THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Lower Bound Estimates for Path Planning in Environment with Obstacles**
Author's name:	**Bc. Kristýna Kučerová**
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Computer Science
Thesis reviewer:	Ing. František Nekovář
Reviewer's department:	Department of Cybernetics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment — challenging

How demanding was the assigned project?

The thesis assignment demands the student to study, understand and propose a novel mathematical formulation for solving the Traveling Salesman Problem with continuous neighborhoods in an environment with obstacles.
Furthermore, the student is assigned to implement a Branch and Bound solution method for the formulated model and make an evaluation based on existing base-line methods.
I believe such a task to be quite challenging for a masters student, with difficulty on level of a Ph.D. work.

Fulfilment of assignment — fulfilled

How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.

The student has completely fulfilled all of the assignment points.
Mathematical mode was presented and extended to include the obstacles.
Several methods of obtaining lower and upper bounds for the BnB procedure were examined in detail.
The computational evaluation is satisfactory with minor remarks, see additional commentary.

Methodology — correct

Comment on the correctness of the approach and/or the solution methods.

The students approach to the assignment is divided into multiple steps in the thesis.
Overview of related literature is made, and most promising related mathematical formulations are improved upon to obtain formulations of the problem suitable for the BnB method.
The proposed solution methods, along with multiple bound-obtaining methods, are then benchmarked on a randomly generated dataset to obtain an adequate result sample.

Technical level — A - excellent.

Is the thesis technically sound? How well did the student employ expertise in the field of his/her field of study? Does the student explain clearly what he/she has done?

The students' expertise in the field of multi-target planning is apparent from the text, proposed methods and background mathematical concepts are explained in detail.
The student makes an effort to not just present the mathematical non-linear problem formulation, but also explains how previously existing formulations were improved upon to introduce obstacles and comments on their computational complexity.

Formal and language level, scope of thesis — A - excellent.

Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?

Apart from several typos in the text, the language used is linguistically correct, clear to read and lacking in ambiguity.
The mathematical notation and used abbreviations are described zealously.
The thesis' extent is satisfactory.
The overall structure of the text is clear, with single exception being the results and conclusion sections, which would benefit from more structured writing. While all necessary information is present, the text itself is hard to follow.

Selection of sources, citation correctness A - excellent.

Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?

The key works on the thesis' subject are present among the citations, along with identified literature on related problem formulations which were then improved upon by the student.
Effort is made in the text to explain this process to distinguish students' contribution.
The citations are in proper bibliographic style.

Additional commentary and evaluation (optional)

Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.

- In introduction, the term "best solution quality" is confusing in the context as BnB is an exact algorithm, and only becomes clear after understanding the presented approaches for fixed ordering of target regions further in text.
- In section 6.3, it is claimed that computational time increase is logarithmic with number of samples. From the presented figure 6.5b however, the increase seems to be exponential. Increasing the number of samples would help to prove the claim, and the combined computational effort should be at most several hours if it is true.
- Use of "quite slow" in the conclusion is an eyesore in an otherwise well-written work.
- Obtaining exact NLP solutions using Alpine solver would be interesting to show quality of locally optimal solutions provided by Juniper, at least for a few instances.
- While out of scope of a masters' thesis, the apparent scientific contribution present in the work is not emphasized enough in my opinion. Future work would benefit from more direct summary of comparisons made with related solution methods, which would clearly stand out of the surrounding text.

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize your opinion on the thesis and explain your final grading. Pose questions that should be answered during the presentation and defense of the student's work.

The student has presented a scientific work on a topic which is both well-written and contains a meaningful contribution in the field of multi-target planning. This is well above the expected quality of a masters' thesis. Ample use was made of the page limit to describe multiple background concepts and utilized algorithms in detail, showing students' understanding of the studied topic. Student has overextended the assignment and presented extensive comparison between presented and baseline solution approaches. The work is excellent.

My questions for the student are as follows:

1. While the Branch and Bound procedure obtains on optimal sequence of targets with given bounding method, discuss the exactness and how global optimum to the problem could be found.

2. As several methods for obtaining both lower and upper bound methods are studied in the work, can you also comment on the optimality gap during the BnB procedure during convergence and hence the quality of intermediate solutions in time for the approaches presented in evaluation?
   Which combination of approaches performs the best when for example intractably large problem is solved and intermediate solution is needed?

The grade that I award for the thesis is A - excellent.

Date: **16.6.2023** Signature: