Room Planning at Universities

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1 Introduction

University Timetabling is the problem of assigning courses to rooms and timeslots, as defined by Schaerf (1999). As shown by Rudová et al (2011), the entire timetabling process consists of many steps before a final timetable is put into production. In the literature, the timetabling problem is mostly considered as an operational problem, where the available resources, for example rooms, are fixed. As illustrated on Figure 1 there are other related decision problems that exists on a strategic level.

One of these problems that the universities face is the problem of deciding the number and sizes of rooms that they should have. This happens both in long term and short term space planning when the university are renting rooms or is considering rebuilding lecture rooms into offices. These decisions are crucial as buildings are a big cost and universities wants to minimize these expenses while still ensuring that a feasible timetable can be made and that the quality of future timetables for both students and professors are acceptable.

We will base our analysis on the curriculum-based course timetabling defined for the second international timetabling competition in Di Gaspero et al

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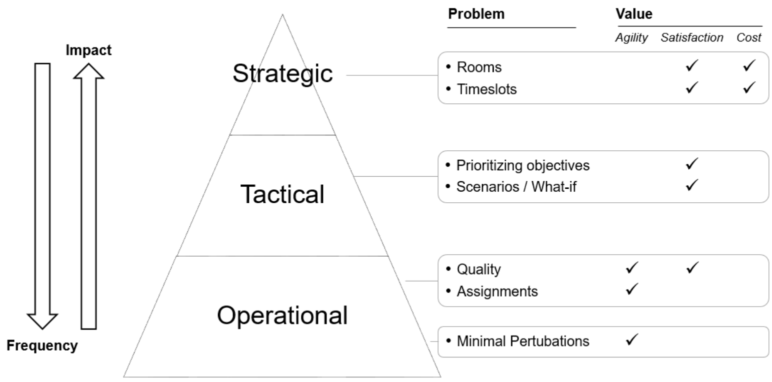

Fig. 1 Different variations of the timetabling problem occurs at different strategic levels. In a Danish context the value from the operational problems are mostly agility and satisfaction where the value is cost at the strategic problems.

(2007). We will present a bi-objective mixed integer model to investigate the relationship between the room profile and the quality measures to investigate how they impact each other.

2 Seats vs. Quality

The originally proposed problem consists of soft-constraints, the less violated the better quality. A MIP-model of this is proposed in Lach and Lübbecke (2012). In order to simplify the problem The soft constraint `RoomStability` is removed. Besides this the objective `RoomCapacity` is made into a hard constraint as this part is considered in the second objective. This means that the two soft constraints, `MinimumWorkingDays` and `CurriculumCompactness`, will be the quality measure f_1.

The following sets are used:

$\mathcal{C}$: Set of courses
$l(c)$: The number of lectures for course $c \in \mathcal{C}$.
$mnd(c)$: The minimum working days for course $c \in \mathcal{C}$.
$dem(c)$: The demand of ie. number of students for course $c \in \mathcal{C}$.
$\mathcal{R}$: Set of rooms
$cap(r)$: The capacity of room $r \in \mathcal{R}$.
$\mathcal{S}$: Set of unique room capacities including zero. Ordered from lowest to highest.
$\mathcal{C}_{\geq s}$: Set of courses with a demand larger than $s \in \mathcal{S}$.
$\mathcal{R}_{\geq s}$: Set of rooms with capacity larger than $s \in \mathcal{S}$.
$\mathcal{CU}$: Set of curricular
$\mathcal{P}$: Set of time periods
$\mathcal{D}$: Set of days

As defined by Beyrouthy et al (2006) the utilization per seat can be expressed in the following way:

$$\textit{Utilization per seat} = \frac{\sum_{c \in C} l(c) \cdot dem(c)}{|\mathcal{P}| \sum_{r \in \mathcal{R}} cap(r)}$$

As the courses are fixed, we can maximize this by minimizing the total number of seats given by f_2. This gives the model shown in Model 1.

$$
\begin{aligned}
\min \quad & f_1 : \sum_{c \in \mathcal{C}} 5 \cdot w_c + \sum_{cu \in \mathcal{CU}, p \in \mathcal{P}} 2 \cdot v_{cu,p} && && \text{(1a)} \\
& f_2 : \sum_{s \in \mathcal{S}} cap(s) \cdot r_s && && \text{(1b)} \\
\text{s.t.} \quad & r_s^+ - \sum_{s' \in \mathcal{S}_{\geq s}} r_{s'} = 0 && \forall s \in \mathcal{S} && \text{(1c)} \\
& \sum_{c \in \mathcal{C}_{\geq s}} x_{c,p} - r_s^+ \leq 0 && \forall s \in \mathcal{S}, p \in \mathcal{P} && \text{(1d)} \\
& \sum_{p \in \mathcal{P}} x_{c,p} = L(c) && \forall c \in \mathcal{C} && \text{(1e)} \\
& \sum_{p \in \mathcal{P}} x_{c,p} - z_{c,d} \geq 0 && \forall c \in \mathcal{C}, d \in \mathcal{D} && \text{(1f)} \\
& \sum_{d \in \mathcal{D}} z_{c,d} + w_c \geq mnd(c) && \forall c \in \mathcal{C} && \text{(1g)} \\
& \sum_{c \in \mathcal{CU}} x_{c,p} - q_{cu,p} = 0 && \forall cu \in \mathcal{CU}, p \in \mathcal{P} && \text{(1h)} \\
& - q_{cu,p-1} + q_{cu,p} - q_{cu,p+1} - v_{cu,p} \leq 0 && \forall cu \in \mathcal{CU}, p \in \mathcal{P} && \text{(1i)} \\
& \sum_{c \in \mathcal{C}(t)} x_{c,p} \leq 1 && \forall t \in \mathcal{T}, p \in \mathcal{P} && \text{(1j)} \\
& x_{c,p} \in \mathbb{B} && \forall c \in \mathcal{C}, p \in \mathcal{P} && \text{(1k)} \\
& w_c \in \mathbb{Z}^+ && \forall c \in \mathcal{C} && \text{(1l)} \\
& q_{cu,p} \in \mathbb{B} && \forall cu \in \mathcal{CU}, p \in \mathcal{P} && \text{(1m)} \\
& z_{c,d} \in \mathbb{B} && \forall c \in \rfloor, d \in \mathcal{P}_d && \text{(1n)} \\
& r_s^+ \in \mathbb{N} && \forall s \in \mathcal{S} && \text{(1o)}
\end{aligned}
$$

Model 1 Bi-objective MIP-model for the Seats (f_2) vs. Quality (f_1) Problem.

3 Results

We use the instances from ITC2007, based on real-world examples from the university of Udine to test our model and method. The frontiers for all 21 datasets are seen on Figure 2.

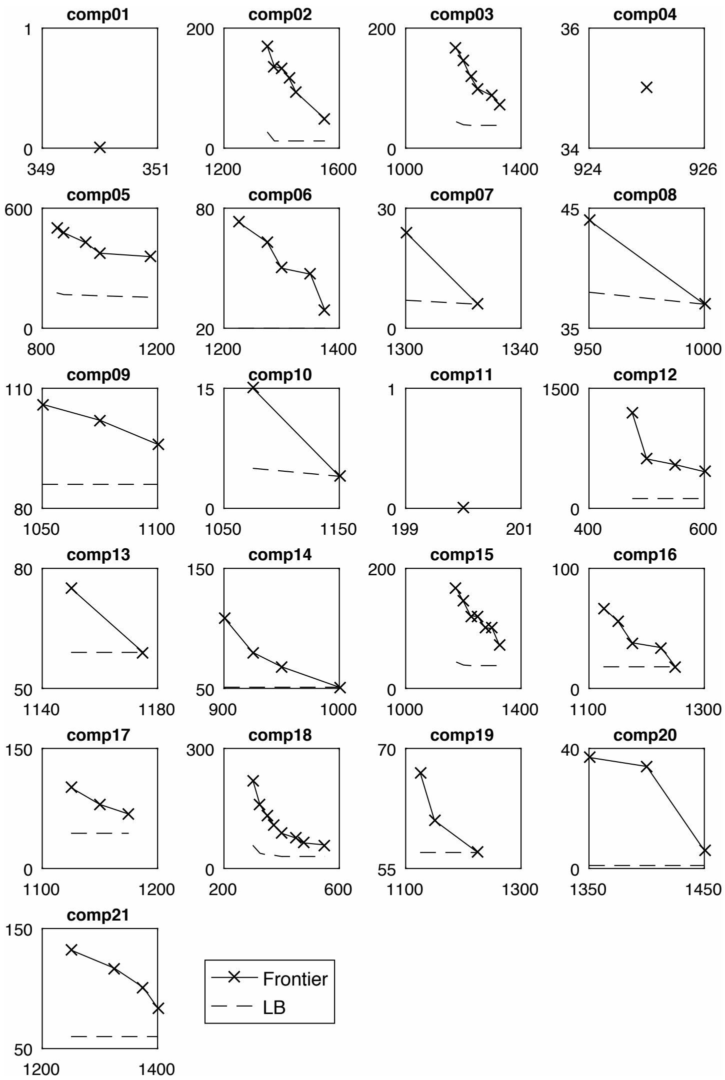

Fig. 2 The solution frontiers for the Seats vs. Quality problem. In general the bounds are very bad. Notice that three of the problems only have one solution.

It is seen that `comp01`, `comp04` and `comp11` only have one solution meaning that there is no benefit of adding extra seats and some of the other datasets only have very little benefit from adding additional seats. Though can it be seen that e datasets `comp02`, `comp03`, `comp15` and `comp18` there is a big trade-off between seats and quality.

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