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Event based simulations: enabling improved development planning and partnerships

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1 ABSTRACT

Even though conomic appraisal in the real estate field is currently based on the assumption that the built environment is static, buildings and its management represent a dynamic “system” whit a “behavior” we are able to design and develop. The fitness of this system, its ability to react to changing user demands, demographic development, etc. is imperative for sustainable environmental, economic and social urban development. Due to missing methods and technology the flexibility of property and the facility management behavior are either not considered or play a very minor role in the practice of the real estate development.

In the research and development project “discreteFD” at the Swiss Federal Institute of Technology Zurich (ETH Zurich) discrete event simulations were developed in cooperation with the Swiss industry partners SUVA and redKG and the German BASF AG, which map “system behaviour” of facilities and facilities management across the life cycle of a property. As a consequence, urban real estate development concepts can be optimized for sustainable use over a single day and the entire life cycle. The consequences of development plans and their sensitivity concerning possible events can be simulated over time. Alternative concepts become much more transparent for investors as well as for urban planners. New avenues of communication are opened and new partnerships are formed.

Empirical tests of the new simulation models and the software tools proved that the complex dynamic system of Real Estate and Facilities Management can be evaluated more precisely via discrete event simulations, thus achieving an enormous optimisation potential for Real Estate Development (RED) and Facilities Management. The congress contribution focuses on possible applications of the event based simulations in urban development projects and public private partnerships.

2 INTRODUCTION

Due to the increasing pace in which both individual lifestyles and the general economic situations of companies change, properties that are inflexible, poorly interpretable, badly managed and/or have high operating costs no longer meet the changing needs of users or tenants. The results of this development can be observed in many cities. Properties are vacant, renovated for alternative use at high costs or demolished for redevelopment at an early stage of their life cycle. As a consequence, neither the targeted return on capital nor a sustainable use is achieved.

Research at the ETH Zurich showed that institutional investors, as well as users, are increasingly developing buildings that are flexible in their use over time. Within in the framework of the research and development project “discreteFD”, funded by the Kommission für Technologie und Innovation (KTI), the ETH Zurich in cooperation with its partners SUVA und redKG , developed new concepts of real estate development where the layout of the building is developed simultaneously with the respective facilities management concepts. As a result, these concepts ensure successful long-term investments. Even though improved risk management and the tapping of the market for service-enhanced properties represent current research objectives in real estate, adequate methods and tools to evaluate and estimate the risks of these new types of facilities are lacking. Additionally, there are no methods and tools for the optimization of building, use, financing and operation concepts. The task to prepare facilities for a dynamic and complex future remains.

The objective of the project “discreteFD“ was to understand current and future business models within real estate development, to find adequate abstractions for the application of simulations in life cycle oriented real

estate development, to develop simulation tools enabling a transparent win-win situation for all partners and to optimize various layers of real estate concepts.

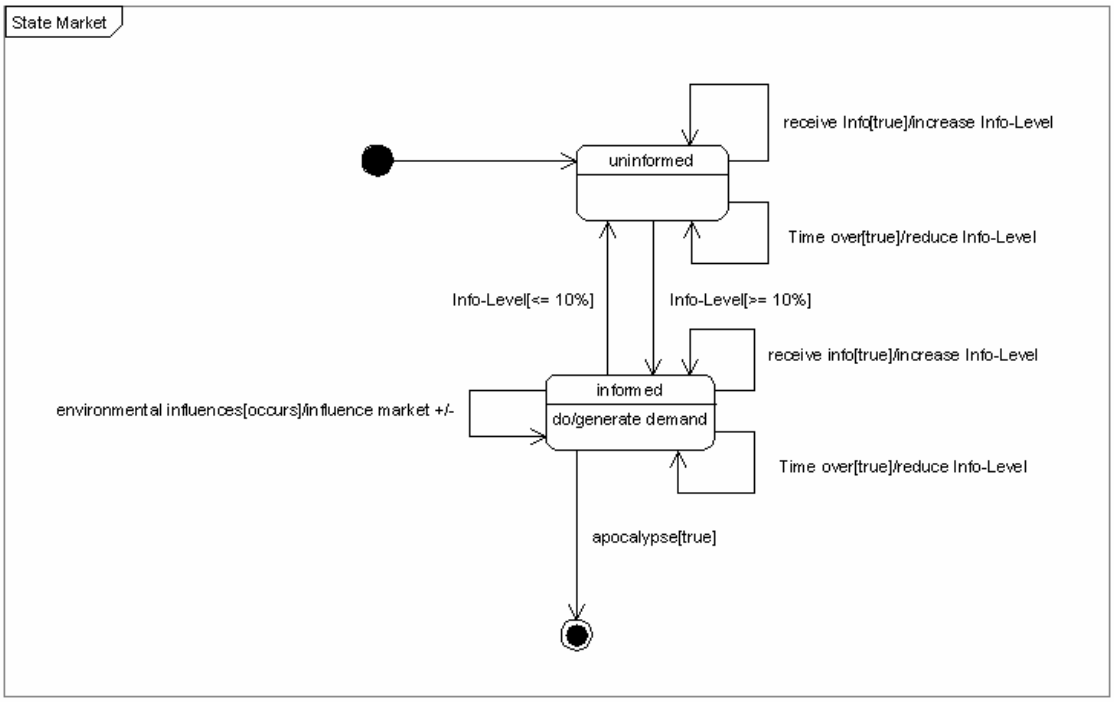
3 RESEARCH- AND DEVELOPMENT APPROACH

Research at the ETH Zurich regarding Discrete Event Simulations (DES) relates to facility developments defined as the phase prior to the actual building planning and to projects where building, use, financing and operation is developed in an integrative way. It is based on the thesis that the adaptability of a building, its interpretation potential, i.e. fitness; the types of management within the operating phase and the property-related services are all critical for sustainable property value and use. In the preliminary studies, the concepts of facilities management are to be optimized in relation to possible future events on which the developer or operator have no bearing. Such an approach is evident for owner-occupied properties (CREM) and public real estate (PREM) and is becoming increasingly important for the letting and sales of properties to third parties: The more customers regard the aspects of performance and adaptability of properties and services as significant and the legislator requires transparency, e.g. in the form of a "building pass", the more relevant this approach will become.

"discreteFD" pursues business simulation and information technology related objectives. Methods and tools from business analysis and business modeling on the basis of software development were applied. Via the narrative forms of story telling from eXtreme Programming , the business processes of facilities development, the requirements of the business field and the expectations of the end-user were collected and defined.

In addition, business data of the project partners and their customers were evaluated empirically in order to find influencing factors, which decide success or failure of facilities development (FD). From this, a Meta model for FD was deducted representing the basis for test implementations and simulation software. Based on the methodology of eXtreme Programming, potential modeling types, technical solutions and software architecture were evaluated with various test implementations and Architecture-Spikes . These test implementations perform single features (user stories) in order to answer the simulation questions, for example, the question of the optimal room mix of a hotel (single and double rooms) for an assumed demand.

For the translation of the simulation Meta model, in which the business processes were abstracted into software, transition diagrams and state charts were used; specifications of Unified Modeling Language (UML) .



Graph 1: State chart of the marketing of facilities

The validation of the simulation Meta model and tests of the software through practical cases represented the last step of the project.

4 STATE OF THE ART SIMULATIONS AND RISK MANAGEMENT IN THE CONSTRUCTION SECTOR AND FM

In some areas of civil engineering sporadically dynamic simulations were applied. Chahrour and Franz (Chahrour and Franz, 2004) specifically applied simulations from Logistics and Business Engineering in construction site organization in order to determine the utilization of specific equipment and their waiting time. At the 16th International Conference on the Application of Computer Science and Mathematics in Architecture and Civil Engineering in Weimar in 2003 Eichenauer, B. (IBE Simulation Engineering GmbH) and Scherer, K. (Fraunhofer-IMS and inHaus-Zentrum Duisburg) made a presentation on "Modeling and Simulations of Intelligent Building Systems with attributed Petri-Nets ." Literature research showed that whilst event simulations are in some areas of civil engineering, the application of simulations in real estate development represent a new phenomenon.

For a current assessment of the profitability of an investment, methods of dynamic investment analysis, also known as Discounted Cash Flow or Net Present Value method, are applied. With the help of spreadsheet analysis (Excel) the future progression of the net present value and of the interest rate is projected. These methods are often referred to as dynamic calculations (Schulte und Allendorf, 2005; Ropeter, 1998; Schelkle, 2005) through their inclusion of the interest payment for equity and dept capital over time. Strictly speaking, these methods represent merely static simulations as they do not include a simulation clock and in the instance of conditions and event, no changes in the system status occur. To our knowledge, dynamic event simulations in real estate development and FM have yet to be applied.

Because real estate development represents the business with the highest risks involved in the sector, the appropriate handling of risk is of vital importance. In real estate development, at the time of investment, reliable information is not available on the expected costs or on the prospective return. In addition, real estate development is confronted with unpredictable events, which are not within the influence radius of the developer. Consequently, a higher risk involved, on the one hand, generates extremely high returns, but on the other hand, the cooperation may get into financial disorder in the case of the poor development of a project. However, decisions on investments are generally still taken subjectively rather than analytically.

Only two publications on risk management in real estate development (Wiedenmann (2005) and Schelkle (2005)) are known. Real estate development as an academic discipline was first described in Bone-Winkel (1994) at the European Business School. Isenhöfer expanded this approach in 1999 in his publication on the strategic management of real estate development companies.

Several authors have dealt with general risk management in the real estate industry and specifically which risks are typically involved in real estate development (et al. Brauer, 2003; Diederichs, 2006; Hellerforth, 2001; Vogler, 1998; Wüstefeld, 2000; Schulte, 2005; Maier, 2004; Ropeter, 1998). The options to manage those risks, though, have not been examined or covered.

5 RESEARCH RESULTS

5.1 Analysis and Evaluation of Alternative Modeling Types and Simulation Tools

The first milestone of the project "discreteFD" was to examine whether the event based simulation is more suitable than other methods, like, continuous simulations for mapping reality, for example, the life cycles of facilities from a facilities development perspective. For this reason, utilising various modeling methods and tools, existent real estate development and properties in operation were analysed and test implementations of life cycle mappings of respective properties were developed and evaluated.

For the various test implementations, different simulation methods and tools were used:

- Monte Carlo Method (MC)
- System Dynamics
- Petri-Nets
- Discrete Event Simulations (especially eM-Plant)
- Simulation package SimPy and the programming language Python as Excel-AddIn

The Monte Carlo simulation represents one of the most used simulation methods and got its name from the world-famous casino. The method is particularly appropriate for the analysis of static problems with known probabilities. The Monte Carlo simulation represents a static simulation and does not cover dynamic situational or status changes.

System Dynamics represents a systems theory, based on the paradigm of information feedback as the behavior-determining structural component. System Dynamics has its roots in the findings of cybernetics and applies continuous simulations in order to examine behavior of non-linear models over time. This theory does not map results.

Petri Nets represent a modeling type, which is very neutral in terms of application. It is able to model and analyse dynamic system behavior. An event-based simulation may be applied with a time-related Petri Net model. Various simulation tools are based on Petri Net theory e.g. PACE, Umberto, etc. For practical use higher-level Petri Nets are required for which no constituent notion exists. Higher-level Petri Nets are complex to develop and analyse.

The simulation software eM-Plant represents an integrated simulation system. The advantage of eM-Plant is the complex support of simulation projects. The user concentrates on mapping the relevant system components and not on programming. The efficiency of modeling with eM-Plant is generally higher as with other simulation languages, but the high costs of purchase and operation of the software represent a disadvantage. In addition, there is a risk the results may be misinterpreted by inexperienced users. The simulation software partially includes its own programming language, which must be acquired for efficient and professional use.

According to expert interviews, facilities development is always based on assumptions of events for which probabilities concerning their certainty-to-happen are assumed. The empirical analysis of life cycles demonstrated that the events or conditions which are considered to be certain-to-happen generate a system behavior, which contributes significantly to success or failure of a project: Customer behavior, behavior of FM, etc. The modification of properties tends to be volatile. The exact process between events is of minor interest, that is, discrete event based simulations, which jump over time from event to event and simulate discrete modification of the system status in relation to the event, are highly suitable to map the life cycle of facilities appropriately.

In the project „discreteFD“, not only the question of which tools are the most appropriate for the simulation was raised, but also the question of how the simulation tool developed was to be applied. The project partners, e.g., the future users of the tool decided against a component simulator, which would have enabled them to develop individual models, but instead, decided in favour of a proprietary development of a parameter-based model where parameters are changeable.

5.2 Integration of System Behavior in Economic Appraisal

As a result of the findings, outlined distribution probabilities and system behavior of simulations of life cycle related real estate development were included in the development of “discreteFD”. Discrete event simulations (DES) were developed to provide a tool for new forms of real estate development and risk management for the industry project partners. The simulations implemented primarily generic features, which are applicable within a wide range of projects.

The performance of facilities over the life cycle, that is, the profitability for investors, operators and users, and also the eco-efficiency depend on a multitude of factors. The project “discreteFD” modeled and simulated those factors in a variable and flexible form including the factor time, which were defined as relevant on the basis of data analysis and expert interviews and which have not been mapped before.

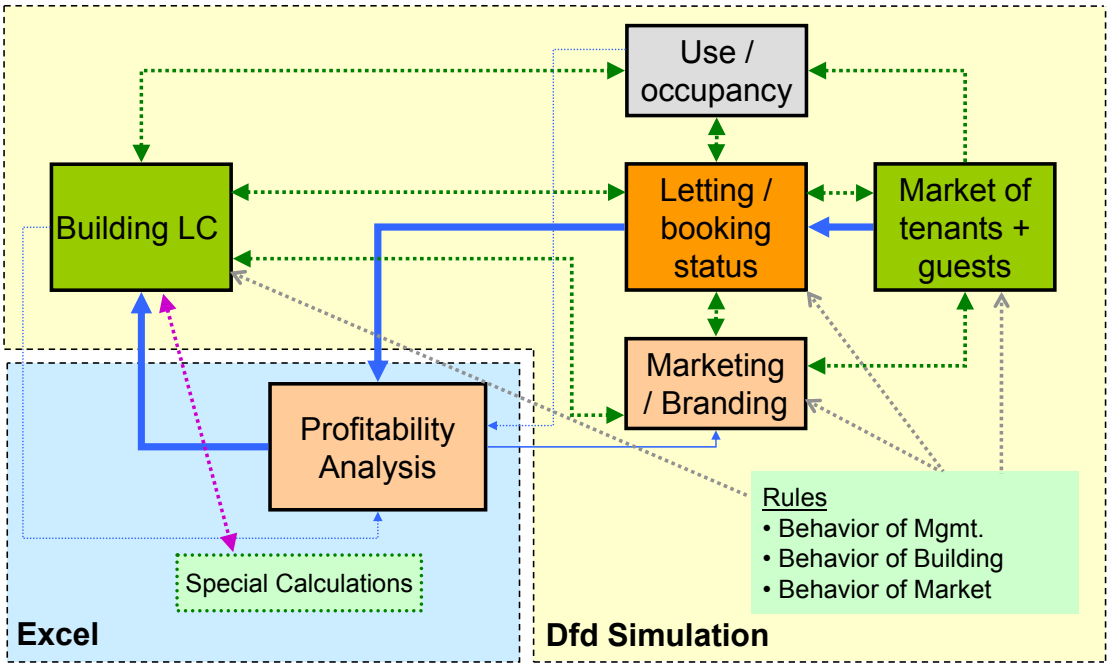
The life or durability of properties and building components, which has an important impact on the performance of facilities in connection with time, is not included in the simulation. “discreteFD” simulates on the level of building concepts.

5.3 Conceptual Model for Discrete Event Simulations of Facilities Development

The questions, which are to be answered by the simulation tools, were defined by the project partners as follows:

- Optimization of the building layout, e.g.: What is the best room mix for a hotel or how many conference rooms are necessary in a building?
- Management optimization in development, e.g.: What is the best point in time to inform the market, what are the letting terms?
- Optimization of rooms and accommodation management of school buildings, e.g.: What room mix in connection with which accommodation management is required for the most efficient use of the building during teaching hours?

On the basis of the questions defined, a life cycle of facilities was modeled from the perspective of facilities management and continuously evaluated by the project partners. Thus, the system structure was developed and mapped in a conceptual model including the system processes, the individual components, as well as their interrelations and impacts.



Graph 2: Conceptual facilities development simulation model

The conceptual model is divided into modules and classes respectively, which communicate via information (blue) and cash flows (green). The facilities in this model are presented in four categories and are able to adopt various statuses within those categories, mapping reality closely:

- Building LC: the status of a building over the life cycle of a property (from planning to use)
- Letting / booking status
- Marketing of the facilities
- Use / occupancy level: balance of the actual activities happening in the building

The cash desk (the profitability analysis) is required in order to determine the value of real estate development. Here the relevant key figures such as net present value are evaluated. Through the inclusion of existing valuation models in Excel, the users of the simulation are able to change the calculation modes in Excel.

Changes in the status of one entity class may cause status changes in others. Occupancy may inform life cycle that the occupancy level has reached a defined threshold and consequently the property is to be used alternatively. In the case of an insufficient occupancy level, the type of use of a building can be changed. If there is no more demand for hotel rooms, part of the building can be converted to offices or apartments. In the case of a high occupancy rate, an extension of the building or an alternative use of other parts of the building can be considered.

The modular structure supports the flexibility of the model. The fact that the life cycle of a building needed to be implemented only once facilitated the transformation into a flexible model.

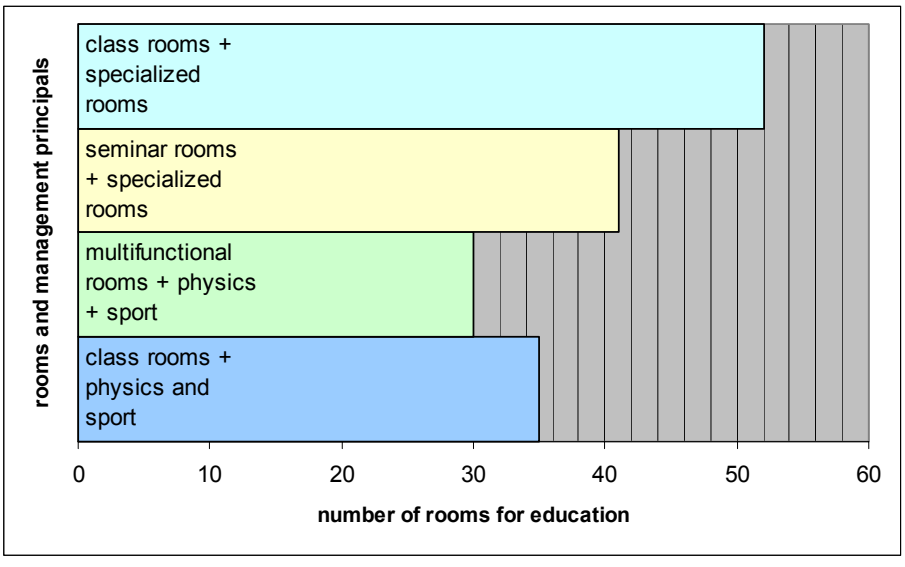
5.4 Implementation and Testing

In order to answer the questions outlined, flexible models were developed from component simulators (eM-Plant) and open source modules (SimPy/Python), which then were validated and tested through existing projects from the hotel, retirement and nursing home and schooling sectors. For illustration purposes, the empirical findings are demonstrated using the example of school buildings.

The questions determined, which were to be answered by the simulation concerning this sector are related to optimal room number, room quality and strategic accommodation management. First, rooms were distinguished into rooms for general use and rooms for use for specific subjects such as Biology, Arts, etc. The room demand was assumed as identified i.e., a specific number of teaching hours for a specific number of classes must be catered for with accommodation. The accommodation principles varied as follows:

- Classroom and subject specific classroom principle: Physics, Chemistry, Art, Music, Information Technology and Sports are taught in special rooms assigned for these purposes. Classes are exclusively assigned to a specific classroom for general teaching.
- Classroom principles apart from the subjects Chemistry and Sports: Chemistry and Sports are taught in specially equipped class rooms, all other subjects are taught in an exclusively assigned class room.
- Teachers' room principle: Teachers are assigned to specific room either via desk sharing or hoteling solutions. Student/pupils change rooms when teachers vary within the schedule.
- Specific classroom and course room principle: Corresponds to option 1. Classroom principle is substituted by course room principle.
- Course room principle for all subjects apart from Chemistry and Sports: Subjects apart from Chemistry and Sports teaching hours and classes can be assigned freely to rooms

At Bildungszentrum SeeCampus Niederlausitz an event based simulation was conducted for the classes 7 to 13. The results of the simulation show that when the classroom and subject specific classroom principle is no longer applied which usually represents general practice, 50% of the room capacity could be saved or made available other uses. Considering the fact that school buildings represent the largest segment within the public real estate portfolio, the economic and ecological potential of event based simulations in facilities management becomes evident.



Graph 3: Accommodation management principles and accommodation need/demand illustrated by the example of a German school (Forms 7-13)

The development of an independent simulation software for life cycle oriented facilities development framed the completion of the project "discreteFD". The software is, through focused user guidance at the time of data entry, extremely easy to use. It allows for once defined simulation models to be modified and used

again. With each simulation project, the amount of input effort is reduced for the application of discrete event simulations in new real estate development projects.

6 CONCLUSION

Discrete event based simulation tests of flexible facilities in the retirement, educational and hotel sector showed that with the help of simulations, optimized building layouts and management concepts can be developed. An idea, which due to the complexity and the dynamic of the business field, could not be developed without these tools. The imputed operating costs per teaching unit at the SeeCampus Niederlausitz could be reduced by 40% through the application of a simulation of the life cycle costs and benefits as well as the resulting optimization of the building and operation concept.

As outlined, the optimization of facilities development concepts and the evaluation of risks can be improved significantly and designed more realistically with the methods and tools developed within the project "discreteFD". Event based simulations enable transparency concerning the economic, ecological and social effects of real estate development over time, thus, enabling enhanced Public Private Partnerships. Even though the project "discreteFD" represents a generic approach to facilities development, not all problems are solved as real estate developments. For example, the questions raised in connection with development projects vary significantly especially in comparison to production and logistics. The expenses for modeling, development and implementation can be determined via the resulting increase in efficiency of facilities development projects. For the application of discrete event based simulations on a broader scale i.e., mass production, it is a prerequisite that real estate developers and investors are prepared to increase their investment during the planning phase in view of future benefits. The ETH Zurich plans to transfer and expand the outlined project to questions of eco-efficiency as well as to provide tools supporting the efficient operation of facilities and the decision making process during the various operating phases respectively.

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