

# R E V I E W

by  
prof. eng. Vladimir Monov, PhD

of dissertation for obtaining an educational and scientific degree "Doctor"

Author of the dissertation: **eng. Yordanka Lyubomirova Boneva**

Topic of the dissertation: **Optimization of traffic in urban environment**

Field of higher education: **5. "Technical sciences"**

Professional field: **5.2. "Electrical engineering, Electronics and Automation"**

Scientific specialty: **Application of the principles and methods of cybernetics in various fields of science**

Scientific supervisor: **prof. Todor Stoilov, D.Sc.**

By Order No 273/29.12.2020 of the Director of IICT-BAS I have been appointed as a member of the Scientific Jury for conducting the defense of the dissertation. By decision of the Scientific Jury at a session, held on 08.01.2021 I have been appointed as a reviewer of the dissertation. As a member of the Scientific Jury, I received:

1. Dissertation for obtaining the educational and scientific degree "Doctor".
2. Abstract of the dissertation with abstract in English.
3. Copies in full text of five publications on the dissertation.
4. Information on fulfillment of the minimum requirements of IICT for the educational and scientific degree "Doctor".
5. Copies of documents for received awards and diplomas.

For the evaluation of the dissertation it has been followed the legislative requirements for acquiring the educational and scientific degree "Doctor", defined by Law on the Development of the Academic Staff in the Republic of Bulgaria (article 6, paragraph 3), Regulations for application of the Law (article 27, paragraph 1 and point 2), as well as the Rules on the specific conditions for acquiring academic degrees and for occupying academic positions in the Institute of Information and Communication Technologies (article 3, paragraph 1, point 1.1).

## **1. Structure and content of the dissertation.**

The dissertation has a volume of 132 pages and consists of Introduction, 4 chapters, Conclusion with a summary of the results, Contributions to the dissertation and Bibliography. It contains 37 figures and 11 tables. The list of bibliographic sources contains 122 titles, including sources in Bulgarian and Latin. Data for two citations of a single-author publication of the PhD student are presented. The participation in two research projects is noted, guidelines for future research are formulated. According to

the requirements, a Declaration of originality of the obtained results is attached to the dissertation.

The dissertation was discussed and proposed for defense at an extended session of the department "Distributed Information and Control Systems" of IICT-BAS, held on 01.12.2020.

## **2. Relevance of the problem developed in the dissertation in scientific and scientific-applied terms**

The topic of the dissertation is related to solving optimization problems in road traffic control in urban environment. The general goal of the dissertation is to develop a mathematical model allowing the optimization of traffic in an urban type of transport network. To achieve this goal, six research tasks are appropriately formulated. The need for effective urban traffic control stems from a number of factors related to the increase of the urban population and the number of vehicles, the complicated road infrastructure and congestion of the road network, pollution of the living environment, efficient use of energy resources, etc. These factors are of paramount importance, both in terms of traffic and urban transport in our country and globally, which undoubtedly determines the relevance of the developed problems and the usefulness of the scientific and applied results obtained in the dissertation.

## **3. Degree of knowledge of the state of the problem and creative interpretation of the reference sources**

In the Introduction and Chapter 1 of the dissertation an analytical review of the principles and methods for modeling and management of traffic light-controlled intersections in the city network is made. Basic concepts for the dissertation are defined, such as traffic light cycle, cycle duration, green signal duration as a part of the cycle, signal phases, etc. The models for traffic flow are analyzed, with special attention paid to the model using the store-and-forward principle, which is applied to define and solve the tasks in the dissertation. The literature review and analysis of the current state and current trends in the problem area of the dissertation show in-depth knowledge of the subject and current problems, as well as potential opportunities for their solution. The main tasks related to traffic control in urban environment are outlined, and attention is paid to the peculiarities of solving the problem in Bulgaria. On this basis, the purpose and tasks of the dissertation are formulated.

## **4. Correspondence of the chosen research methodology and the set goal and tasks of the dissertation with the achieved contributions**

The formulated general goal of the dissertation is to develop a mathematical model for solving a research problem for optimizing road traffic in an urban type of transport network. To achieve this goal, the following tasks are formulated.

- Development of a mathematical model of urban transport network.
- Development of a hierarchical model for management of a network of crossroads.
- Defining and solving hierarchical optimization problems.
- Building a computer model and simulations in a software environment Aimsun;
- Testing of results without and with data from the solved optimization problem in simulation environment Aimsun.
- Evaluation of the obtained solutions by comparison with TRANSYT - a software product that is used worldwide for evaluation of control strategies in the field of road traffic.

A network of four connected, light-regulated crossroads, located on Shipchenski Prohod Boulevard in the city of Sofia, Bulgaria, was chosen for a specific object of study in solving the set tasks. A bi-level control model is developed for optimization of the selected section of the urban transport network. The task of the upper level of optimization is to find the optimal duration of a traffic light cycle, and the problem in the lower level is to find the maximum throughput of the network. The simulation tests were performed in Aimsun environment, and a software product TRANSYT was used to evaluate the obtained results.

The chosen approach for bi-level optimization, as well as the methodology for solving the optimization tasks and conducting the research fully correspond to the definition of the general goal and specific tasks of the dissertation. An important advantage of the developed bi-level model is the ability to apply traffic control in real time. The obtained results show that the doctoral student has successfully used the chosen research approach to obtain new results with scientific-applied and practical contribution.

## **5. Characteristics of the dissertation**

The dissertation demonstrates in-depth knowledge and opportunities for research work of the author in the thematic area of the dissertation. I am familiar with her presentation at the preliminary discussion. Compared to the previous version, it can be noted that the overall content of the dissertation has been improved, taking into account the remarks and recommendations made.

Chapter 1 introduces basic concepts and theoretical formulations in the field of urban traffic. Models of traffic flow in the transport network are considered, including a kinematic wave model, a store-and-forward model and a dispersion-and-store model. Some real-time traffic control strategies for urban networks are analyzed.

Chapter 2 formulates the task of bi-level traffic control in an urban transport network, which essentially integrates two interconnected optimization tasks. The formal description of the respective optimization criteria and constraints are presented, as well as the strategy for obtaining the global solution of the problem.

Chapter 3 applies the bi-level optimization approach based on the store-and-forward model for traffic control in the urban transport network. The object of research is described, representing a transport network of four light-regulated intersections. The results of numerous simulations for traffic optimization using the TRANSYT and Aimsun software products are presented. An assessment of various traffic and environmental indicators was performed, a complex model of the transport network was considered with the addition of the effect of tram stops, parked vehicles, etc.

Chapter 4 analyzes in detail the results of the conducted experimental studies and for their comparison graphical and tabular representations are suitably used. The comparative analysis shows that the results of the bi-level optimization approach proposed in the dissertation are comparable with the results of the well-known software product TRANSYT, as one of the bi-level tasks for green signal optimization gives an advantage over TRANSYT in three indicators - intensity, speed and number of stops.

The final part of the dissertation summarizes the results obtained and lists the contributions, which are essentially defined as scientifically-applied and applied. A plan for future development of the conducted research and the obtained results is also presented.

The dissertation is characterized by an in-depth analysis of the studied problems and the use of appropriate methodology for their solution. The numerous experiments and the analysis of the experimental data confirm the correctness of the chosen approach and the applicability of the obtained results.

## **6. Scientific and scientifically-applied contributions of the dissertation**

I accept and evaluate positively the scientifically-applied and applied contributions, formulated in the dissertation and the abstract. In summary, they can be listed as follows:

1. A mathematical model of an urban road network, regulated with light signaling, has been prepared, in order to optimize the traffic and determine optimal values of the light signaling of a system of traffic lights.

2. A mathematical model is defined, consisting of two hierarchically connected tasks for optimization of urban traffic, which allows to determine simultaneously the optimal values of control variables such as cycle and duration of green light of a system of crossroads.

3. The problem for optimization of the light signaling of traffic lights and the duration of the cycle is solved by applying the developed hierarchical model.

4. A simulation computer model of a network of crossroads has been developed, allowing to take into account additional conditions in traffic control, which cannot be analytically formalized, such as taking into account the presence of a tram line, parking permit and parked vehicles, etc.

5. As a result of the performed comparative analysis of the results obtained from the analytical optimization through the developed bi-level model and the simulation results of the computer model, it has been established that the bi-level model allows application of real-time control.

A good attestation for the results obtained in the dissertation is the fact that they were used and applied in the development of two research projects funded by the National Research Fund.

#### **7. Assessment of the degree of personal participation of the dissertation in the contributions**

The obtained results and the contributions contained in them show that the PhD student has fulfilled the main goal and tasks of her dissertation. I know the PhD student personally and I have direct impressions of the work of the team in which she participates, which gives me reason to believe that the dissertation and its contributions are her personal work, received under the direct supervision of her scientific supervisor.

#### **8. Evaluation of the dissertation publications**

It is presented 5 publications on the dissertation topic, of which 4 are single-authored and 1 is co-authored. Four of the publications are in English and one in Bulgarian. Two of the publications presented are impact-ranked publications (Scopus SJR), one of which was reported and awarded a prize and a crystal award at the International conference "ComSysTech'20". All publications on the dissertation are in the period 2018-2020 and as a volume and quality meet the requirements for obtaining the educational and scientific degree "Doctor". With the publications made the results of the dissertation have become available to our and the international scientific community.

#### **9. Significance of the results of the dissertation work in science and practice**

The dissertation develops an approach for bi-level traffic control in a traffic signal-regulated urban road network. A mathematical model of the network has been derived, the traffic control task has been formulated and solved, consisting of two interconnected optimization tasks.

Simulation studies and comparative analysis have been performed, illustrating certain advantages of the proposed approach. In general, the obtained results contain contributions of scientifically-applied and applied nature, which relate to the development of new and improvement of existing methods and approaches, as well as the application of practical solutions for effective traffic control in the urban road network.

#### **10. Assessment of compliance of the abstract with the requirements for its formatting**

The abstract has a volume of 51 pages and meets the requirements for its formatting. Its content corresponds to the content of the dissertation and presents exactly the main results in the dissertation. An abstract of the dissertation in English in a volume of 37 pages is also presented.

#### **11. Assessment for fulfillment of the minimum national requirements and the additional requirements according to Article 1a, paragraph 2 of Regulations**

## **For The Implementation Of The Law On The Development Of The Academic Staff In The Republic Of Bulgaria**

According to Regulations For The Implementation of The Law on the Development of the Academic Staff in the Republic of Bulgaria for obtaining educational and scientific degree "Doctor" in professional field 5.2. "Electrical engineering, Electronics and Automation", it is required a minimum of 50 points on indicator A and 30 points on group G. The same number of points is required in the Rules on the specific conditions for acquiring academic degrees and for occupying academic positions at IICT-BAS. From the submitted Report for fulfillment of the requirements for obtaining educational and scientific degree "Doctor", it is evident that the PhD student fulfills the requirement according to indicator A, and according to indicators from group G she has reported 130 points, which significantly exceeds the required minimum number of points.

### **12. Opinions, recommendations and remarks**

The dissertation is developed in detail and represents a completed research work. The PhD student has carried out an in-depth and systematic study of the problem and has offered original scientifically-applied and applied results that fully meet the goal and objectives of the dissertation.

I have no critical remarks in essence on the dissertation and the results presented. Of an editorial nature, I have the following remark. On page 111 in the dissertation 5 contributions are formulated, and in the table on the next page 6 results are listed, 4 of which are defined as scientifically-applied contributions and 2 as applied contributions. I believe that this discrepancy is due to editorial inaccuracy and does not reduce the value of the contributions of the dissertation.

My recommendation to the PhD student is to continue the research activity in accordance with the plan for future work outlined in the dissertation, as well as to publish the results in prestigious international journals.

### **CONCLUSION**

I positively evaluate the work done and the results obtained in the dissertation. The dissertation meets all legislative requirements of The Law on the Development of The Academic Staff in The Republic of Bulgaria, the Regulations for its application, as well as the Rules on the specific conditions for acquiring academic degrees and for occupying academic positions in the Institute of Information and Communication Technologies. I convincingly propose to the honourable Scientific Jury to give eng. Yordanka Lyubomirova Boneva the educational and scientific degree "Doctor" in the field of higher education: 5. "Technical Sciences", professional field: 5.2. "Electrical engineering, Electronics and Automation".

Sofia,  
15.02.2021 r.

Reviewer:   
/ prof. eng. V. Monov, PhD/