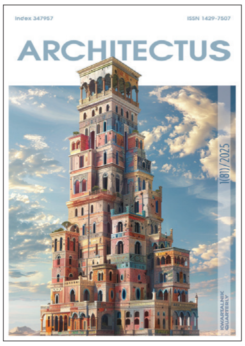

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Rafał Rucki*, Janusz Rębielak, Janusz Gołdasz*****

The impact of modifications to BIM environment tools on reducing the time required for developing drawing documentation in architectural design

Abstract

This article explores the impact of changes to the tools used in Building Information Modeling (BIM) technology on the efficiency of creating technical drawings in residential building projects. The study analyses how modifications to these utilities affect the time requisite to produce architectural documentation. The authors focused on the most commonly used BIM tools for this purpose.

BIM technology significantly accelerates the construction industry's creation of project documentation. Owing to its integrated structure, BIM software has the potential to improve further the tools used for specific design tasks. Three residential building projects with similar components were developed to identify the benefits of the proposed improvements. Virtual building models and their documentation were created using computer scripts that simulated work in two versions of the BIM environment: the default and customized. This method excluded delays and ensured the achievement of objective results.

The time demanded to complete the drawing documentation for a single-family house in the customized BIM environment was 49.87% shorter; for a multi-family building, it was 36.54% shorter; and for a building complex, it was 79.74% shorter. To compare the benefits derived from the changes against the time invested in modifications, experienced BIM users were tasked to model one of the projects, and their work time was measured. The outcomes were then averaged and juxtaposed with the time obtained by the computer, establishing a ratio between human and computer performance. The results also accounted for the time entailed to implement changes in the BIM environment, allowing an assessment of the cost-effectiveness of these modifications. In the cases studied, customizing the BIM environment proved advantageous for buildings accommodating a surface area of 600 m^2. Such a substantial modification process is typically required only once, with subsequent projects benefiting from the already-developed environment, leading to further time and cost savings. The results confirm that it is worthwhile to customize BIM tools and cultivate more profound software knowledge. The method described is one of the few that precisely demonstrates the tangible benefits of using BIM technology.

Key words: Building Information Modeling, BIM productivity, BIM objects, detailed design, environment customization

Introduction

The digital revolution has significantly influenced all science, technology, economics, and social life domains. The construction sector has undergone a profound transformation with the advent of computer-aided design (CAD). As a result of the rapid development of computational methods, Building Information Modeling (BIM) technology was introduced. BIM is a complex digital information system in building design, construction, and operation. It reduces design and implementation costs while improving the quality of produced documentation (Yang, Chou 2019). BIM is an advanced process that integrates creating, managing, and exchanging digital representations of buildings' physical and functional characteristics. Its primary goal is to improve collaboration, communication, and decision-making among all stakeholders. Additionally, BIM ensures data integrity across different software platforms. It enables real-time updates for automated processing at every project lifecycle stage

* ORCID: 0000-0001-7942-7282. Faculty of Architecture, Tadeusz Kosciuszko Cracow University of Technology, Poland, e-mail: rafal.rucki@doktorant.pk.edu.pl

** ORCID: 0000-0003-3135-5384. Faculty of Architecture, Tadeusz Kosciuszko Cracow University of Technology, Poland.

*** ORCID: 0000-0002-0226-3360. Faculty of Electrical and Computer Engineering, Tadeusz Kosciuszko Cracow University of Technology, Poland.

(Borkowski 2023)[1]. The prudent assignment of appropriate physical values to the properties of the digital model enables numerous beneficial procedures. These encompass clash detection, comprehensive documentation, schematics, visualizations, analyses, cost estimates, and logistical plans. Interdisciplinary coordination within the BIM environment can support early identification and resolution of potential issues before construction begins. Real-time sharing of construction schedules and asynchronous supervision on the BIM platform allows stakeholders to monitor venture progress. This collaboration platform ultimately improves process alignment and reduces the risk of venture delays (Cha, Kim 2020). Beyond its primary application, BIM technology also assists in building management and quality control. It provides detailed information on building components and systems. This technology is also employed in renovation and modernization planning, emergency interventions, and mitigating the environmental impact of buildings and offers valuable insights into their energy consumption (Sarvari et al. 2020; Azhar et al. 2012).

Despite its numerous advantages, BIM adoption in developed countries remains at approximately 70% of the market share within the construction sector's digital technologies (NBS 2020). As technology advances, governments increasingly introduce regulations in this field, encouraging investors and designers to utilize BIM. New standards are being proclaimed or implemented in developing countries, whereas numerous regulations are already enforced in developed countries. The protracted and delayed adoption of BIM can be explained by six key factors: existing legal frameworks, demand, interdisciplinary collaboration, the need for innovation, software costs, and implementation expenses (Edirisinghe, London 2015; Singh, Holmström 2015; Alreshidi, Mourshed and Rezgui 2017; Mitera-Kiełbasa, Zima 2024). Although costly, investing in BIM implementation often yields vast benefits in the design and management process. However, the perceived high cost of BIM software – especially in emerging markets – and the lack of awareness regarding implementation expenses, comprising training and software adaptation, hinder its full global adoption in the construction industry (Hong et al. 2020; Bui, Merschbrock and Munkvold 2016; Herr, Fischer 2019; Charef et al. 2019; Othman et al. 2021; Blanco, Chen 2014; Mitera-Kiełbasa, Zima 2023).

Each country has its own BIM standards, just as every professional user of this software has an individual approach to design. Consequently, BIM allows for tailoring its utilities according to user preferences. These customization options typically include interface settings, library objects, tools, and keyboard shortcuts. The next step in software personalization can involve creating and storing predefined configurations of tools and objects within a template file, which expedites project preparation. Moreover, using specially prepared BIM libraries augments user capabilities while curtailing the likelihood of abandoning BIM standards in favour of traditional CAD systems.

The primary objective of this study is to determine the ramifications of targeted customization of the BIM environment on the time needed to consummate three residential building projects explicitly designed for this research, each composed of similar housing units. The outcomes of the analyses provide nuanced insights into the merits of thorough implementation of BIM standards within the scope of this study. Additionally, the research proposes an innovative time measurement method to establish objective evaluation criteria for assessing the capability of this technology. A secondary objective is demonstrating the investment yield of individually targeted alterations to selected BIM environment functions.

State of research

As this article reflects, numerous scientific studies highlight BIM technology's noteworthy advantages. However, most of these studies rely on subjective perceptions, often presented as assertions lacking solid empirical evidence and on the widespread belief in BIM's pre-eminence. Another source of research is user surveys of BIM software, which consistently demonstrate the clear advantages of this technology over CAD. Ultimately, such studies can serve only as the BIM technology reception indicators. The primary criteria for assessing the advantages and usability of digital technology are increased efficiency – a reduction in the time allocated to accomplish specific tasks – and return on investment (ROI), defined as the ratio of profits to capital contribution.

Israel Kaner and his co-authors conducted four case studies on implementing BIM in prefabricated concrete structure projects by two medium-sized structural engineering firms (Kaner et al. 2008). They concluded that using this technology markedly improved project quality, with documentation containing fewer errors and requiring less temporal investment to validation, ultimately diminishing company costs despite the designers not being fully proficient in using the software.

Rafael Sacks and Ronen Barak conducted experiments to evaluate the assets of BIM in structural design, focusing on creating general and detailed drawings (Sacks, Barak 2008). They demonstrated an efficiency increase in documentation production ranging from 21% to 61%, incorporating an average improvement of over 40%. The total efficiency increase ranged from 15% to 41% for design documentation preparation and 16% to 48% for all engineering tasks. Additionally, they suggested that BIM could revolutionize design firms by diminishing the necessity for drawing documentation personnel and introducing a new professional role – the so-called structural modeler.

Salman Azhar presented case studies highlighting BIM's exceptional economic viability across various applications (Azhar 2011). One case study emphasized significant cost savings in the early design stage owing to clash detection, which is challenging to identify in 2D drawings. In another project utilizing a budget of $46 million, the estimated savings surpassed $200,000. In a different instance, presenting the client with three BIM models led to selecting the most cost-effective version, saving over 15% of the planned

[1] Based on a synthesis of existing BIM definitions.

budget. An ROI analysis for ten projects showed an average return of 1,633%, ranging from 140% to 39,900%.

In their case study, Kristen Barlish and Kenneth Sullivan pointed out the lack of a proper calculation method and a reliable basis for evaluating the strengths of BIM compared to CAD (Barlish, Sullivan 2012). They proposed a framework-based computational model derived from large-scale industrial settings, considering parameters such as formal requests for information, change orders, and schedule adjustments from an architectural and structural design perspective. This method was tested in three cases, showing substantial upsides of using BIM in the examined applications.

Nam-Hyuk Ham and his team investigated the use of BIM technology in generating production documents for prefabricated steel structures (Ham, Yang and Yuh 2019). They analysed the extraction of production documents for two modules consisting of 1,965 and 1,216 drawing sheets, including general layouts and single-part and single-plate assembly drawings. A comparative analysis between 2D CAD-based extraction and 3D BIM revealed improved efficiency, with documentation preparation time reduced from 17 to 16 hours for the first module and 12 to 7 hours for the second module. The efficiency of assembly drawing preparation increased by approximately 48.75%, curtailing the documentation processing time from 281 to 144 hours.

Beata Grzyl and her co-authors compared the time devoted to completing different design stages for a dental clinic and a residential building using traditional 2D CAD versus modern BIM (Grzyl, Migda and Apollo 2019). Their case study examined how both approaches impact design efficiency. They found that BIM saved 41% of total work time compared to the 2D approach, equivalent to 32 hours. BIM significantly reduces time requirements, with some design stages showing up to a 75% difference. Furthermore, transitioning from BIM to conventional 2D design can involve up to 70% more time, underscoring BIM's efficiency compared to traditional design methods.

A literature review identified a gap in research exploring the relationship between BIM environment customization and designer productivity. Despite this limitation, the scope of existing studies referenced in this article can be extrapolated to comparisons between CAD and BIM technologies, where industry-standard CAD programs can be related to the default BIM environment.

Methods

In the initial stage of the research, study samples were prepared in the form of blueprint sheets characterized by a uniform graphic design, allowing for impartial comparative analysis. During the research process, quantitative measurements of the completion time for each project were collected in two environments: default and customized. The default environment had minimal graphic modifications, while the customized environment was meticulously tailored to precise user specifications and preferences. The measurements were obtained using programmed scripts that simulated user actions when constructing the BIM model by replicating their interactions with essential peripheral devices used for computer control, i.e., the mouse and keyboard. The time expended on the project documentation completion was a benchmark for further calculations. Additionally, the time allocated to targeted modifications of the BIM environment was measured. The average time professional software users spent completing a given task was compared with the execution time of the script under identical conditions, allowing for an assessment of the efficiency ratio of human labour relative to computer processing time.

Implementation subject

Three documentation drawing sheets were prepared: a floor plan of a single-family house (Fig. 1a), a multi-family building layout incorporating a horizontal communication path (Fig. 1b), and a floor plan of a building complex with three vertical communication shafts per building module (Fig. 1c). The schematic plans presented in the aforementioned illustrations have a coherent graphic representation in the original project documentation at a scale of 1:50. Each of them contains the same library objects and shares residential units, assuming a minimal area is allocated for technical shafts and internal building communication. The single-family house includes a living space featuring a total area of 100 m^2 located on the ground level. In the multi-storey, multi-family building, ten apartments per tier are accessible from a common corridor and staircase. The living space on a single storey is 600 m^2, which represents 78.8% of the total floor area. The final case is a multi-storey complex with four identical modules arranged along two orthogonal axes. Each part of the complex has three staircases with elevators. A single level of this arrangement has 2,400 m^2 of living space, accounting for 77.67% of the total floor area. This last example is essential for research primarily attributable to its modular modelling method in BIM software. The created components allow mirroring and rotation to replicate the module within the model space, truncating the time devoted to documentation preparation. The time savings correlate with the number of inserted derivative elements, provided the BIM model adheres to the software standards.

The documentation of each project consists of three parts: the building plan, project information, and references, which together form a complete blueprint sheet (Fig. 2). The plan depicts the building with all relevant data for industry designers or construction contractors during the building process. The informational section contains all identification data related to project stakeholders, the object's location, and documentation details. The references explain abbreviations and symbols used in the project, while tables expand on drawing data by providing a comprehensive summary of separate zones, total building area, and details of structural partitions along with their components. BIM structures, which are virtual representations of building elements, namely walls, columns, beams, slabs, windows, doors, stairs, railings, and zones, constitute the drawing section of the documentation. Labels describing walls and slabs include their coded names, whose expansion in the reference section provides a precise description

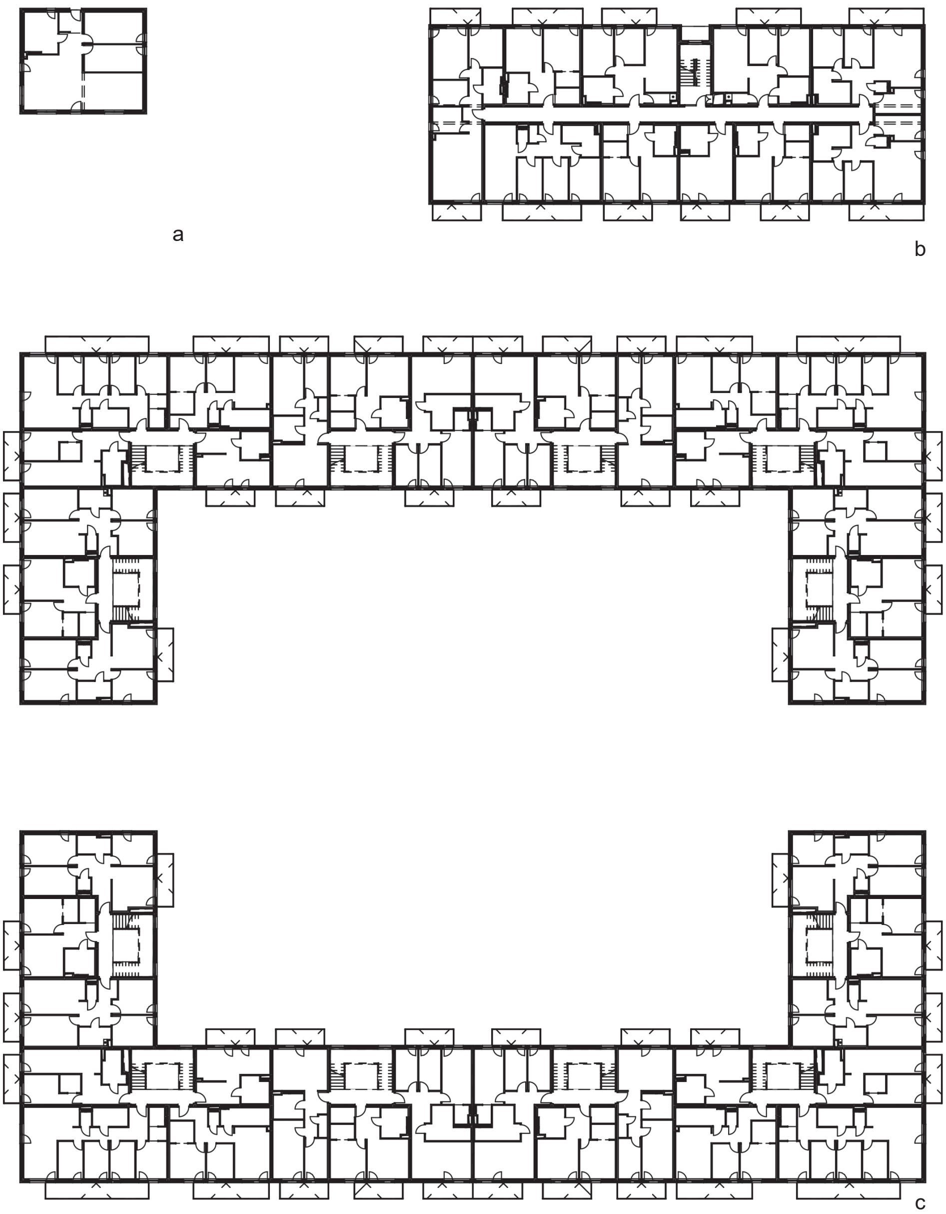


Fig. 1. Residential buildings plans scheme:
a) single-family house – 100 m^2,
b) multi-family house – 600 m^2,
c) block of flats – 2400 m^2
(elaborated by R. Rucki)

Il. 1. Schemat projektów budynków mieszkalnych:
a) dom jednorodzinny – 100 m^2,
b) budynek wielorodzinny – 600 m^2,
c) zespół zabudowy wielorodzinnej – 2400 m^2
(oprac. R. Rucki)

of each layer. The thickness of partition layers is also provided via internal dimensions in the plan, whilst the overall dimensions of columns and beams are designated using a dedicated tool. Zone metrics assign spaces to specific functions, detailing an identification number, zone name, type of floor finish, and the measured area of a given room. Information on windows and doors is presented using markers, i.e., labels displaying dimensions, identification numbers, object types, and the zone number in which they are located, following a sequential pattern within each residential unit. Additionally, these labels indicate the lintel and sill height, among other attributes.

Fig. 2. Layout division scheme
(elaborated by R. Rucki)

Il. 2. Schemat podziału arkusza projektu
(oprac. R. Rucki)

BIM tools

Projects consist of several types of BIM tools: structures, auxiliary components, and independent objects. In this article, BIM structures represent building components created using specially designed utilities. These include walls, slabs, beams, columns, roofs, windows, doors, and zones. Auxiliary components, by connecting with BIM structures, display attributes such as the code of their layered structure, dimensions, element height, or any other parameter previously entered in the building component. Auxiliary components also include dimensions in the BIM model, such as linear, height, radial, and angular, each with a dedicated tool. For these tools to work correctly, they must be interconnected to their source elements. Independent BIM objects represent building components without separate tools, such as numerical furniture or construction equipment models. This classification may vary depending on the BIM software.

Customized components

Interface

The program interface has been appropriately customized to optimize its functionality in this study. Therefore, tools that accounted for at least 4% of total utility usage in the documentation process were integrated into the one-click workflow or assigned to a keyboard shortcut. As a result, the interface allocated 31.1% of the screen area to tools and 68.9% to the workspace (Fig. 3). The impact of the ratio of workspace area to tool area on the project completion duration was not scrutinized in this study.

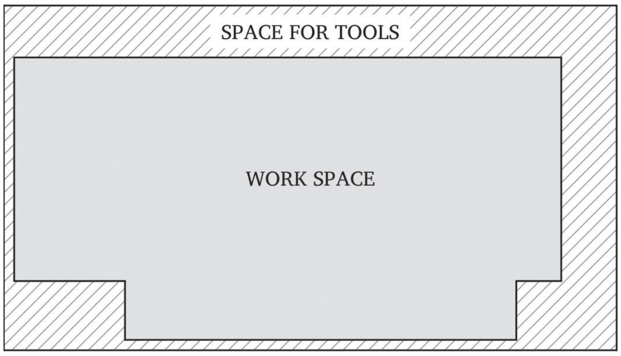


Fig. 3. Software's work space division scheme (elaborated by R. Rucki)

Il. 3. Schemat podziału ekranu roboczego w oprogramowaniu (oprac. R. Rucki)

Predefined tool settings and BIM object's properties

In BIM technology, tool settings and the properties of the structures and objects used are crucial, as they are later used in analyses, summaries, or schedules and influence the time committed to creating documentation. Each tool and object were predefined and placed within a two-click cycle in the customized environment.

BIM objects

All the BIM objects used serve to define the space precisely or specify the required construction techniques. They come from the default library and were modified in the source code for research purposes, as shown in Figure 4, along with the time invested in modifications and the deviation from the default object expressed as a percentage.

The following changes were made to the BIM objects:

– Sink: The static placement of water connections allowed the faucet position to be changed on the sink mounting side.

– Bathtub/Shower: The ability to display the object's dynamic dimensions on the plan was added to avoid problems in later stages of construction.

– Composite Profile Label: This object consists of two parts: the body and the line. It is commonly used to display a unique BIM structure code, referred to in the software as a composite profile. Reference to this value is explained in the appropriate section of the documentation sheet. The label lists all components of BIM structures, particularly walls, slabs, and roofs, along with their individual and total thicknesses. The modification was designed to automatically maintain a constant distance between the object's body and the BIM structure, thereby ensuring the readability of the drawing. As a result, the line length now matches the element thickness, which previously required manual adjustments for each structure.

– Door and Window Marker: In the BIM software, doors and windows are treated as separate objects with their tool, but they lack text data. Their presentation is handled by the marker object, which displays different data depending on the BIM structure. Improvements were made to the door and window markers, which now automatically include the building number, staircase, and apartment number. The marker was also enhanced to display the sill and lintel height and fix the fire resistance class display, eliminating limitations in integrating this object with schemes.

– Entry Label: This object is placed next to each apartment entrance, and its characteristic black triangle symbolizes the main door of the residential unit. The code's implementation facilitates seamless integration with the BIM structure by linking to the door object symbol and automatically capturing the apartment number, which is then displayed next to the apartment's abbreviation.

– Surface Label: Another improvement stems from the graphic representation of the project. Initially, the object displayed the name of the surface finish for the selected BIM structure. It was connected with a triangle-shaped indicator to ensure proper data readability. Using it as a labelling tool allowed it to be automatically affiliated with the BIM structure and a parameter referring to its finish.

– Zone Marker: Zones in the BIM software are crucial for storing and displaying data related to individual rooms, among others, floor area, floor finish type, or room volume. The customization project introduced significant changes aimed at streamlining the user's work. For example, the room ID number was tied to the building and staircase number to automatically generate the entire ID sequence, divided by a separator chosen by the user. The introduced function allows quick selection from predefined floor finish types, further speeding up the blueprint assembly. Such customization immensely reduces the time needed for zone numbering and potential modifications.

Results

User performance

A group of six experienced architectural designers, each with 5–6 years of proficiency in BIM software, was selected to create the second project (Fig. 1b) in the customized environment. Table 1 presents the parameters of their computer equipment. After familiarizing themselves with the configuration, they were provided with a template file containing predefined data, layout sheets, and operational

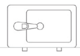
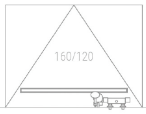
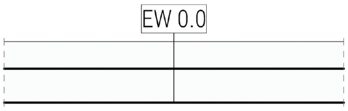
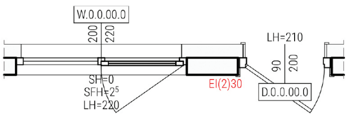
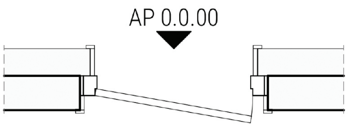
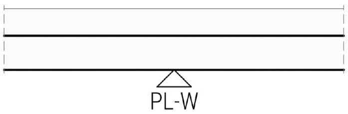
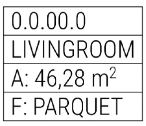
BIM OBJECT NAME	TIME SPENT ON CUSTOMIZATION [s]	CHANGE IN THE SOURCE CODE [%]	2D REPRESENTATION ON PLAN
WASHBASIN	3 210	2,85	
BATHTUB	1 220	3,33	
SHOWER CABIN	1 960	3,47	
COMPOSITE OF PROFILE NAME	1 340	2,76	
DOOR AND WINDOW MARKER	4 310	5,61	
ENTRY LABEL	1 470	3,84	
SURFACE LABEL	1 010	7,86	
ZONE STAMP	1 080	0,07	

Fig. 4. List of customized BIM objects (elaborated by R. Rucki)

Il. 4. Lista dostosowanych obiektów BIM (oprac. R. Rucki)

Table 1. List of software and hardware used in the research (elaborated by R. Rucki)
Tabela 1. Lista użytego oprogramowania i sprzętu komputerowego w badaniu (oprac. R. Rucki)

	Software						
Name, Version	ARCHICAD 24 INT, BUILD: 4018						
	Hardware						
Computer ID	User 1	User 2	User 3	User 4	User 5	User 6	Scripts
Operating system	macOS BigSur 11.5	Windows 10 21H1	macOS BigSur 11.5	macOS BigSur 11.5	Windows 10 21H1	Windows 10 21H1	macOS BigSur 11.5
Resolution	5120×2880	2560×1440	5120×2880	5120×2880	1920×1080	1920×1080	5120×2880
Processor	Intel Core i5 3.1 GHz 6-Core	Inter Core i7-8700K 3.7 GHz 6-Core	Intel Core i7 3.8 GHz 8-Core	Intel Core i5 3.4 GHz 4-Core	Intel Core i5-11400F 2.6 GHz 4-Core	Intel Xeon E5-2620 v2 2.1 GHz 6-Core	Inter Core i9 3.6 GHz 8-Core
RAM Memory	16 GB 2667 MHz DDR4	24 GB 3200 MHz DDR4	16 GB 2667 MHz DDR4	8 GB 2667 MHz DDR4	8 GB 2667 MHz DDR4	4 GB 2667 MHz DDR4	40 GB 2667 MHz DDR4

Table 2. Results of executing the second sample project by professionals in the customized BIM environment (elaborated by R. Rucki)
Tabela 2. Wyniki realizacji drugiego projektu przez specjalistów w dostosowanym środowisku BIM (oprac. R. Rucki)

Identification number		1	2	3	4	5	6	7
Run 1	Time [s]	33 149	33 642	31 693	33 732	30 814	–	38 369
	Compliance level [%]	99.12	99.61	96.53	99.45	94.20	–	99.41
Run 2	Time [s]	–	–	33 487	–	34 180	33 863	–
	Compliance level [%]	–	–	99.27	–	99.08	99.59	–
Average time [s]		33676						

guidelines and began modelling. The accuracy of their work, assessed using an image pixel analysis program, mandated that drawings achieve an accuracy of over 99%.

Half of the participants completed the task within a time difference of no more than 2%, meeting the required accuracy criteria (Table 2). Two drawings did not meet expectations, achieving accuracies of 96.53% and 94.20%, respectively. The authors were asked to correct the errors, and their completion times were recalculated. One participant met the accuracy criteria, but his lead time was significantly worse than the previous ones. Due to non-compliance with the BIM model instructions and the inability to repeat the attempt in light of learning effects, another designer was invited to perform the same task. Ultimately, the variability in all results remained within a 3% range of the times recorded for all participants, with the average completion time recorded as 9 hours, 21 minutes, and 16 seconds.

Computer performance

For each project, sets of source codes were developed to carry out tasks in two BIM environments: default and customized. Each command executed via the keyboard and mouse was recorded using specialized software, which saved it as a line of code upon receiving a signal from the controller. The code was then run in isolated conditions, and time measurements were made. This method ensured consistency in all results and excluded drafting delays. The time between operations was constant, eliminating discrepancies caused by changes in computer performance attributable to background operations, particularly system processes and data indexing. Although each delay was slight, their cumulative effect could significantly affect the measurements. Scripts were executed using Python modules – Pynput and Pyautogui – enabling simultaneous use of mouse and keyboard operations. The details of the computer equipment used for measurements are provided in Table 1.

Controllers

Mouse operations involve functionally separate commands related to screen pixels. The scripts operated in the native screen resolution of 5120 × 2880. The programmed commands had to be divided into operations for moving, dragging, single-clicking, double-clicking, and multiple-clicking within a specified time frame while simultaneously recording cursor position and time of movement. Scrolling was replaced with other commands, simplifying the programming process. Keyboard operations involved only pressing and releasing different keys or key combinations. Multithreading allowed the scripts to interpret more intricate procedure sets appropriately.

Measurement results

Table 3 presents the results of the time measured for completing computer tasks (CTET) in two columns. For the opening two samples, the right column shows the outcomes for the customized environment. For the third sample, the last column displays the time to create the documentation without the modules. The data show a significant difference between the compared environments. Using an individually addressed BIM environment reduced the time for drawing preparation by 49.87% for the single-family house project, 36.54% for the multi-family building project, and 79.74% for the complex building ensemble project.

The preliminary hypothesis assumed that time savings in the customized BIM environment would increase proportionally with the project size. However, the time obtained for the first sample contradicts this hypothesis. The first project uses the same number of BIM objects as the other projects but includes only single copies. This phenomenon highlights the significant time required to configure tools before use as part of the total documentation lead time.

User-computer task performance ratio

The user-computer ratio (UC RATIO) was calculated to account for the time devoted to file preparation and customization. This ratio was determined by dividing the average time for user-generated documentation in the second sample by the time taken for the programmed scripts, resulting in 2.8476. This ratio was then multiplied by each project's computer task performance time (CTET) individually to obtain the simulated user completion time.

Summary of calculations

Table 3 presents the study's results, showing the time devoted to creating documentation for three architectural projects of varying scales. The environment preparation time (EPT) was added to the time taken by the user (UTET) to assess the cost efficiency of the proposed adjustments. Analysis of the obtained results shows that considering

Table 3. Computer task execution time with following calculations (elaborated by R. Rucki)
Tabela 3. Czas wykonania przez komputer i dalsze obliczenia (oprac. R. Rucki)

Sample Number (Living Area)		1 (100m^2)		2 (600m^2)		3 (2400m^2)		
Virtual Environment Type (EPT[s])		Default (5723)	Customised (23158)	Default (5723)	Customised (23158)	Default (5723)	Default *MOD (5723)	Customised (23158)
CTET	[s]	1 961	983	18 637	11 826	86 731	46 920	17 571
	[hrs:min:s]	00:32:41	00:16:23	05:10:37	03:17:06	24:05:31	13:02:00	04:52:51
UTET (CTET * UC RATIO)	[s]	5 584	2 799	53 071	33 676	246 975	133 609	50 035
	[hrs:min:s]	01:33:04	00:46:39	14:44:31	09:21:16	68:36:15	37:06:49	13:53:55
UTET + EPT	[s]	11 307	25 957	58 794	56 834	252 698	139 332	73 193
	[hrs:min:s]	03:08:27	07:12:37	16:19:54	15:47:14	70:10:38	38:42:12	20:19:53
Relative Performance [%] (Default/Customised)		43.56		103.45		345.25		
Return on Investment [%] (Profit/Investment)		–84.03		11.24		1029.57		

Note: CTET – Task Execution Time by Computer, UC RATIO – User-Computer Ratio, UTET – Task Execution Time by User, EPT – Environment Preparation Time, *MOD – modules.

the time spent on modifying the BIM environment, the total time for plan development for the first sample was 129.56% longer than the default environment. However, for the second project, adjusting the environment reduced the time by 3.33%. The time consumption for the third project highlights the exceptional economic value of individually addressed BIM tool customization. When applied, the time for creating drawing documentation was reduced by 71.04%.

Additionally, presenting the data as an investment return indicator in the last row excellently exemplifies the savings in required work effort in the customized BIM environment compared to the costs of the customization process. This indicator was –84.03% for the first project, indicating a loss. The second project returned +11.24%. For the third sample, the investment was returned with a result of +1029.57%, emphasizing the significant rewards of addressed BIM environment customization for larger architectural projects.

Conclusions and discussion

The findings of the conducted research indicate a substantial increase in the efficiency of the designer's work when using the customized BIM environment for creating virtual building models and project documentation. The application of the developed environment demonstrated a substantial increase in productivity, notably diminishing the time necessary to complete drawing documentation sheets, ranging from 36.54% to 79.74% across all cases. An ancillary research goal aimed at determining the economic viability of this customization is complementary and relies on the outputs from a relatively small number of participants. The breakeven point for the investment in the customized BIM environment, where the savings from the investment cover its costs, was achieved for a building with just under 600 m^2 of residential space. Despite this limitation, experienced BIM users can compare their needs and estimate when such commitment might pay off in their cases. Future research should focus on gathering more detailed data on experienced BIM users worldwide to identify the size of a representative research group.

It is important to emphasize that such an extensive BIM environment customization is required only once in each design firm. Similar customization methods and the same objects, with occasional minor modifications, could prove helpful in subsequent projects. The ensuing adjustments may arise from changes in design assumptions, software updates, new ideas to extend functionality, or a desire to optimize the code. However, the time and resources needed for these improvements will constitute only a minuscule part of the initial outlay. For this reason, when calculated per unit of designed building area, the return on such an investment should almost proportionally increase with the number of completed projects. It is also worth adding that the presented results refer only to the initial version of the project. Any changes to the project would engender an increase in the profitability of this customization. Correctly executing the modules can multiply these benefits, elucidating the over 1000% return on investment for the third sample layout. In future research, it would be valuable to analyse the gains from customizing the BIM environment in the context of other types of buildings, such as non-residential ones, and projects from other industries beyond architecture. Also, an interesting avenue of exploration would be to examine the consequence of changes in the project on the return on investment in the BIM environment.

This research highlights the positive outcomes of addressing customized BIM environments and may encourage designers to invest in software improvements to increase their work efficiency. Such customization not only shortens modelling time but also improves the quality of documentation and the BIM model itself.

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Rafał Rucki

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Streszczenie

Wpływ modyfikacji narzędzi środowiska BIM na skrócenie czasu opracowywania dokumentacji rysunkowej w projektowaniu architektonicznym

Tematem artykułu jest wpływ zmian w narzędziach wykorzystywanych w technologii BIM (Building Information Modeling) na efektywność opracowania rysunków technicznych w projektach budynków mieszkalnych. Przedstawiono w nim wyniki badania analizującego, w jaki sposób modyfikacje tych narzędzi wpływają na czas tworzenia dokumentacji architektonicznej. Autorzy skoncentrowali się na najczęściej używanych narzędziach BIM wykorzystywanych do tego celu.

Technologia BIM znacząco przyspiesza proces tworzenia dokumentacji projektowej w branży budowlanej. Ze względu na swoją integralną strukturę, oprogramowanie BIM ma potencjał do dalszego doskonalenia narzędzi używanych do specyficznych zadań projektowych. Aby zidentyfikować korzyści wynikające z proponowanych usprawnień, opracowano trzy projekty budynków mieszkalnych złożone z podobnych części. Wirtualne modele budynków i ich dokumentację wytworzono za pomocą skryptów komputerowych, które symulowały pracę w dwóch wersjach środowiska BIM: domyślnej i dostosowanej. Taka metoda pozwoliła na zredukowanie opóźnień i zapewnienie uzyskania obiektywnych wyników.

Czas realizacji dokumentacji rysunkowej dla domu jednorodzinnego w dostosowanym środowisku BIM był krótszy o 49,87%, dla budynku wielorodzinnego o 36,54%, a dla zespołu zabudowy o 79,74%. Aby zestawić korzyści uzyskane z wprowadzonych zmian odnośnie do czasu poświęconego na modyfikacje, projektanci biegli w obsłudze oprogramowania BIM zostali poproszeni o wykonanie modelu jednego z projektów, a ich czas pracy został zmierzony. Te wyniki zostały następnie uśrednione i porównane z czasem uzyskanym przez komputer, dzięki czemu ustalono stosunek między wydajnością pracy człowieka i komputera. Wyniki te uwzględniały również czas potrzebny na wprowadzenie zmian w środowisku BIM, co pozwoliło na ocenę opłacalności ich wdrożenia. W badanych przypadkach dostosowanie środowiska BIM okazało się korzystne dla budynku o powierzchni

600 m^2. Tak obszerny proces modyfikacji jest zazwyczaj wymagany tylko raz, a kolejne projekty mogą korzystać z już opracowanego środowiska, co doprowadzi do dalszych oszczędności czasu i kosztów. Otrzymane wyniki potwierdzają, że warto dostosowywać narzędzia BIM oraz rozwijać wiedzę projektantów w tej dziedzinie. Opisana metoda jest jedną z nielicznych, które dokładnie pokazują rzeczywiste wymierne korzyści z używania technologii BIM.

Słowa kluczowe: modelowanie informacji o budynku, BIM, wydajność BIM, obiekty BIM, projekt wykonawczy, dostosowanie środowiska BIM