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Reducing Buildings' Eco-Footprints through Utilization-Increase

Štefan Emrich, Sanja Zerlauth, Dietmar Wiegand
Institute of Urban Design and Landscape Architecture
Shabnam Tauböck, Niki Popper, Felix Breitnecker
Institute of Analysis and Scientific Computing
Vienna University of Technology
Vienna, Austria
Email: stefan.emrich@tuwien.ac.at

Abstract — *Shifting from the classical and unsatisfying definition of the ecological footprint to a more significant "footprint / utilization-ratio" forces to change the focus when planning buildings. As utilization is a major factor of buildings' ecological impact, it can be drastically influenced by room management.*
Big potential for improving the public footprint lies within universities and school buildings, as (in many countries) these represent the largest segment of public buildings. Hence this paper describes a project aimed at improving university room management and construction planning. For this purpose a simulation model - combining methods from the field of mathematical modeling and know-how from facility management and project-planning - is created. With a desirable side-effect: savings in a chronically underfunded governmental department.

I. Problem–Setting

Alongside the global-warming-debate "ecological footprint" has entered everyday life and language. While various methods for this calculation exist, most of them have one shortcoming in common: They neglect an interrelationship of the footprint and its "benefit". Compared only by their footprint a passive house-mansion will outrival a 50-apartment house built in the 1970-ies from precast concrete slabs. Taking into account that the mansion is used a few days per year (e.g. for skiing-weekends in the alps) while the second building is housing 200 people 365 days a year, the impact of these buildings has to be judged differently.

As the focus of this work is not a (new) definition for the ecological footprint, it is sufficient to agree that, when evaluating buildings, the footprint needs to be set in relation with the "number of usage-units" (man-hours spent inside the building – to stay with the above example). This "new" perspective allows and encourages to use existing buildings more efficiently rather than building additional ones!

Schools and universities represent one of the largest segments in the portfolio of public buildings (roughly 65% in Austria [1]), thus they offer great potential for improvement. As a preliminary research project at ETH Zürich [2] pointed out, propper space management allows for spatial reductions of up to 40% for such buildings. Hence utilization of existing buildings can be increased (reducing the "footprint / utilization-ration") and – if building plans could be evaluated in advance – future buildings could be built optimized according to their purpose.

II. How to Increase Room Utilization

The key to increased utilization of universities lies with efficient room/space management. Thus the problem translates into allocation of adequate rooms (e.g. equipment, capacity, location, etc.) for all scheduled university-courses (events).

Since it is not feasible to test the impact of space management strategies "in vivo" another form of evaluation becomes necessary: In the present case a simulation-tool that is taking into account all relevant factors.

A. Units of Measurement

To compare results a scale is essential. Needless to say that a weight-function strongly depends on the optimization goal (e.g. higher satisfaction of academic staff by reduced office-to-lecture-hall-distance).

In the present case the number of *erroneous entries*, *room utilization* and *room usage* were set to be the main evaluation units. An *erroneous entry* denotes one room request (for a single, specific time slot of an event) that cannot be met, *room utilization* is defined as the fraction of (core) time a room is in use and *room usage* expresses the extent to which the capacity of a room is exhausted.

B. The Booking Process

Simulation-projects often end without adoption of the implemented models because their place within the surrounding system was not considered prior to or during development. To avoid this and for a deeper understanding of the room-booking process the "global" system was captured using business process models (BPM, see [3] for more details).

In this process a major bug within the code of the booking-system was uncovered and consequently removed. Further it became obvious that it is necessary

to collect and pool booking requests in order to process them efficiently — requiring to change the first-come, first-served reservation-system currently in place.

C. Creation of a Simulation Model

To the author's knowledge neither tools nor appropriate methods exist to simulate room utilization to the necessary extent. Thus a model capable to solve this task has been created by combining mathematical modeling and knowledge from facility- and space management. This is necessary as this model needs to incorporate the exact structure of the building (number, size, equipment, location, etc. of rooms) as well as their "usage" (how many people will use it when and where, for what purpose, ...). Consequently a one-sided approach would not cover the problem sufficiently.

The chosen approach is based on a discrete event simulation (DEVS) framework that holds the space– and facility management know-how in terms of sets of management-rules. Optionally a sub-model, based on cellular automata (CA), can be connected to simulate realistic on-campus walking times between lecture rooms. See [4] for a more detailed model description.

D. Optimizing the System

Based upon data collected via the universities information system, that was manually completed in a time-consuming process, numerous simulation-runs with varying scenarios and different management-strategies have been conducted.

As the created model only consumes several minutes to simulate a semester for the whole university (roughly 20000 students!), the challenge was to extract meaningful information out of the resulting data. For this task evaluation– and data-mining routines were programmed in MATLAB, which where later – as reports – incorporated into the corresponding Access database.

III. Results and Outlook

Besides a thorough understanding of the universities (previously not analyzed) booking-process, several interesting facts were uncovered — even though the project not yet being in its final stage. As mentioned above a major bug was identified, as well as possible future structures for the booking-process defined.

Further it was shown, that the number of erroneous entries can easily be reduced by more than 50% only through changes in the management and introduction of a flexible room structure. This is shown in fig. 1 where the bars depict the number of erroneous entries (left y-axis) and the line those of successful bookings (right y-axis).

Analysis of lecture room utilization unveiled additional savings capacity if lectures would be rescheduled to spread over time more evenly. As this would drastically "increase" space additional buildings would become obsolete.

A. Future potential

As seen simulation allows to test and find proper space management which leads to a more efficient use of existing (university) buildings. Further such tests can also be applied to building plans and thus these can be optimized before construction.

By translating these results into public policy, governments could reduce the public footprint as well as save money in a chronically underfunded department.

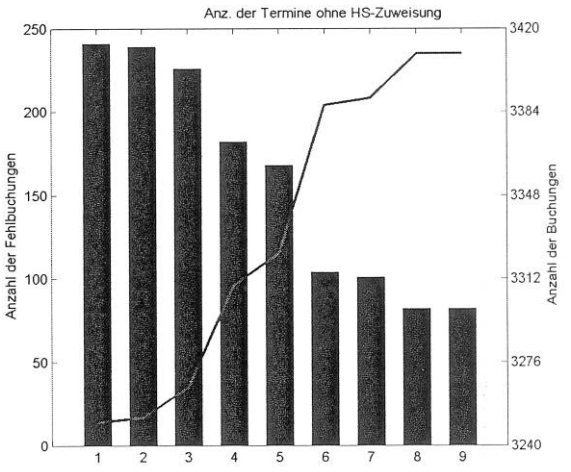

Figure 1: Number of erroneous entries vs. successful bookings under the influence of management strategies.

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Technische Universität Wien
Karlsplatz 13 | A-1040 Wien
Tel. +43-1-58801-0
Fax +43-1-58801-41099