









Table 3: Estimating the parameters of ESM algorithms.

#	Description	Name	Algorithm (see Table 1)		
			1	2	3
1	Smoothing constant, $\alpha$	ALPHA	3860,9018	3849,8462	3855,8791
2	Trend smoothing constant, $\beta$	BETA	0,0001	0,0001	0,015
3	Seasonal smoothing constant, $\gamma$	GAMMA	0,0001	0,0001	0,0001
4	Akaike information criterion	AIC	3867,3779	3857,2197	3863,2526
5	Bayesian information criterion	BIC	3902,7437	3894,3033	3900,3361
6	Model mean absolute error	MAE	0,0455	0,0412	0,0433
7	Model standard error	STD	0,0565	0,0531	0,0551

These views are generated in the user schema and can be used to display modeling results in an APEX-based application. More details about Exponential Smoothing model parameters here [12].

Table 3 shows the estimated parameters of the model from the views DM\$VGPIT1523 for all three algorithms when forecasting data for the period from June 2023 to June 2024. Some explanations for the estimates:

- *Akaike's Information Criterion* (AIC) is a measure of the trade-off between model accuracy and complexity. A lower AIC value indicates a better model.
- *Bayesian Information Criterion* (BIC). BIC is an alternative information superiority criterion that penalizes more complex models. A lower BIC value indicates a better model.

As can be seen from Table 3, by most estimates, the best algorithm for our time series is the Holt-Winters Multiple Exponential Smoothing Model with Damped Multiple Trend, Multiple Seasonality (EXSM\_WINTERS\_MUL\_TREND\_DMP).

Given sufficient accuracy, this algorithm was used to estimate the decrease in PIT in 2022 due to the armed aggression of the Russian Federation, since the model was trained on pre-war time series and the predicted values could correspond to the peaceful state of the economy. The forecasting results for 2021-2023 and the absolute errors are shown in Table 4.

As can be seen from the table, the absolute error of the simulated PIT revenues for 2021 is 0,65%, and the forecast error for 2022 is 11,26%, which is

explained by the fact that the model could not predict the war and its impact and the model error, in fact, determines the amount of PIT losses. Probable PIT losses in 2022 may reach an average of  $674 \pm 1\%$  million UAH. An estimate of the simulated PIT values for 5 months of 2023 gives a 6.4% absolute forecast error. It should be noted that the mean absolute error (MAE) shows that the mean absolute difference between the observed values and the predicted values for all predictions is  $< 4\%$ , which is a good result.

Figure 5 shows a graph of actual and simulated PIT data for 2015-2024 with confidence intervals (confidence level 0,95), obtained in the OML notebook (Holt-Winters model algorithm #2, Table 1). You can see significant differences between the forecast values and the actual values at the beginning of the pandemic (2020) and during the armed aggression of the Russian Federation. However, the following values are already taken into account by the model and the quality of the forecast improves.

As already mentioned, the simulation results can be used when creating analytical applications using Oracle APEX (Application Express). Application Express is a supported feature of the Oracle Database and is included, at no additional cost, with every Oracle Database, both on-premises and in the cloud. There are no additional licensing costs based on the number of developers, applications or end-users. Application Express is also included with every Oracle Database Cloud Service, from the low-priced Oracle Database Exadata Express Cloud

Table 4: Estimating actual and forecast revenues PIT.

Year	Actual revenues PIT, UAH	Forecast of revenues PIT, UAH	Absolute error, per year, UAH	Relative error of revenue PIT per year, %	MAE
2021	5 836 364 394,25	5 798 285 924,96	-38078469,29	0,65%	0,0367
2022	5 986 078 790,44	6 659 949 560,32	673870769,88	-11,26%	0,0357
2023 5 months	2 470 910 417,81	2 628 752 677,00	157842259,19	6,40%	0,0397

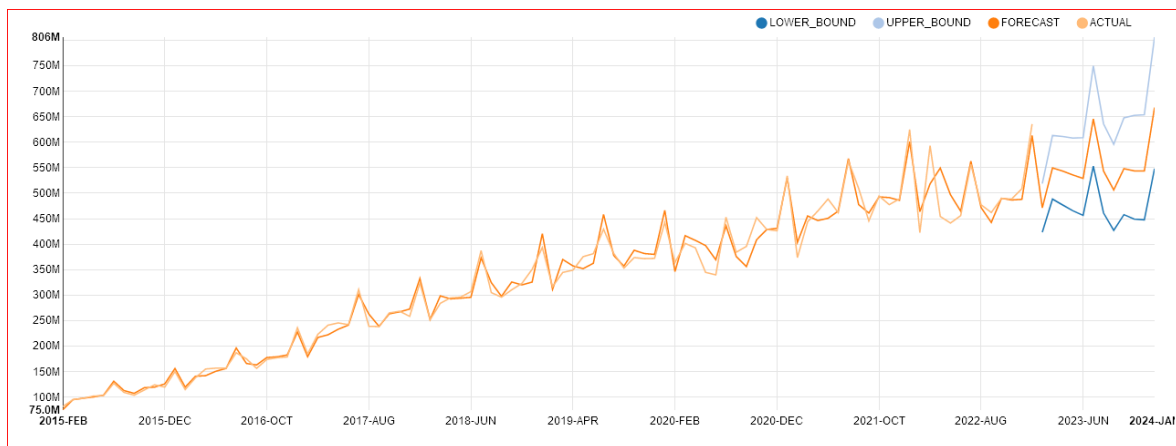


Figure 5: Chart of actual and forecast values of PIT in Ivano-Frankivsk region 2015-2024 (confidence level of 0.95).

Service all the way up to the Oracle Database Exadata Cloud Service [13].

Features of creating an Apex schema user to access OML:

- 1) Create the Workspace and the user schema on APEX.
- 2) When creating a Workspace, a user schema with the same name is automatically created in Cloud DB (ATP or ADW).
- 3) Register as an Oracle Cloud Database Administrator and go to the user administration tab.
- 4) Select the created user, activate the access to OML button in the edit menu.

For example, in the view DM\$VPPIT1523, the model forms columns of actual, forecast and calculated values for the lines of the confidence level specified in the parameters (lower\_bound and upper\_bound). All calculated values of the model coefficients and detailed information can also be displayed on the APEX pages.

### 3 CONCLUSIONS AND FURTHER RESEARCH

The following results were obtained in the study:

- 1) Among the 14 Holt-Winters algorithms implemented on the OML platform and used in the forecasting of PIT receipts (data from the Ivano-Frankivsk region for 2015-2023), the best forecasting accuracy was shown by the algorithm of Holt-Winters multiplicative exponential smoothing model with damped multiplicative trend and multiplicative seasonality (MAE = 3,57%).

- 2) The effectiveness of the algorithms can be explained by the use of an extended state space method for exponential smoothing, including the assumption of a single source of error (SSOE).
- 3) The results of modeling tax revenues in 2022 indicate that estimated losses of PIT in Ivano-Frankivsk region. due to the aggression of the Russian Federation, they may amount to UAH 654± 1% million UAH.
- 4) APEX, which is a supported and free feature of the Oracle database, allows fast, low-code creation of applications using simulation results. This enables convenient access to the OML toolkit and simulation results for a wide range of employees of corporations, enterprises, regulatory agencies, in particular, divisions of the State Tax Service, whose information systems are being developed on the Oracle platform.

Further research will be focused on exploring the algorithms of Oracle Machine Learning for Python (OML4Py), which enable the utilization of specialized libraries for data processing, machine learning, and graphical analysis available through the Oracle Autonomous Database service. OML4Py is a module that allows users to manipulate data in Oracle database tables using Python syntax. OML4Py functions and methods transparently transform selected Python function sets into SQL commands for execution directly on the Oracle database.

Subsequent investigations are planned to consider the integration of OML, REST, and Oracle Big Data services for a wide range of data collection and utilization tasks, validation of the obtained

results on tax revenue data from other regions, utilization of the discussed toolkit in studies of tax policy, and the development of methodological recommendations for the implementation of machine learning technologies in the operational activities of tax authorities [14, 15].

## REFERENCES

- [1] O. Puhachenko and T. Fomina, "Information support for expert studies and tax audits of the procedure for calculating and paying taxes and fees," *Economics and society*, no. 52, 2023, [Online]. Available: <https://doi.org/10.32782/2524-0072/2023-52-72>.
- [2] T.V. Donchenko and A.V. Oliynyk, "Stages of formation of the tax system of Ukraine in the context of the development of the digital economy," *Collection of scientific works of the State Fiscal Service University of Ukraine*, no. 1, pp. 45-62, 2019, [Online]. Available: <https://core.ac.uk/download/pdf/287302574.pdf>.
- [3] S.P. Kanzyuba, R.M. Matviychuk, Y.M. Sydorovych, and P.M. Musienko, "Electronic document flow. Reengineering of administrative processes in public authorities," *Electronic governance and electronic democracy. Education manual*, vol. 9, 64 p., 2017, [Online]. Available: [https://books.google.de/books?id=paW4DwAAQBAJ&printsec=frontcover&hl=uk&source=gbs\\_ge\\_summary\\_r&cad=0#v=onepage&q&f=false](https://books.google.de/books?id=paW4DwAAQBAJ&printsec=frontcover&hl=uk&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false).
- [4] O. Totska and I. Dmytruk, "Individual income tax in Ukraine: national and regional dimension," *FCS*, vol. 1, no. 8, pp. 30-39, Mar. 2023, [Online]. Available: <https://doi.org/10.26565/2786-4995-2023-1-04>.
- [5] E.I. Maslennikov and A.O. Gusev, "Income tax of individuals in Ukraine: current state and ways of reform," *Black Sea Economic Studies*, no. 57, pp. 47-50, 2020, [Online]. Available: <https://doi.org/10.32843/bses.57-8>.
- [6] Oracle, "Oracle Machine Learning for SQL Use Cases," 2023, [Online]. Available: <https://docs.oracle.com/en/database/oracle/machine-learning/oml4sql/21/mlsql/machine-learning-functions.html#GUID-E5D374FB-F7D5-49ED-BBD4-272B8B8CADC2>.
- [7] A. Png and H. Helskyaho, "Oracle Machine Learning in Autonomous Database. In: *Extending Oracle Application Express with Oracle Cloud Features*," Apress, Berkeley, CA, pp.139-191, 2022, [Online]. Available: [https://doi.org/10.1007/978-1-4842-8170-3\\_5](https://doi.org/10.1007/978-1-4842-8170-3_5).
- [8] P.R. Winters, "Forecasting Sales by Exponentially Weighted Moving Averages," *Management Science*, vol. 6, no. 3, pp.324-342, 1960.
- [9] C.E. Holt, "Forecasting Seasonals and Trends by Exponentially Weighted Averages," *ONR Memorandum*, no. 52, Carnegie Institute of Technology, Pittsburgh, USA, 1957. Available from the Engineering Library, University of Texas at Austin, 2003. Published in *International Journal of Forecasting*, vol. 20, pp. 1-13, 2004, with additional commentaries.
- [10] C. Chatfield, "The Holt-Winters Forecasting Procedure," *Journal of the Royal Statistical Society. Series C (Applied Statistics)*, vol. 27, no. 3, pp. 264-279, 1978, [Online]. Available: <https://doi.org/10.2307/2347162>.
- [11] J. K. Ord, et al., "Time Series Forecasting: The Case for the Single Source of Error State Space Approach," *Working Paper, Department of Econometrics and Business Statistics, Monash University, VIC 3800, Australia, April 2005*, [Online]. Available: <https://robjhyndman.com/papers/SSOE.pdf>.
- [12] Oracle, "DBMS\_DATA\_MINING - Algorithm Settings: Exponential Smoothing," 2023, [Online]. Available: [https://docs.oracle.com/en/database/oracle/oracle-database/21/arpls/DBMS\\_DATA\\_MINING.html#GUID-A95A0A38-8A5A-4470-B49F-80D81C588BFC](https://docs.oracle.com/en/database/oracle/oracle-database/21/arpls/DBMS_DATA_MINING.html#GUID-A95A0A38-8A5A-4470-B49F-80D81C588BFC).
- [13] Oracle, "Oracle® APEX," 2023, [Online]. Available: <https://docs.oracle.com/en/database/oracle/apex/23.1/htmnrn/index.html#Oracle%20%AE-APEX>.
- [14] L. Canali, Z. Baranowski, and P. Kothuri, "Integration of Oracle and Hadoop: Hybrid Databases Affordable at Scale," *Journal of Physics: Conference Series*, vol. 898(2), 2017, doi: 10.1088/1742-6596/898/4/042055.
- [15] A. Png and H. Helskyaho, "Oracle Machine Learning REST Services. In: *Extending Oracle Application Express with Oracle Cloud Features*," Apress, Berkeley, CA, pp.193-232, 2022, [Online]. Available: [https://doi.org/10.1007/978-1-4842-8170-3\\_6](https://doi.org/10.1007/978-1-4842-8170-3_6).