REFERENCE
of the domestic scientific supervisor
for the PhD thesis of Olzhas Nauryzbayevich Akylbekov
entitled "Development and research of machine learning methods for the analysis of three-dimensional spatial data in territorial planning systems"

I, Aiman N. Moldagulova, Candidate of Physical and Mathematical Sciences, Associate Professor, Professor of the Department of Software Engineering at Satbayev University (Kazakh National Research Technical University named after K. I. Satpayev), am the domestic scientific supervisor of PhD candidate Olzhas N. Akylbekov and am well acquainted with his research activities. The dissertation is devoted to the integration of artificial intelligence algorithms with spatial data analysis methods in the process of territorial planning. Under the conditions of rapid urbanisation, the need to ensure sustainable urban development and the transition to digital methods of urban planning regulation, this research direction is both timely and practically significant. The author consistently combines geoinformation systems, machine learning and deep learning technologies and, using real geospatial data of the city of Alatau, develops an intelligent GeoAI model for assessing urban development suitability and risk zones; this fully corresponds to current global trends in GeoAI and "smart" urban planning.

The aim of the dissertation is to develop and investigate spatial data analysis methods in territorial planning systems using machine learning algorithms in order to improve the justification and quality of urban planning decisions. The subject of the research comprises machine learning technologies, models and algorithms, as well as software tools aimed at classifying land surface parcels by classes of urban development suitability and supporting decision-making in territorial planning. Within the framework of the work the author has formed an integrated geospatial database for the territory of Alatau city, including satellite imagery, a digital elevation model, land-use information, functional zoning, transport and engineering infrastructure, as well as climatic and demographic indicators; developed the architecture of the GeoAI model and a system of features for assessing land suitability; trained and compared several machine learning and deep learning models, including a hybrid CNN+MLP architecture; and created a web application that implements multi-criteria assessment of urban suitability and visualises the results in the form of thematic maps.

The obtained results are substantiated by a series of computational experiments on real data using a confusion matrix; an overall agreement of about 63% has been achieved, with the hybrid CNN+MLP model demonstrating the best quality indicators among the tested variants. The author also considers the prospects of using alternative transformer-based models (U-NetFormerLite, ViT) and justifies the advisability of their further development at the next research stage. The theoretical and practical significance of the dissertation lies in the advancement of GeoAI-based spatial data analysis approaches for territorial planning tasks, in the application of hybrid neural network models to the assessment of urban development suitability of land parcels, and in the integration of heterogeneous geospatial data sources into a unified analytical framework. The developed web application enables the use of multi-criteria assessment results in the practice of architecture and urban planning authorities and design organisations when preparing territorial planning materials, refining functional zones, selecting sites for development, and identifying areas with elevated engineering and environmental risks.

It should be noted that in 2023 the author, with this project, won the state youth grant "Tauelsizdik urpaktary" in the field of "Information Technologies" and is currently continuing research on improving the proposed models. In addition, Olzhas Akylbekov is a performer within the "Zhas Galym" research grant No. AP25793497 "Automatic Detection of Pipeline Leaks Using Thermal Imagery from Fixed-Wing Drones and Convolutional Neural Networks", where he conducts studies in a related area of applying deep learning methods to the analysis of spatial and visual data. The presence of such grant support and the successful implementation of projects testify to the high scientific potential and stable research trajectory of the candidate. The main results of the dissertation have been presented at international and national scientific and practical conferences, discussed at scientific seminars of the Institute of Automation and Information Technologies and the Department of Software Engineering, and published in journals indexed in international databases and recommended by the Committee for Quality Assurance in the Sphere of Education and Science.

All key results of the work – the formation of the geospatial database, the design of the GeoAI model architecture, the implementation of hybrid neural network algorithms, the conduct of experimental studies and the development of the web application – were obtained under the leading role of the PhD candidate; his personal

contribution to the presented developments is unquestionable and substantial. Taking into account the scientific novelty of the research, the level of methodological elaboration, the correctness of the obtained results and their practical significance for territorial planning tasks, I consider it reasonable to allow the dissertation to be submitted for defence and fully support the awarding of the degree of Doctor of Philosophy (PhD) in the specialty 8D06102 – "Machine Learning & Data Science" to Olzhas Nauryzbayevich Akylbekov.

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