REVIEW

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

Danail Dichev Stratiev

PhD thesis title
"Modeling of Oil Refining Processes using Generalized Nets and InterCriteria Analysis"

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

The PhD thesis addresses real industrial problems through innovative mathematical methods, helps achieve more efficient production, and provides a mathematical framework for making complex management decisions. In the modern world, oil refineries are faced with the need to transition to "smart manufacturing". The use of Generalized Nets (GN) allows for the modeling of extremely complex, parallel processes that traditional mathematical models often fail to describe. This makes the work highly relevant as a tool for building so-called "Digital Twins" of real production facilities.

The PhD student aims to investigate the modeling of production processes for all petroleum products in a modern oil refinery using Generalized Nets and the selection of crude

oil raw materials using InterCriteria Analysis (ICrA). To achieve this goal, seven tasks are defined:

1. To model the process of production of various grades of motor gasoline in an oil refinery using GN.
2. To model the process of production of various grades of diesel engine fuels in an oil refinery using GN.
3. To model the process of production of various gas fuels, propylene, and polypropylene in an oil refinery using GN.
4. To model the process of production of various grades of heavy fuel oils and road bitumens in an oil refinery using GN.
5. To model the overall process of transforming crude oil into final commodity products in an oil refinery using GN.
6. To investigate the relationships between the general properties and the properties of fractions of a large number of oil types and the degree of similarity between them by applying ICrA.
7. To model the oil selection process using ICrA and the GNs.

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

In the PhD thesis, 239 literary sources are cited. The PhD student presents a quantitative analysis of a very large number of publications dedicated to GN over a long period (1999–2023). There is a lack of analysis regarding the significant scientific results achieved to date. The PhD student draws conclusions such as: "In the future, it is recommended that researchers applying the GN method direct their efforts towards publishing their research in journals with an impact factor and open access and in journals indexed by ScienceDirect.com." In my opinion, it is expected to draw conclusions on the strengths and weaknesses of GN in various applications and what existing research directed the PhD student to use GN specifically for modeling petroleum refining processes.

The PhD student formulates and solves two tasks dedicated to the application of ICrA, yet the literature review does not discuss scientific results related to ICrA. At the beginning of Chapters 2–6, there are references to published results that should have been analyzed and summarized in Chapter 1.

3. General analytical characteristics of the PhD thesis

The PhD thesis consists of 151 pages and includes: a list of abbreviations; an introduction; Chapter 1 (literature review); Chapters 2–6 containing main theoretical propositions, scientific results, and applications; a conclusion – a summary of the results; contributions; a declaration of originality; a bibliography of 239 sources; a list of publications; and a list of citations.

Chapter 2 demonstrates the capabilities of GN for modeling the production of different types of motor gasoline. The LUKOIL Neftohim Burgas refinery in Bulgaria is used as an example. A full description of the proposed GN model and the specific details of its simulation

in GN IDE are presented. The presented GN model details the production cycles for various classes of motor gasoline. According to the PhD student's summaries, the GN model can be integrated into real-world control and automation systems for the purpose of synchronizing and optimizing operations. Furthermore, the model can serve as an analytical tool for forecasting risk scenarios and assessing their impact on the environmental footprint, refining profit, and the regional economy.

Chapter 3 presents a GN model that describes the production processes of various types of diesel fuels in an oil refinery. It is stated that this model can also be used for the synchronization and optimization of production processes for different diesel fuels within a real control and automation system. At the end of the chapter, evaluations in the form of IF pairs are introduced, but it remains unclear how these evaluations can be or are being utilized.

Chapter 4 presents results from the modeling of fuel gas, liquefied petroleum gas (LPG), propylene, and polypropylene production using GNs. These are part of the refinery's hydrocarbon gas production chain, serving as a supplement to the modeling of motor gasoline and diesel fuel production. The proposed GN model is described. Here, for the first time, linear and dynamic programming are mentioned as possible approaches, though noted as not being as effective as GN models. UML diagrams are also mentioned in a single sentence, without clarity on how they relate to the results in Chapter 4.

Chapter 5 describes the modeling with GN of the production process of heavy petroleum products in an oil refinery. The processes occurring in five technological units have been modeled. With the development of these models, it is claimed that GN has been used to model the processes for the production of petroleum products in an oil refinery (I assume this refers to the LUKOIL Neftohim Burgas refinery).

Chapter 6 presents a GN model of the LUKOIL Neftohim Burgas refinery, according to a simplified technological diagram of the refinery (Nelson Complexity Index 10.6). The model describes the parallel processes that occur during oil refining and the production of final petroleum products. The GN models presented in the previous chapters are included as subnets in the current GN model. In this chapter, through ICrA, the links between the physicochemical properties of a large number of oils and their fractions, and the degree of similarity between them, are investigated. Based on expert experience in oil refining and the ICrA results, a selection of potentially profitable raw materials for processing in the refinery can be made. Finally, the PhD student presents a GN model of the oil selection process in the oil refinery, where, based on ICrA, a list of the most suitable crude oils for processing is obtained.

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

I accept the contributions formulated in the PhD thesis, namely:

1. For the first time, a GN model has been developed for the production of automotive gasolines in a modern oil refinery.
2. For the first time, a GN model has been developed for the production of automotive diesel fuels in a modern oil refinery.

3. For the first time, a GN model has been developed for the production of gas products (fuel gas, propane-butane, propylene) and polypropylene in a modern oil refinery.
4. For the first time, a GN model has been developed for the production of all oil products in a modern oil refinery.
5. A GN model of the crude oil selection process in an oil refinery has been developed, which includes an inter-criteria analysis, allowing the selection of a suitable crude oil to be carried out by applying this GN model and using historical information on the processing of different types of crude oil in a modern oil refinery.

The contributions could be formulated in a way that avoids the repetitive phrase 'For the first time, a GN model has been developed for the production ...' without diminishing their significance. For example:

1. For the first time, four GN models have been developed for production in a modern oil refinery, covering:
   a. motor gasolines;
   b. automotive diesel fuels;
   c. gas products (fuel gas, LPG, propylene) and polypropylene;
   d. all petroleum products.

   The proposed GN models describe the production processes in sufficient detail to be used for forecasting, analysis, and optimization, aimed at assessing the environmental footprint, refining profitability, and the impact on the regional economy.
2. A GN model of the crude oil selection process in an oil refinery has been developed, which includes an inter-criteria analysis, allowing the selection of a suitable crude oil to be carried out by applying this GN model and using historical information on the processing of different types of crude oil in a modern oil refinery.

3. Assessment of PhD thesis publications

The results of the PhD thesis have gained wide recognition in the scientific field. The PhD student presents 8 publications – four with an impact factor and one with an impact rank. Three of them are in the journal Mathematics (MDPI, Q1) – undoubtedly a high-class journal – where he is the first author. One publication is in the journal Comptes rendus de l'Académie bulgare des Sciences (Proceedings of the Bulgarian Academy of Sciences). The rest are in proceedings of international conferences, one of which is published in the Springer series Lecture Notes in Networks and Systems. The publication activity is impressive. The PhD student also presents 11 citations of his publications. D. Stratiev's Scopus h-index is 7. The publication of the results in reputable journals in the field and the independent citations determine the high level of the scientific research and results. D. Stratiev is the first author on 7 out of the 8 publications, which is a testament to the PhD student's active personal involvement in the research.

4. 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. The PhD student should have presented the main results in a more concise manner. An autoreferate of 79 pages is not considered good practice.

5. Critical notes on the PhD thesis

It is indisputable that the obtained results have been published in some of the most reputable journals and have received recognition from the scientific community through known citations; however, some critical remarks can be made regarding the prepared PhD thesis. During the analysis of the chapters of the PhD thesis, certain questions arose, which are described in Section 3, "General Analytical Characteristics of the PhD thesis". I would like the PhD student to address these questions and briefly justify the choice of using OM and ICrA.

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

Given the proven scientific value of the research conducted and the contributory nature of the results achieved, I provide a positive evaluation of the PhD thesis of Eng. Danail Stratiev.

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 IBPhBME – BAS. The achieved results give me reason to propose to the respected Scientific Jury to award the educational and scientific degree "Doctor of Philosophy" to Eng. Danail Dichev Stratiev in the professional field 4.6 Informatics and Computer Sciences, PhD programme Informatics.

05.02.2026 Scientific Jury member: .....

Sofia /Prof. Olympia Roeva/