

Table 2

**Results of regression analysis of the dynamics of the dust-carts number increase in Ukraine**

№	Type of regression	Correlation coefficient R	№	Type of regression	Correlation coefficient R
1	$y = a + bx$	0,93430	9	$y = ax^b$	0,91980
2	$y = 1 / (a + bx)$	0,93277	10	$y = a + b \cdot \lg x$	0,91814
3	$y = a + b / x$	0,81234	11	$y = a + b \cdot \ln x$	0,91814
4	$y = x / (a + bx)$	0,99917	12	$y = a / (b + x)$	0,93277
5	$y = ab^x$	0,93354	13	$y = ax / (b + x)$	0,81982
6	$y = ae^{bx}$	0,93354	14	$y = ae^{b/x}$	0,81606
7	$y = a \cdot 10^{bx}$	0,93354	15	$y = a \cdot 10^{b/x}$	0,81606
8	$y = 1 / (a + be^{-x})$	0,78167	16	$y = a + bx^n$	0,88544
17	$y = a \cdot \arctg(bx+c)+d$	0,99999			

Thus, according to the results of the regression analysis, on the base of the data of Table 1, the following regression dependence is assumed to be the most adequate:

$$n_{CB} = 165,2 \arctg[2,726(t - 2013) - 9,087] + 3618 \quad [\text{units}], \quad (1)$$

where  $n_{nd}$  – is the number of the dust-carts in Ukraine, units;  $t$  – is the year.

Fig. 1 shows the actual and theoretical graphic dependence, describing the dynamics of the dust-carts number increase in Ukraine.

Comparison of the actual and theoretical data showed that theoretical dynamics of the dust -carts number increase in Ukraine, calculated by means of regression equation (1), does not differ from the data, presented in the studies [22 – 27], this proves the sufficient accuracy of the obtained dependence.

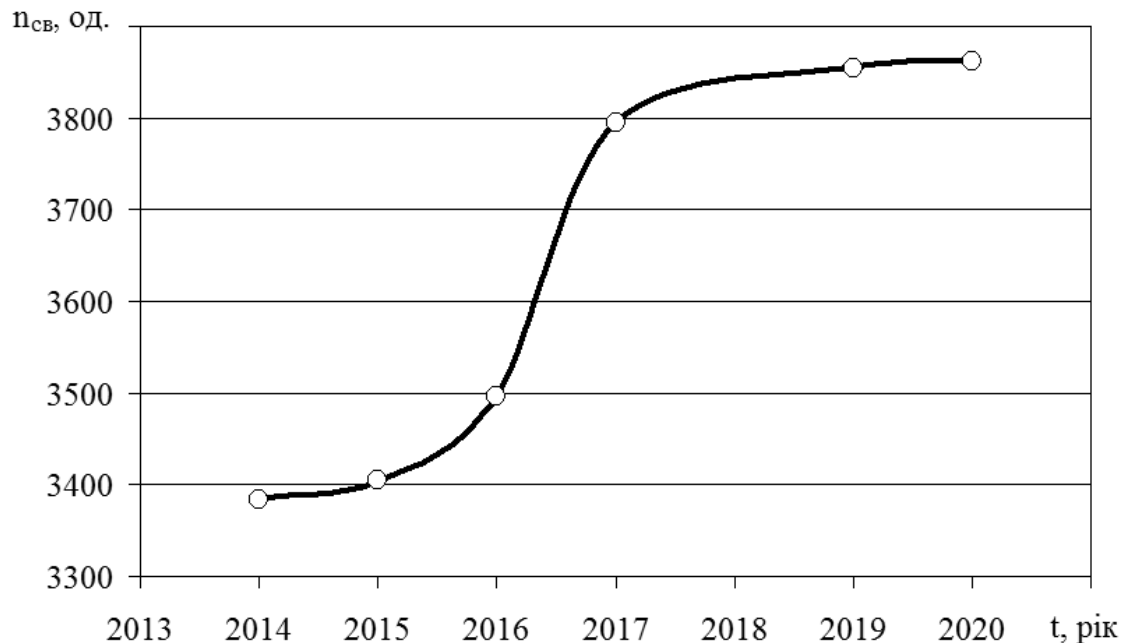


Fig. 1. Dependence, describing the dynamics of the dust-carts number increase in Ukraine during 2014 – 2020 : actual  $\circ$ , theoretical —

Using the dependence (1), it can be predicted that the dust-carts number in Ukraine will increase up to 3873 units in 2030 at the existing rate of growth.

### Conclusions

1. Regression dependence, describing the dynamics of dust-carts quantity increase in Ukraine is determined, the given regression can be used in the process of the dust-carts quantity prediction.
2. Graphic dependence, describing the dynamics of the dust-carts quantity increase in Ukraine is constructed, it enables to illustrate the given dynamics and show the sufficient convergence of the theoretical and actual results.
3. It is established that the number of the dust-carts in Ukraine in the period of 2014 – 2020 increased in accordance with inverse tangent dependence.
4. It is predicted that the number of the dust-carts in Ukraine at the existing rate of growth in 2030 will reach 3873 units.

### REFERENCES

1. Lemishko K. K. Usage of the industrial waste of energy and chemical branches of industry in the technology of the construction materials production / K. K. Lemishko, M. Yu. Stadnychuk, M. S. Lemeshev // Materials of scientific-practical conference “Energy. Business. Comfort”, 26 December, 2018 – Odessa : ONAFT, 2019. – P. 23 – 25. (Ukr).
2. Lemeshev M. S. Binding materials, using the industrial waste of Vinnytsia Region / M. S. Lemeshev // Abstracts of the reports at XXIV International scientific-practical conference “Information technologies: science, engineering, education health”, Kharkiv, May 18-20, 2016. - Kharkiv Polytechnic Institute – P. 381. (Ukr).
3. Ocheretnyi V. P. Usage of the limestone waste and industrial waste for the production of dry mix mortars / V. P. Ocheretnyi, V. P. Kovalskyi, A. V. Bondar // Modern technologies, materials and structures in the construction sphere. – 2009. – № 1. – P. 36 – 40. (Ukr).
4. Kovalskyi V. P. Sludge-ash-carbonate pressed concrete, based on the industrial waste / V. P. Kovalskyi, A. V. Bondar // Scientific Works of VNTU, 2022, № 4

Abstracts of the reports at XXIV International scientific-practical conference, Kharkiv, May 18-20, 2016. – Kharkiv Polytechnic Institute, 2015. – P. 209. (Ukr).

5. Binding material on the base of the industrial waste [Electronic resource] / M. S. Lemeshev // Scientific studies and their practical usage. Modern state and ways of the development 2017 : Materials of the International scientific-practical Internet conference, 10-17 October, 2017. – Moscow (Russia) : SWorld, 2017. – 6 p. – Access mode : <http://www.sworld.com.ua/index.php/ru/artsarchitecture-and-construction-317/modern-construction-technologies-317/29547-317-027>. (Ukr).

6. Bereziuk O. V. Structure of the machines for the collection and primary recycling of solid municipal waste / O. V. Bereziuk // Bulletin of machine-building and transport. – 2015. – № 2. – P. 3 – 7. (Ukr).

7. Popovych V. V. Characteristic features of transport facilities usage in the process of transporting, sorting, disposal and phytomelioration of solid municipal waste / V. V. Popovych / Scientific Bulletin of UNFU of Ukraine : Collection of Scientific Works. – Lviv : RVV UNFU of Ukraine. – 2012. – Issue 22.10. – P. 90 – 96. (Ukr).

8. Bereziuk O. V. Ways of improving the efficiency of solid municipal waste pressing in the dust-carts / O. V. Bereziuk // Modern technologies, materials and structures in construction industry : Proceedings. – Vinnytsia : UNIVERSUM-Vinnytsia, 2009. – № 1. – P. 111 – 114. (Ukr).

9. Bereziuk O. V. Dehydration and compaction drive for solid municipal waste in the dust-cart / O. V. Bereziuk // Bulletin of machine-building and transport. – 2016. – № 2. – P. 14 – 18. (Ukr).

10. Bereziuk O. V. Experimental study of solid municipal waste grinding during the dehydration by means of the worm press / O. V. Bereziuk // Bulletin of Vinnytsia Polytechnic Institute. – 2019. – № 5. – P. 75 – 80. – <https://doi.org/10.31649/1997-9266-2019-146-5-75-80>. (Ukr).

11. Law of Ukraine «On basic principles (strategy) of State ecological policy of Ukraine for the period until 2020» // Bulletin of the Verkhovna Rada (Parliament) of Ukraine. – 2011. – № 26. – P. 218. (Ukr).

12. Cabinet of Ministers of Ukraine. Resolution № 265 “On the approval of the Program of solid municipal waste management” [Electronic resource] 4 March, 2004. / Access mode : <http://zakon1.rada.gov.ua/laws/show/265-2004-%D0%BF>. (Ukr).

13. Teletov O. S. Usage of marketing in the conditions of the solution of economic-ecological problem of the region / O. S. Teletov, M. G. Zubenko // Mechanism of the economy regulation. – 2008. – № 1. – P. 89 – 102. (Ukr).

14. Zolotar L. V. Determination of functional-planning zones of primary points of solid municipal waste collection / L. V. Zolotar // Urban development and territorial planning. – 2012. – Issue 46. – P. 235 – 245. (Ukr).

15. Ministry of construction, architecture, housing and municipal affairs. Order №176 of June 7, 2010. On the approval of the Rules of organization of collection, transport, recycling and disposal of solid municipal waste. [Electronic resource] / Ministry of civil construction, architecture, housing and municipal affairs. – Access mode : <https://zakon.rada.gov.ua/rada/show/v0176662-10#Text>. (Ukr).

16. Bereziuk O. V. Dynamics of wear and tear of garbage trucks in Khmelnytskyi region / O. V. Bereziuk, V. I. Savulyak, V. O. Kharzhevskiy // Problems of Tribology. – 2022. – № 27 (3/105). – P. 70 – 75. – <https://doi.org/10.31891/2079-1372-2022-105-3-70-75>.

17. Bereziuk O. V. Dynamics of the dust-carts wear in Vinnytsia Region / O. V. Bereziuk, M. S. Lemeshev // Bulletin of Vinnytsia Polytechnic Institute. – 2022. – № 5. – P. 16 – 21. – <https://doi.org/10.31649/1997-9266-2022-164-5-16-21>. (Ukr).

18. Bereziuk O. V. Study of the dynamics of the dust-carts wear in Zhytomyr Region / O. V. Bereziuk, I. V. Vishtak // Modern technologies and prospects of the automobile transport development : Abstracts of the reports of the XV<sup>th</sup> International scientific-practical conference, October 24-26, 2022. – Zhytomyr : Zhytomyr Polytechnics, 2022. – P. 27 – 29. (Ukr).

19. Altunina M. S. Improvement of the system of technical maintenance and repair of the rigid body-type dust-carts : Dissertation for the Degree of Candidate of Science (Engineering) : specialty 05.05.04 / Altunina Marija Sergeevna. – Novocherkask, 2015. – 145 p. (Rus).

20. Maltsev D. V. Improvement of the solid municipal waste transport process by the automobile transport : Dissertation for the Degree of Candidate of Science (Engineering) : specialty 05.22.10 / Maltsev Dmitriy Viktorovich. – Orel, 2016. – 175 p. (Rus).

21. Shliakhovoy V. Dust-carts, you have chosen the correct way! Telematics in the dust-carts [Electronic resource] / V. Shliakhovoy // Capital assets. – 2017. – № 1. – Access mode : <https://os1.ru/article/9607-telematika-v-musorovozah-vernym-putem-idete-musorovozy>. (Rus).

22. State of the sphere of solid municipal waste management in Ukraine during 2014 [Electronic resource]. – Access mode : <https://www.minregion.gov.ua/napryamki-diyalnosti/zhkh/terretory/stan-sferi-povodzhennya-z-pobutovimi-vidhodami-v-ukrayini-za-2014-rik/>. (Ukr).

23. State of the sphere of solid municipal waste management in Ukraine during 2015 [Electronic resource]. – Access mode : <https://www.minregion.gov.ua/wp-content/uploads/2016/04/Zbortpv4-oblasti1.pdf>. (Ukr).

24. State of the sphere of solid municipal waste management in Ukraine during 2016 [Electronic resource]. – Access mode : <https://www.minregion.gov.ua/wp-content/uploads/2017/03/TPV-4-2016.pdf>. (Ukr).

25. State of the sphere of solid municipal waste management in Ukraine during 2017 [Electronic resource]. – Access mode : <https://www.minregion.gov.ua/wp-content/uploads/2018/04/TPV-4-2017.pdf>. (Ukr).

26. State of the sphere of solid municipal waste management in Ukraine during 2019 [Electronic resource]. – Access mode : [https://www.minregion.gov.ua/wp-content/uploads/2020/03/rozdil\\_4\\_oblasti.xls](https://www.minregion.gov.ua/wp-content/uploads/2020/03/rozdil_4_oblasti.xls). (Ukr).

27. State of the sphere of solid municipal waste management in Ukraine during 2020 [Electronic resource]. – Access mode : <https://www.minregion.gov.ua/napryamki-diyalnosti/zhkh/terretory/stan-sferi-povodzhennya-z-pobutovymi-vidhodamy-v-ukrayini-za-2020-rik/>. (Ukr).

28. Bereziuk O. V. Computer program "Regressive analysis" ("RegAnaliz") / O. V. Bereziuk // Certificate of the State Registration of the Rights to the Copyright Object № 49486. – K. : State service of the intellectual property of Ukraine. – Date of

registration: 03.06.2013. (Ukr).

29. Bereziuk O. V. Determination of the regression of the compaction coefficient of the solid municipal waste on the height of the landfill on the base of computer program "RegAnaliz" / O. V. Bereziuk // Automated technologies and production processes. – 2015. – № 2 (8). – P. 43 – 45. (Ukr).

30. Bereziuk O. V. Determination of the regression of waste disposal parameters and the need in the compaction mechanisms on the base of the computer program "RegAnaliz" / O. V. Bereziuk // Bulletin of Vinnytsia Polytechnical Institute. – 2014. – № 1. – P. 40 – 45. (Ukr).

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