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We can get “back to command”.

The other message of our slogan is <Back to command>.

In the expanding world of IT applications there is a need for the ready change of preliminary models by
using parameters and scripts. These approaches retrieve the feeling of command-oriented systems,

Why CAADence in architecture?

“The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition
to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By

personally selected or invented musical phrases, interspersed with previously played themes – in short,
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CAADence in Architecture

Proceedings of the International Conference on Computer Aided Architectural Design

16-17 June 2016
Budapest, Hungary
Faculty of Architecture
Budapest University of Technology and Economics

Edited by Mihály Szoboszlai
The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory. Architects who keep up with the new design demanded by the building industry will remain at the forefront of the design process in our IT-based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

Our slogan “Back to Command” contains another message. In the expanding world of IT applications, one must be able to change preliminary models readily by using different parameters and scripts. These approaches bring back the feeling of command-oriented systems, although with much greater effectiveness.

Why CAADence in architecture?

“The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By definition, a cadence is a solo that precedes a closing formula, in which the soloist plays a series of personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation.”

Nowadays sophisticated CAAD (Computer Aided Architectural Design) applications might operate in the hand of architects like instruments in the hand of musicians. We have used the word association cadence/caadence as a sort of word play to make this event even more memorable.
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Members of our local organizing team have supported this event with their special contribution – namely, their hard work in preparing and managing this conference.

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Forecasting Time between Problems of Building Components by Using BIM

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Abstract: Because the conservation of buildings constructed during Japan’s period of high economic growth is now an urgent problem, this paper reports on the development of a method of forecasting the time between problems of building components that integrates building information modeling (BIM) data and building repair records in order to enable more effective and strategic facilities management. In addition, because numerous buildings and facilities are suffering from worker shortages, thus making efficient management and maintenance essential, it is necessary to gain an understanding of how the conditions of components in a building change over time. To that end, building models were created using building blueprints and BIM data was extracted, which was then used in our calculations. Attempts were also made to calculate time between problems of building components via multiple regression analysis. In this process, explanatory variables were collected from BIM and repair record data.

Keywords: BIM, FM, Existing building, Repair record, Regression analysis

DOI: 10.3311/CAADence.1637

INTRODUCTION
Numerous buildings were constructed during Japan’s period of high economic growth, which occurred from the mid-1950s to early 1970s, and the conservation of those buildings is now an urgent problem. Many of the blueprints for these buildings, which were printed on paper, have since deteriorated — rendering some of them unusable — while others have been lost entirely. Accordingly, it is imperative that the remaining plans be preserved so that they can be used effectively to repair and maintain existing building stocks. While there are many ways of storing paper documents electronically, we have been focusing on the conversion of paper design documents into three-dimensional (3D) models by using building information modeling (BIM) software [1]. In addition, we have pushed forward a study regarding the resulting BIMs [2].

The effectiveness of BIM in the architecture engineering and construction (AEC) industry is widely acknowledged and increasingly well understood. However, in contrast to new construction, the maintenance of existing buildings depends primarily on two-dimensional (2D) blueprints, which play an important role in the conservation of existing buildings even now. However, to increase the effective use of BIM, it is necessary that tra-
Additional facilities management tools and methods be carefully considered.
At the large university campus chosen for our case study, an ongoing labor shortage requires numerous existing buildings to be checked and maintained by a limited number of workers. As a result, it is important to promote efficient management and maintenance practices. To facilitate this, it is necessary to grasp the problems particular to each building, and identify the troublesome components that contribute to those problems. Since usage and repair histories have been recorded and maintained for most existing buildings, it was considered likely that these records, as well as BIM, could be used for calculating time between component problems, and that BIM would prove useful for facilities management.

Furthermore, BIM technology has the potential to enable fundamental changes in project delivery, and thus support a more integrated and efficient process [3]. To that end, a common format has been developed to transmit information necessary for facilities management [4]. In a case study conducted over time, the use of BIM data for facilities management using numerous software applications at a university was examined [5], and a system that displays BIM data generated from BIM software on a website was developed [6]. Recently, research aimed at utilizing BIM in existing buildings has increased. For example, in existing buildings, unlike new construction, it is necessary to consider numerous problems, such as the unavailability of design documents and uncertainty in building conditions [7].

At present, even though a number of studies focused on developing facility management systems using BIM have been conducted, none have focused on the integration of BIM data with existing repair records.

**OBJECTIVE**

This study aims at forecasting the time between problems of the building components by integrating BIM data with repair records. Note that, whenever possible, original paper documents will be used to create the building models used in our method. In addition, attempts were made to calculate the time between problems of the building components via multiple regression analyses using explanatory variables from BIM and repair record data.

**REPAIR RECORDS USED FOR CALCULATION**

Tsukuba University’s repair records for this building were collected for integration with BIM data. An overview of the process and a simple totaling of the repair records are described below.

**Overview**

Table 1 shows an overview of the collected records. In our university, building users ask the Facilities Dept. to conduct inspections or repairs when problems occur. The document used to request service is transmitted to the Facilities Dept. by facsimile or email. Depending on the consultation contents, drawings and photographs of the building may be attached to the document. This format of repair record was selected because it is used most frequently. Additionally, since it is necessary to grasp the season-specific characteristics of each consultation, the documents for a full year were collected. This format is used for all of the 391 buildings on our campus.

<table>
<thead>
<tr>
<th>Item of information</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
<td>Document submitted for contacting the Facilities Dept. when building problems occur.</td>
</tr>
<tr>
<td>Period</td>
<td>April 1, 2014 - March 31, 2015</td>
</tr>
<tr>
<td>Coverage</td>
<td>Tsukuba campus (391 buildings)</td>
</tr>
<tr>
<td>Quantity</td>
<td>3,407</td>
</tr>
</tbody>
</table>

Table 1: Overview of Collected Repair Records
Results of Simple Totaling

Simple totaling was carried out based on the building name and reported consultations in order to gain an understanding of the characteristics of the collected documents. The consultation content results are shown in Figure 1. Because the category of “others” was seen most frequently among the items entered in this format, those contents were classified and counted. Based on those results, it was determined that consultations regarding “lamp bulb, fluorescent lamp” were most common, followed by “air conditioner”, “door”, “lighting fixture”, and “toilet drainage”.

A list of the buildings with the highest number of consultations is shown in Table 2. To consider the tendency of the buildings, two items extracted from documents obtained from the Facilities Dept. were added to the list. The results show that buildings with greater total floor area tended to have higher consultation numbers. On the other hand, post-construction building age was found to have no impact on the number of consultations.

<table>
<thead>
<tr>
<th>Building</th>
<th>Quantity</th>
<th>Year constructed</th>
<th>Total floor area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory of Advanced Research D</td>
<td>124</td>
<td>2003</td>
<td>14,651</td>
</tr>
<tr>
<td>Laboratory of Advanced Research B</td>
<td>121</td>
<td>2003</td>
<td>17,430</td>
</tr>
<tr>
<td>Medical Science Building</td>
<td>115</td>
<td>1976</td>
<td>24,340</td>
</tr>
<tr>
<td>Institutes of Engineering Sciences (Bldg. F)</td>
<td>105</td>
<td>1979</td>
<td>20,088</td>
</tr>
<tr>
<td>Building 5C</td>
<td>87</td>
<td>1973</td>
<td>18,027</td>
</tr>
</tbody>
</table>

FORECASTING TIME BETWEEN PROBLEMS

Next, we attempted to forecast the time between problems of various building components by performing a multiple regression analysis. This method enabled us to consider which factor determines the time between problems for a particular component. Information acquired from BIM data was added to provide explanatory variables. The components “door” and “air conditioner” were chosen in this study because they led to the highest number of consultations. In the buildings with the highest number of consultations, Building 5C was chosen.

Conversion from Paper Drawings to BIMs

This study utilized BIMs created manually from blueprints to forecast building lifetimes. In our previous study, we investigated this conversion process with the objective of determining how much of an elaborated 3D model could be reconstructed from existing drawings alone [1]. More specifically, using the Autodesk Revit BIM modeling software, which is widely used in the AEC industry, blueprints for Building 5C on the campus of the University of Tsukuba were converted into a case study BIM. An overview of this process is shown in Table 3. The same process was used to create the BIMs used in this study. Building 5C, which has been in use since the opening of University of Tsukuba in 1973, is a multipurpose building with laboratories and rooms for offices, meetings, and classes. Seismic reinforcement work on the building was carried out from 2006 to 2008, during which time the air conditioning, plumbing, and electrical systems of the entire building were also renovated.
### Explanatory Variable

A list of collected explanatory variables is shown in Table 4. The left table contains building variables and the right contains room variables. Building variables were acquired from repair records along with other materials. Years after construction, total floor areas, and number of floors were extracted from documents obtained from the Facilities Dept. and added. Power consumption peaks were extracted from the university’s electricity management system, while the highest temperature was acquired from meteorological data.

The conversion was performed using the design documents from the most recent renovation projects implemented in 2007 and 2008. Documents from the building’s original construction were used as reference material when areas not described in the renovation documents were identified. The 3D model created via this process is shown in Figure 2.

The inclusion relationship between classes is shown in Figure 3. Fixtures are included in rooms, and rooms are included in buildings. In this study, a multiple regression analysis is premised on relationships between classes, and the room variables can be to be added to the building variables when a room-based objective variable is adopted. Room variables, including attribute information for door and floor values were primarily obtained from BIM data. Doors, air conditioners, and air terminals within a room were counted in BIM data. Use of Autodesk Revit DB Link, allowed attribute information to be exported from BIM software to the database. In addition, lecture units, which were complied using a syllabus, were also added.

### Objective Variable

For time between problems, which was used as an objective variable, both building and room values were prepared. The former indicates the time between problems of the target class within a building and the latter indicates the time between problems of the target class within a room. These values were arranged by confirming the dates written in the entry columns for a building or a room.

---

**Table 3: Overview of Building 5C**

<table>
<thead>
<tr>
<th>Item of information</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Tsukuba campus (University of Tsukuba)</td>
</tr>
<tr>
<td>Year constructed</td>
<td>1973</td>
</tr>
<tr>
<td>Structure</td>
<td>S (partly steel-encased reinforced concrete [SRC])</td>
</tr>
<tr>
<td>Floors</td>
<td>B1F–6F</td>
</tr>
<tr>
<td>Total floor area (m²)</td>
<td>18,027</td>
</tr>
</tbody>
</table>

**Figure 2:**
3D model of building 5C

**Figure 3:**
Inclusion relationship between classes
Multiple Regression Analysis

Multiple regression analysis was carried out using SPSS, which is a statistical analysis software package. The forced entry method was adopted for the analysis, the results of which are shown in Table 5.

The coefficient of determination in the case of a room-based objective variable was higher than that achieved when a building-based objective variable was used. However, for only the air conditioner, the adjusted R-squared in the case of a room-based objective variable was slightly higher than that achieved when a building-based objective variable was used. When it was considered whether BIM was used or not, the adjusted R-squared using BIM was lower than that achieved when BIM was not used. But, because only one building was sampled, three variables were excluded when multiple regression analysis was carried out using a room-based purpose variable. The explanatory variables acquired from BIM data were not persuasive in this attempt.

Since a building-based objective variable was replaced with a room-based objective variable and candidates for explanatory variables increased by considering relationships between classes, the coefficient of determination would have become higher. However, because the numbers of explanatory variables were different between the cases, it is necessary to continue to examine the effects of the variables obtained from BIM data by increasing the number of samples.

CONCLUSION

In this study, in order to consider the integration of BIM data and repair records, we attempted to calculate time between problems of building components by performing a multiple regression analysis. A comparison of results calculated with and without BIM data was also performed. The multiple regression analysis results show that, for the adjusted R-squared, the value that was acquired using BIM data tended to be smaller than that obtained without BIM data. It was difficult to identify a persuasive variable from information from the BIM data in comparison with building variables. Because influences on the coefficient of determination by adding room variables were different between a door and an air conditioner, it is possible that it will depend on the class whether the coefficient of determination gets higher or not.

In this paper, our examination focused on items related to building fittings and air conditioners. Future work will involve carrying out multiple regression analyses regarding items related to electrical equipment. In addition, it will be necessary to increase the number of samples used in the calculations by adding buildings or expanding the period of repair records.
### Acknowledgements

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