

R E V I E W

from

Prof. Olympia Roeva, PhD

Institute of Biophysics and Biomedical Engineering - BAS

Bioinformatics and Mathematical Modeling Department

for awarding of the educational and scientific degree “Doctor of Philosophy”

Professional field:

4.6 Informatics and computer sciences,

with a candidate

Petar Rumenov Zhivkov

PhD thesis title

**“MODELING THE STATE OF AIR QUALITY
BASED ON HEALTH AND ECONOMIC ASPECTS”**

1. Relevance of the problem developed in the PhD thesis in scientific and scientific-applied terms.

According to the European Court of Auditors' Social Report No. 23, "Excessive levels of pollutants in ambient air, such as fine particulate matter (PM), nitrogen dioxide and ozone, cause around 400,000 premature deaths each year." It is undeniable that the aim of the PhD thesis – studying the impact of fine particulate matter on acute diseases in Sofia and developing strategies to mitigate the effects of pollution – is relevant, both scientifically and in a scientific and applied sense. The PhD student aims to develop and implement solutions for calibrating PM data and to propose solutions for route selection concerning pollution in a common software system for collecting and processing data from various stations and IoT devices. As a result, several algorithms have been proposed and implemented in software systems. The developed software can find wide applications. For example, it to be used by air quality control organizations for monitoring and managing air quality in real time.

To achieve this aim, the following four problems are defined:

1. Investigate the relationship between fine particulate matter and health indicators for acute morbidity in Sofia;
2. Improve data from citizen air quality monitoring stations through calibration using a machine learning-based two-step method;
3. Develop a software tool for optimizing and evaluating cycling routes by characterising cyclists' exposure to air pollution;
4. Develop an IoT platform for aggregating and modelling air quality sensor data.

As a result of the implementation of the problems set, several algorithms have been proposed and implemented in software systems.

2. Degree of knowledge of the state of the problem and creative interpretation of the literature

109 references are cited in the PhD thesis. The PhD student has become familiar with the standards for permissible concentrations of PM and related EU legislation and WHO guidelines in relation to air quality control. He has examined air quality monitoring systems. He has presented the certification of air quality monitoring stations. He has become familiar with supervised machine learning techniques; parametric and non-parametric statistical tests; and technologies such as Django, Python, GraphQL and Rest API.

Petar Zhivkov shows a high degree of knowledge of the state of the problem and the appropriate tools and approaches to solve the problems set and achieve the goal of the PhD thesis.

3. General analytical characteristics of the PhD thesis

The PhD thesis is well structured and logically consistent according to the problems set for solving. The thesis is 115 pages long and contains: Chapter 1 (introduction, relevance and motivation, aim of the PhD thesis and problems, research methodology and presentation of the results); Chapters 2, 3, 4 and 5 with basic theoretical statements and scientific results of the study, conclusion – summary of the results obtained, main contributions of the PhD thesis, list of publications on the thesis, declaration of originality of the results and bibliography, numbering 109 sources.

Chapter 2 examines the relationship between PM pollution and health indicators for acute morbidity. The standards for permissible PM concentrations in the EU and the guidelines developed by the WHO are presented. The differences in the WHO norms and European legislation are determined. The geographical area of study is determined – the city of Sofia. The methodology of the study on air pollution with particulate matter, the data used on pollution and diseases, as well as the parametric and non-parametric statistical methods used are presented. The increase in acute respiratory infections during periods of increased above-normal concentrations of FPM for the studied area, the city of Sofia, is proven.

Chapter 3 is devoted to the use of machine learning for the calibration of PM sensors. The methods for measuring PM concentration, and the certification of measuring stations are considered and their advantages and disadvantages are analysed. A methodology for

calibrating PM10 concentration measurements is developed. A two-step calibration model using an artificial neural network is proposed, which is implemented on the wireless sensor network Luftdaten. Data on temperature, humidity, pressure, PM10 concentration from the previous day, wind speed, etc. were used for calibration. Comparison of the models with calibrated data shows a significant improvement in the accuracy of measurements.

Chapter 4 presents the developed software model for selecting a bicycle route depending on the concentration of PM, traffic, terrain elevation and the cyclist's heart rate. A modified algorithm for finding k-short paths with limited overlap (k-SPwLO) was used to generate the route. The modified algorithm also takes into account information about the road's traffic and elevation. The software model extracts air quality data from standard environmental monitoring tools of the Environmental Protection Agency and sensor networks Luftdaten, Smog, Openaqi, etc. The information is recorded, and the air quality data from fixed sensors are filtered and calibrated. Field tests were conducted with 10 participants. The results show that when choosing the optimized bicycle route, the inhalation dose of PM1 is reduced by 23% on non-working days and up to 56% during heavy traffic on working days. Approximately the same results were obtained regarding PM2.5.

Chapter 5 presents a software system for air pollution visualization. The process of developing and implementing the specialized software system is described in detail. The software system allows the collection, processing and analysis of data on air quality, meteorological data, traffic, and geographic information systems. Technologies such as Django, Python, GraphQL and Rest API were used in the development of the software system. The software architecture consists of a module for data collection and connection to the API; a central cloud repository; a module for data processing and analysis; a module for forecasting and calibration; a module for measuring PM pollution along a given route; and modules for data visualization and dissemination. The developed system provides real-time air quality measurement and analyses the data in order to inform citizens about the state of the air and the possible impact on health, which is a significant contribution to a particularly relevant and socially significant problem.

The formulation of guidelines for future work at the end of the chapters of the PhD thesis also makes a good impression.

4. Evaluation of contributions of the PhD thesis and their significance

I accept the contributions formulated in the PhD thesis with minor clarifications, namely:

The scientific and applied (practical) contributions are:

1. *A statistical correlation analysis was performed between air pollution and hospital and emergency admissions, identifying important cause-and-effect relationships.*

As I had already pointed out earlier, performing statistical analysis to correlate data is not a contribution. The PhD student should have emphasized the important causal relationships discovered, or more precisely, the “important cause-and-effect relationships” confirmed after the analyses.

2. *An algorithm for calibrating laser sensors was developed using a two-step method with artificial neural networks and anomaly detection. This innovative method supports more reliable and accurate measurements from laser sensors and has the potential to be used in a wide range of sensor applications.*
3. *An algorithm was created to evaluate the influence of humidity, altitude, and atmospheric pressure on air pollution data from laser sensors, allowing a more comprehensive and accurate understanding of the factors affecting air quality. It can also be applied in vertical planning.*

In my opinion, it is more correct to say, "a methodology has been developed to evaluate the impact of".

4. *An algorithm was developed to calculate the optimal cycling route based on PM concentration. This routing method promotes a healthy lifestyle and supports sustainable urban mobility.*

The applied (practical) contributions are:

1. *Software for calibrating PM data from laser sensors was developed, using reference data from official monitoring stations. This software enables air quality control organizations to use more reliable data for decision-making and pollution management.*
2. *A software solution was developed to account for the influence of humidity, altitude, and atmospheric pressure, improving PM data from laser sensors. This software can be used by urban authorities and health organizations to monitor and manage air quality in real-time.*
3. *A software tool for finding the optimal cycling route based on PM inhalation was created. This software can be useful for individual cyclists and city infrastructures that promote cycling.*
4. *An IoT platform for aggregating and analyzing sensor data on air quality was developed. This platform supports automation and facilitates data integration from various sources, enhancing the efficiency and accuracy of air quality monitoring. In addition to meteorological data, it integrates traffic and GIS data. The platform visualizes maps, complemented by measurements from air quality sensors and real-time traffic data.*

5. Assessment of PhD thesis publications

The results of the PhD thesis have been widely disseminated in the scientific field. The PhD student presents 4 publications in proceedings of international conferences. One of the proceedings is published in the prestigious scientific series Studies in Computational Intelligence and has an impact rank (SJR). Two of the publications are indexed in Scopus. Petar Zhivkov is the first author of all 4 publications. His independent publication has two citations in Scopus. All this shows the personal participation of the PhD student in the performance of the problems and the high level of scientific research and results.

6. Assessment of the compliance of the autoreferate with the requirements for its preparation, as well as the adequacy of reflecting the main points and contributions of the PhD thesis

The autoreferate correctly reflects the content of the PhD thesis and gives an idea of the problems under consideration, the results obtained, and the thesis's contributions.

7. Critical notes on the PhD thesis

Petar Zhivkov has considered a large part of the comments and notes that were previously made. I believe that all significant remarks are reflected in the PhD thesis. Some technical errors and inaccuracies are noticeable, but they are not of significant importance.

What makes a bad impression are the omissions and ambiguities in the Bulgarian statement. For example, when defining the problems of the PhD thesis, the first task, "Relationship between fine particulate matter and health indicators for acute morbidity in Sofia," would sound much better as "Research on the relationship between the concentration of fine particulate matter and health indicators for acute morbidity in Sofia."

Another example is the very title of the PhD thesis – "Modeling the state of air quality on health and economic aspects" – modeling on ...? Again, in the English version of the abstract, the title is given as "Modeling the state of air quality based on health and economic aspects", which is different from the title in Bulgarian.

In this regard, I would like the doctoral student to clarify which economic aspects are referred to in the title.

I recommend that Petar Zhivkov pay more attention to details and expression in the future because they are important for the overall perception of the work.

8. Conclusion with a clear positive or negative assessment of the PhD thesis

Based on the scientific research carried out and the achieved results, I give a high assessment of the PhD thesis of Petar Zhivkov.

The PhD thesis meets the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Internal Regulations for its application, as well as the Regulations for the terms and conditions for acquiring scientific degrees and occupying academic positions at the IICT – BAS. The achieved scientific and scientific-applied results give me reason to propose to the respected Scientific Jury to award the educational and scientific degree "Doctor of Philosophy" to Petar Zhivkov in the professional field 4.6 Informatics and Computer Sciences.

23.01.2025

Sofia

Scientific Jury me

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