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More Space – a Hybrid Dynamic Approach for Modelling Lecture Room Management

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Abstract. In this paper Discrete Event Simulation (DEVS) is applied to a Facility Management problem with the corresponding model developed in Enterprise Dynamics. The model is used to investigate effects of space management on the (lecture) room utilization at Vienna University of Technology (TU Vienna) on one hand. On the other hand the model will be used to forecast and optimize effects of room blocking on the scheduled courses during the upcoming reconstruction phase.

As DEVS is a fairly new tool in the field of Facility Management a proper interpretation of entities had to be found. A challenge was to import and map the complete structure of all rooms into the model. For this a module for automatic generation from databases, developed by the research group *"Mathematical Modelling and Simulation"*, has been applied.

Further the specific spatial situation of the TU Vienna with its intra–urban location needs to be considered, especially in terms of travel from one location to another — as the lecture rooms of two subsequent courses might be located in two remote buildings. To tackle this problem the DEVS model is coupled to a cellular automaton model which is taking over the task to simulate traveling entities.

The results obtained by the created model are quite positive. It was possible to show, that many of the potential problems could be overcome by modifications and fairly modest changes of the involved business processes and space management strategies, respectively.

1 Introduction

Vienna University of Technology (TU Vienna) is currently undergoing a major reconstruction process which was initiated by the decision to keep the university's intra–urban location. In the course of the project *"TU Univercity 2015"* two main goals for the 200th anniversary in 2015 have been set. On one hand all university buildings shall be renovated and equipped with an improved infrastructure for research and teaching, on the other hand ever two departments are to be pooled at each of the four existing inner–city sites.

This process is naturally connected to heavy construction work which is taking place parallel to university's daily business. The complexity of this undertaking becomes fully visible as one keeps in mind that TU Vienna has more than 3.000 employees and over 20.000 students — it has been compared by the rector with the attempt to change a tire on a driving car. Thus advance planning of room blocking is not only necessary but essential for the reconstruction project to become a success. This is where the project <more–space> sets in.

The project is a cooperation between the research group *"Mathematical Modelling and Simulation"* and the chair of *"Real Estate Development and Management"* (both located at TU Vienna) with the aim of creating a software–tool to model the lecture room utilization with respect to room management. The necessary first step — as for every interdisciplinary project — of course was to find a common language between the fields of mathematical modeling and facility–/room–management. The precise description of the tool's application areas in this common language were the next step to be taken.

As the tool is to be used to support the planning phase of *"TU Univercity 2015"* as well as for optimization of the room utilization this definition needed to be coordinated not only with the project–team but also with the whole surrounding processes of room reservation, booking procedures and the like. A common "language" capable to meet both of the above demands was found in Business Process Modeling (BPM), as . . .

- BPM is transporting ideas through clear and formalized diagrams. Thus misunderstanding through differently defined words can be widely excluded (e.g. "parameter" being used by FM-people in the context that mathematicians use "variable" for), and . . .
- the processes of the surrounding system can be described by BPM which allows for a better understanding of potential obstacles.

In this paper we will firstly describe the methods used within the project in a more precise way (section 2). In section 3 the hybrid dynamic approach will be covered as the methods are being mold in order to achieve all the set goals of this interdisciplinary project, before we look at some of the findings in section 4. Finally a conclusion and future outlook will be given in section 5.

2 Methods Used

The initially chosen BPM–technique within the project was the Business Process Modeling Notation (BPMN) as its "appealing graphical notation" [3] makes it possible to create flow–diagrams that are "readily understandable by all business users, from the business analysts that create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes" [6].

At a later stage of the project it was decided to reduce the level of detail used for the BPMN models. This means on one hand that the diagrams cannot be called "BPMN–diagrams" in a strict sense any more, but on the other hand cutting back the details further increased readability — which was the principal reason for neglecting the exact specification. The difference between a diagram with exact and reduced BPMN–specifications can be noticed by comparing fig. 1 and fig. 3.

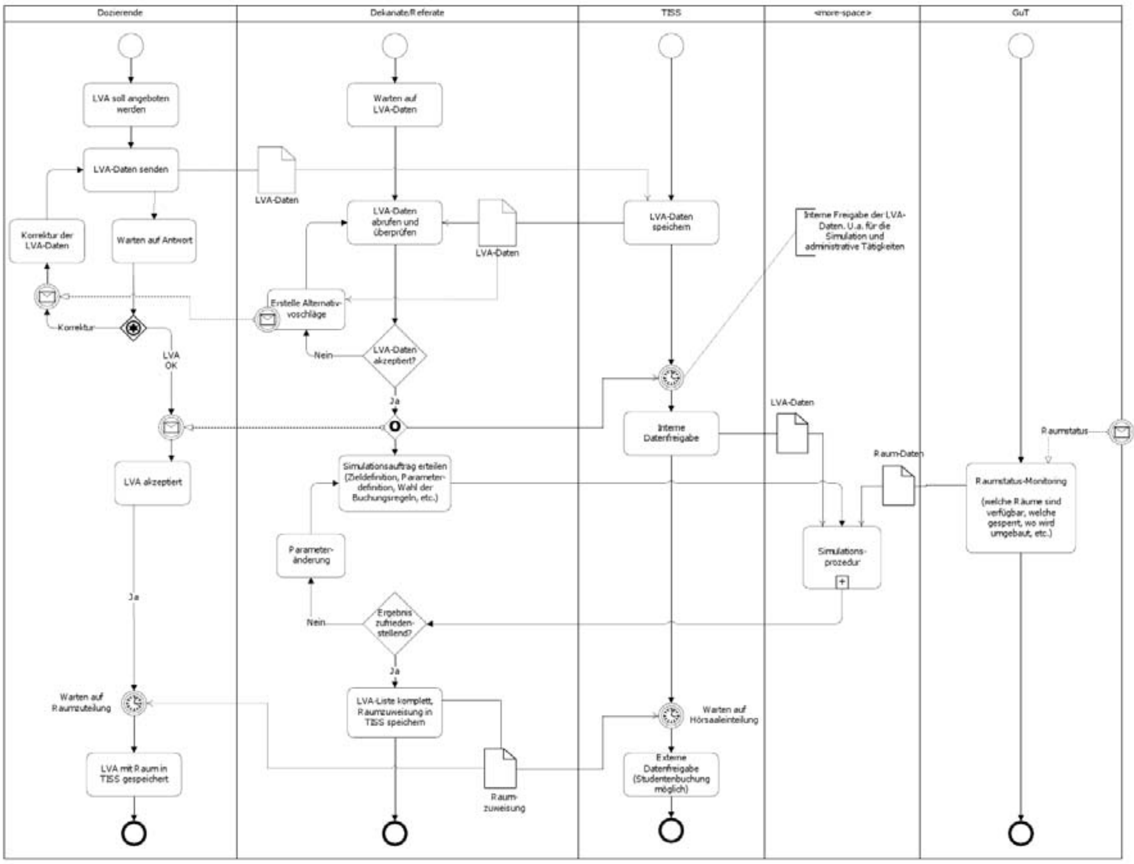

Figure 1: Business process model for scenario III with strict BPMN specifications.

Discrete Event Simulation can by far not be called new as it's roots can be traced back to the late 50ies of the last century [2]. On the contrary, DEVS has proven the test of time and is used in a vast range of business fields. With some of the often cited and well known examples being production and logistics, communication technology, chain supply and even hospital management.

The base of discrete event models is the entity– (resources) or the entity–flow concept: entities (in the previous examples work pieces, data packages, goods to be delivered or patients to be treated) are searching for a way though the process to their resources (industrial robots, servers, distributors or clinics, respectively) while events are defining and controlling this way.

However for the management of room resources and generally speaking for the whole facility management (FM) branch DEVS is a fairly new tool. Currently hardly any literature is to be found on this topic though what is found appears to be promising. For example was it possible to reduce the "imputed operating costs per teaching unit … by 40% through the application of a simulation" [4] in "discreteFD" — a precursor project of <more–space>, conducted at the ETH Zürich.

"Enterprise Dynamics" (ED) was the modeling language of choice for the project because of several reasons. The two main ones being that ED is first of all a proven tool for discrete event simulation as well in industry as in education and secondly that the mentioned module for database-driven automated model generation was developed specially for the use withing ED. In addition the software offers good import and export interfaces starting from JAVA up to various database-applications.

In contrast to modeling of processes which can be previously defined and (to some extent) globally controlled, DEVS is not the number one choice for systems in which the entities are acting as individuals without global control (e.g. human beings). Thus in order to model the behavior of individuals (students) searching for a way from point A to point B within the system a different strategy needed to be found. For this task cellular automata have been used, as their model base lies within the individual cells which are also capable of mapping a spatial structure.

Cellular automata, as discrete event simulation is, are a tried and tested modeling tool as well. One of the main advantages of CA lies within their power while being simple to program and resource–friendly [5] — although this is also one of their shortcomings as they are lacking adaptivity. To overcome this handicap a combination with agent–based elements has shown to be successful (see [1] for details and a comparison of CA and agent–based systems).

3 Model Approach

The Project <more–space> utilizes BPM — a modified version of BPMN to be exact — to embed the simulation model into a structural model of the complex surrounding system. This makes it possible to identify the connections between the actors outside and inside the modeled system. Which is necessary when working in a team with divers specialists and in particular to explain the project to outsiders (e.g. towards the ordering party or third parties from which data is to be acquired). Thus in a first step the scenarios, to which the tool is to be applied, have to be defined. These are:

1. Advance planning of (lecture) room blocking — during construction phase.
   In order to assure that the remaining rooms are sufficient to allow for all lectures and daily business to continue with — if the worst comes to the worst — only minor limitations (see fig. 2 for the associated business process model).
2. Retrospective analysis of applied room management.
   Making it possible to compare the applied management strategy with other strategies, an thereby improve allocation of resources.
3. Beforehand–allocation of rooms to scheduled lectures.
   By this the allocation of lecture rooms can be done in a near optimum way and thus permitting to use the remaining rooms for other purposes (e.g. for group work by students, renting it to external events). The respective graphical presentation can be seen in fig. 3.

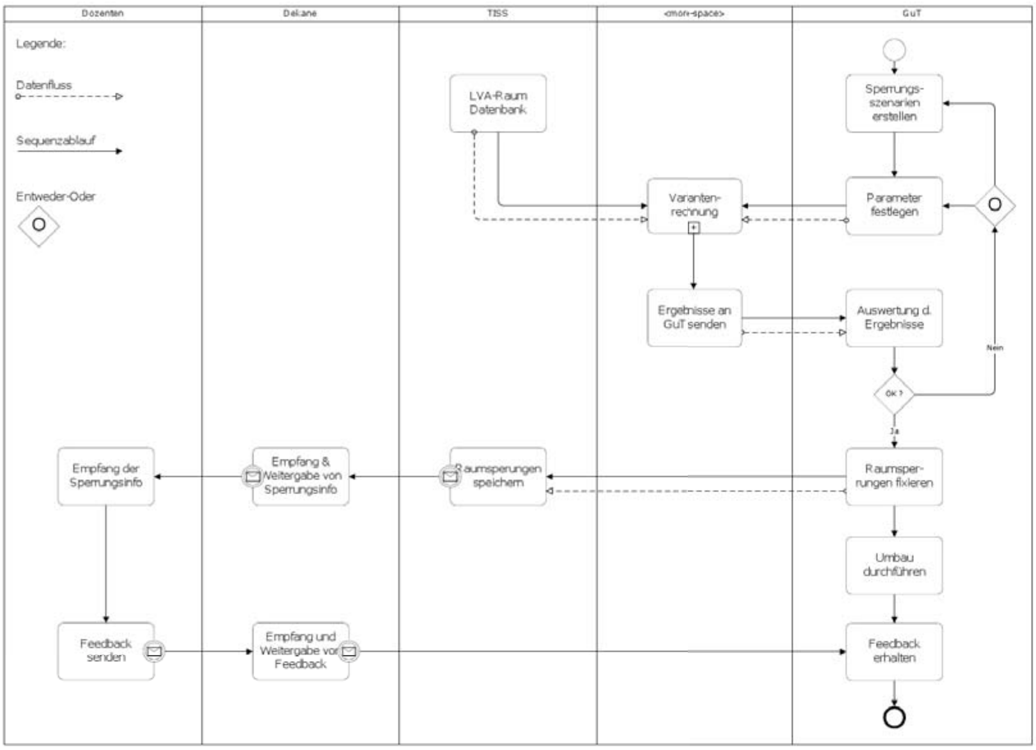

Figure 2: BPM for optimization of room blocking during construction (with loose specifications).

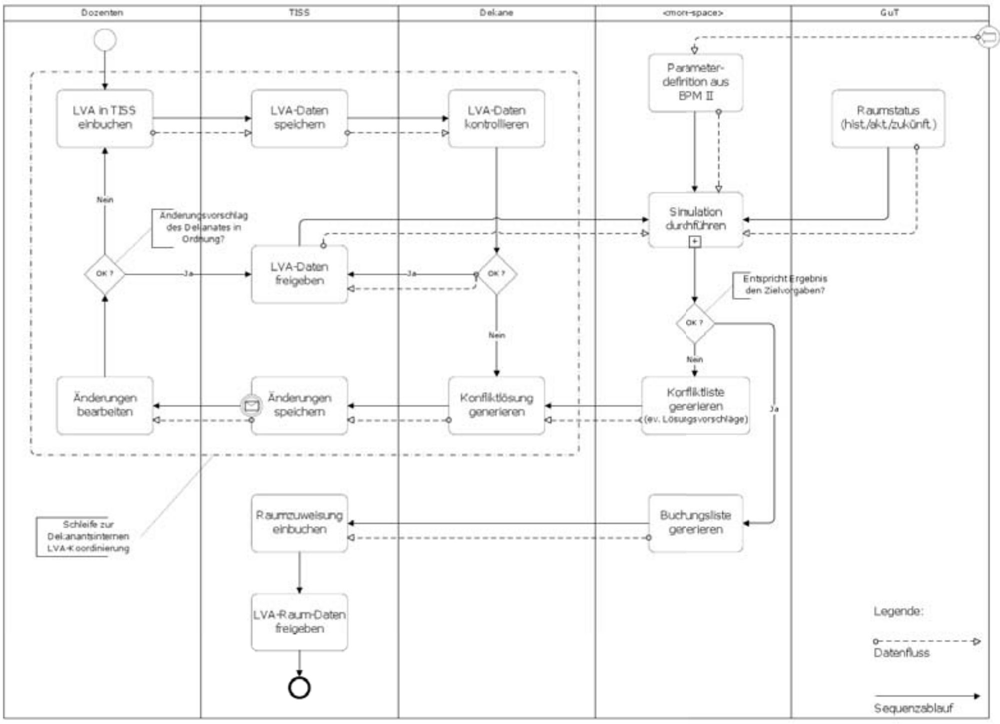

Figure 3: BPM for optimization of room allocation (improved BPM I with loose specifications).

The holistic view sketched in these BPM simplifies identification of potential obstacles on one hands and of communication channels and relations between participating entities on the other. This becomes a major aspect when talking about gathering data for the model–setup and simulation — which is a quite complex undertaking.

In addition to the previously described challenges the models' level of detail had to be set high enough to — for example — allow the modeling of clearing times of lecture rooms depending on the type of course (which will be described more precisely further on). This means that the models smallest units had to be the individual students with their respective curricula — a costly but necessary tribute to the systems complexity. Thus, not only the data regarding the number of students and their curricula and grades had to be captured, but also that of all courses as well as of all (lecture) rooms, both with their respective details.

The entity–relationship diagram of the model was set up with support of the BPM's and is shown in fig. 4. Data was mainly acquired over the university's information system TUWISS++ though with quite big inconsistencies. As it was not necessary in the past to enter all information into the info–system, a lot of data was missing. The elimination of these inconsistencies caused a lot of additional work. To avoid this problem in the future, a task force has been set in place to work out appropriate new specifications for the information system.

The core of the model is — as stated before — a discrete event simulation implemented in Enterprise Dynamics. But before it was possible to utilize DEVS in this FM–context it was necessary to find an interpretation for the projection of the entity–flow concept onto the system. While the resources' mapping onto the rooms is quite direct the more difficult task was that of finding a mapping for the entities as several interpretations are possible. Basically the given demand is booking rooms for certain requirements. This requirement can be identified by certain tasks which involve e.g. working groups, or vice–versa by groups of people that are to conduct particular assignments.

To model student walking times between different lecture rooms cellular automata are used in which the students travel individually. These CA are connected to the ED model and the students passed back and forth between them. Thus the model is a combination of DEVS supported by CA with agent–based elements. To incorporate the ever–changing room structure (e.g. which rooms are or are currently not available) the software also relies on the mentioned module that was developed by the research group *"Mathematical Modelling and Simulation"* (TU Vienna) and is capable of database-driven automated model generation.

This tool is capable of reading databases in various formats and interpreting this data as input for the model. In the present case information regarding the room structure, that was acquired via the university's organizational unit "Building and Technology", is stored in MS Access (MS Excel was used in the early stage of the project). Before starting the simulation the module loads this information and creates the respective rooms with all information (size, capacity, etc.) as atoms in ED. This database–driven technique is not only simplifying the modeling of changing systems but also very beneficial for (future) extensions as it is possible to add further (room) characteristics and thus easily increase the power of the model (e.g. implement fire security provisions).

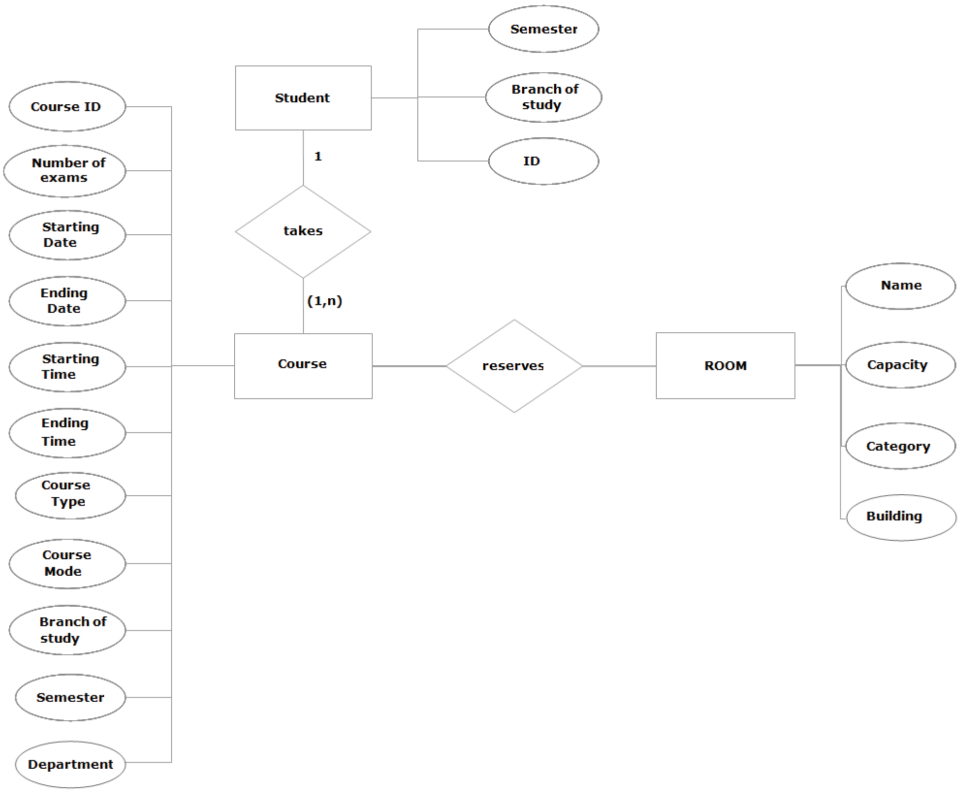

Figure 4: Entity–relationship diagram of the model.

To implement realistic clearing times after lectures a twofold approach has been chosen. The main part of the effective time is determined by the number of students inside the room and the number and size of it's doors. For this the doors were implemented as servers that process the exiting students (see fig. 5). On the other hand varying socket times are assigned to courses depending of required cleaning or packing (e.g. courses that include tinkering). These times are added and determine the time after which the respective room can be used again.

4 Simulation Results

By using the simulation tool developed it is possible to test and analyze a vast number of different settings and sub–scenarios, especially such that could not be tested in real life as they are too expensive or intricate. And it is such settings that often lead to fundamental insights or potential improvements.

Among others the <more–space> project examined different room–management options and their effects on the space utilization. In this field some of the findings where quite astonishing as it was possible to reduce the number of erroneous entries — those requests for booking a room of appropriate size that cannot be fulfilled — by more than 75% (from 200 courses down to 49). This improvement was achieved using a realistic scenario and only through modification of the management decissions.

The importance of this finding can be underlined by the following: The two settings compared are based on the same courses and room structure. The courses being all those offered already by the departments that will be grouped within the respective buildings and the room structure being already that of the future with an additional auditorium, thus increased space. This means, that without any management change it would become necessary to add even more lecture rooms in order to meet the existing demands — not to mention increased student numbers!

Furthermore it was found that, in contradiction to original belief, bottlenecks lie with “large courses” (those attended by more than 200 students). The simulation–runs showed that such “large courses” do not conflict with small(er) courses and that the utilization of “seminar rooms” could be increased by 100% through blocking a part of them (see fig. 6). This means that the blocked rooms could be pooled together to create a bigger lecture room.

Another very useful insight gained was to see that the demand for rooms of certain size is unbalanced over time. For example do certain branches of study require large lecture rooms at the beginning or end of the semester (e.g. orientation week, presentations) and many small (lecture) rooms otherwise. Together with the other knowledge gained, flexible room sizes appear to be a very efficient method of increasing the number of usable rooms of needed capacity. This findings were picked up by the “Building and Technology” unit as flexible rooms will be implemented.

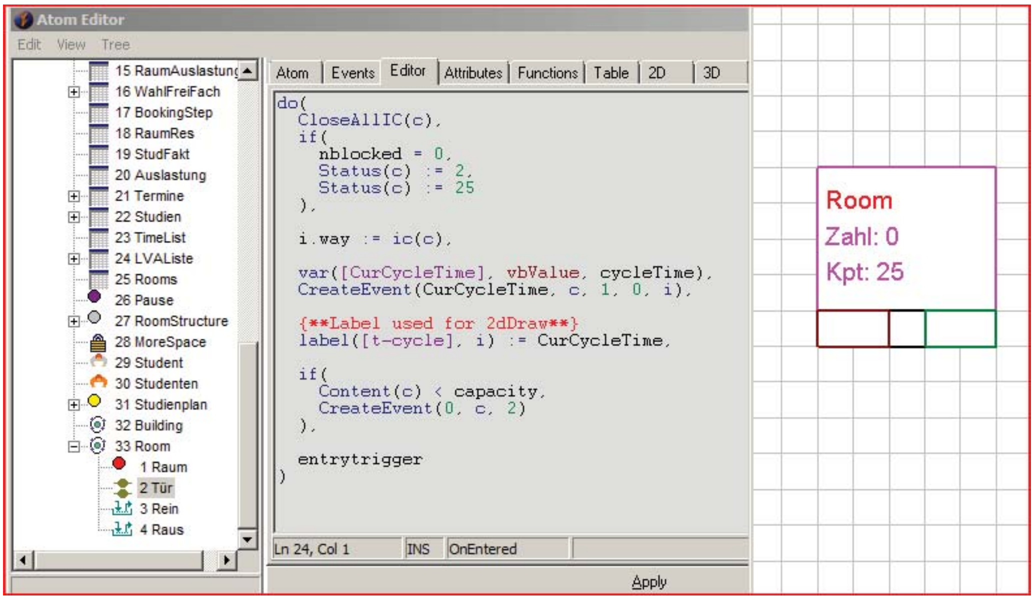

Figure 5: Detailed view of door-atom acting as server for exiting students.

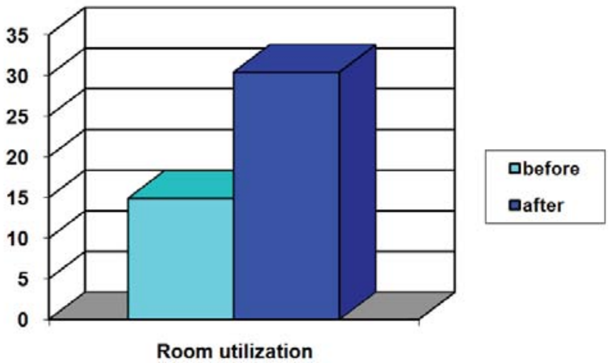

Figure 6: Increase of room utilization through controlled room blocking.

5 Conclusion

As <more–space> is one of the very few approaches in which FM–problems are tackled by simulation the results are of quite importance to future research in this field. This because not only was it possible to combine classical management–techniques such as BPM or room management with simulation tools such as DEVS and CA, but this combination was successfully applied to the problem with promising results!

The project was able to expose various possibilities for optimization of the status quo and for the reconstruction process. Judging by the results it seems justified to say that applying the tool to the three previously described scenarios helps to improve the allocation of (lecture) rooms and thus makes it possible to use the disposable space more efficiently.

This directly leads to a better room utilization and thus to a felt plus of space which can be used for additional or other purposes (e.g. for student working groups, renting it to external events or as reserve for short notice demand). In total this of course reduces — that means improves — the ecological footprint of the Vienna TU by increasing the number of units that are being held inside its rooms while the energy used stays (almost) the same.

Furthermore the findings of <more–space> so far were reason enough for the ordering party to renew the project–contract. Thus even better results can be expected for the future. Regarding the use of discrete (event) simulation in FM good advances could be made. Though, as with every new area of engagement, in the beginning it is necessary to establish common grounds — which especially holds true for a common language.

6 References

[1] Emrich Š.: *Comparison of Mathematical Models and Development of a Hybrid Approach for the Simulation and Forecast of Influenza Epidemics with Heterogeneous Populations*. Diploma Thesis, Vienna University of Technology, 2007.

[2] Nance R. E.: *A History of Discrete Event Simulation Programming Languages*. In: ACM SIGPLAN Notices, Volume 28, No. 3, 1993, 149–175.
[3] White, S.A.: *Introduction to BPMN*. IBM, 2004.
[4] Wiegand D., Mebes P., Pichler V.: *Event Based Simulations: Enabling Improved Development Planning and Partnerships*. In: Proc. Real Corp 007, Wien, 2007, CORP, Schwechat, 2007, 17–23.
[5] Wolf-Gladrow D.: *Lattice-Gas Cellular Automata and Lattice Boltzmann Models*. Springer, Berlin, 2000.
[6] Wolter, C., Schaad A.: *Modeling of Task-Based Authorization Constraints in BPMN*. In: Proc. 5th Intl. Conference, BPM Brisbane, 2007, Springer, Berlin Heidelberg, 2007, 64–79.