PhD Review Report

Advanced Methods and Models for Employee Timetabling Problems

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Initial part of the thesis presents well structured introduction into the general area of timetabling and employee timetabling. Applied approaches are summarized as well as used architectures.

Overall results of this thesis are presented in two rather independent chapters which are related by solving nurse rostering and employee timetabling problems. Each of the chapters is based on a strong journal publication, the first one is accepted in *Computers & Operations Research*, the second one is in major revision in *European Journal of Operations Research*.

The main contribution of the chapter on employee timetabling problem with a high diversity of shifts is a proposal of multistage algorithm which allows to simplify the problem by construction of rough timetable which is further refined in the next stage by matching in bipartite graphs. Classical final improvement by application of the local search algorithm is applied in the last stage. Cross evaluation methodology is proposed to be able to compare the work on a new problem with results on common nurse rostering problems.

To make the text more readable, it would be better to be more careful about explanations and wording (see examples below in minor comments). To provide complete description of the approach it would be better to present tabu search algorithm similarly to the evolutionary algorithm pseudo-code which is also a classical procedure. In addition, I would recommend to be more careful about detail explanation of the experimental problem for each experiment. The data for the base experiments in Section 3.6.4 are clear but the precise experimental setting for Section 3.6.2 is missing. Finally, it would be very good to publish real-life data from airport ground company you apply in your experiments.

The second part of the thesis concerns the nurse rerostering problem, parallelization of the base sequential algorithm and its application on Graphics Processing Units. This approach is rather unique since application of GPUs in the area of OR is scarce and it was not yet applied on nurse rerostering problems. Presentation of the algorithms was accompanied by well prepared examples which is definitely very important to understand the non-standard approach well. Thinking about the provided experiments it was not clear how have you decided about the timing necessary for running of all experiments. Page 94 mentions the amount of time given to sequential version of the algorithms. Do they really needed so much time to compute comparable results? Actually I am missing some experiments which would demonstrate optimization process (relation between time and optimization criterion) for all of the algorithms and which would show that a proper (specifically not too long) amount of time was provided to each particular algorithm.

I have some more questions related with future and related work. Your parallel algorithms tuned for GPUs would be interesting to other types of dynamic (changing) problems. Do you know about any other application of GPUs to the dynamic problems in the area of operation research? To provide clear experimental results, the thesis compares the proposed procedures on existing data with the only objective concerning the minimal number of changes. As another question for the defense, it would be very interesting to discuss possible extension of the proposed approaches by additional criterion taking into account quality of generated timetable.

Some references should be corrected. Namely incomplete references are a bit troublesome.

- Incomplete reference: *Burke, E.K., Curtois, T., 2012. Staff roster solutions –roster booster.*
- Incomplete reference: *Burke, E.K., Curtois, T., Qu, R., Vanden Berghe, G., 2007. A time predefined variable depth search for nurse rostering.*
- Incomplete reference: *Cezik, T., Günlük, O., Luss, H., 2001. An integer programming model for the weekly tour scheduling problem.*
- *Maenhout, B., Vanhoucke, M., 2010b* is cited as a corrected proof. It is in print from 2011.
- Incomplete reference: *Pato, M.V., Moz, M., 2013. The dataset of the nurse rerostering problem instances.*

Minor comments:

It would be better to sort the presented nomenclature in a lexicographic order to make orientation

easier. The same would help for abbreviations.

It would be better to use standard shortcuts. TSA and SAA should be replaced by common shortcuts TS and SA.

There are various small mistakes which should be corrected. See examples below:

- p.13 problematic: noun should be used
- p.14 courses timetabling $\rightarrow$ course timetabling
- p.15: A Employee Timetabling $\rightarrow$ An Employee Timetabling
- p.17: method dealing with ETPs *becomes* from the artificial intelligence $\rightarrow$ method dealing with ETPs *comes* from the artificial intelligence.
- p.26: Please correct: However, *compare* to the Personnel Scheduling phase, there are ...
- p.30 More comments about categorization ASBI | TVNO | PLGM should be given to provide some context.
- p.32: What does it mean *initialized* in "The transformed timetable is initialized by an evolutionary algorithm"?
- p.30-34: The notions of block, block constraints or block of shifts should be described in detail earlier. First we read about block constraints on page 30, next there are blocks mentioned in constraints on page 33 and block of shifts is finally defined on page 34. Also what is the length of block should be described.
- p.37, (3.14): $\forall d = \langle 2, b_{\min} \rangle$ should be changed to $\forall t = \langle 2, b_{\min} \rangle$.
- p.38, (3.15): $\forall d = \langle 2, br_{\min} \rangle$ should be changed to $\forall t = \langle 2, br_{\min} \rangle$.
- p.39: when t consecutive days $\rightarrow$ when τ consecutive days
- p.47: Why RG is missing in the last set with $\#pop = 10^5$?
- p.53: Where is given *the ratio of the fixed shifts* F_R? It seems that is should be present in Table 3.6 but it is not the case.
- p.84-91: References to Algorithm 3 are sometimes incorrect and should be replaced by the reference to Algorithm 4. Actually it would be better to keep Algorithms 3 a 4 with following numbering – it is the same code.
- p.89: Explanation of Roman numerals and corresponding examples are unclear and seem to be incorrect.

Conclusion:
In summary, the author of this dissertation thesis has demonstrated the ability to work independently and creatively in the specific field. The thesis meets the standard requirements imposed on the dissertation thesis in the field. I clearly **recommend its acceptance**.

In Brno July 3, 2015

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