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An investigation on algorithm aided BIM approaches to increase collaboration and optimisation in project phase: A case study

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Abstract

There is a need for new workflow that comes with Algorithm Aided BIM to be used and modified by different users within business association. If efficiency of new workflow is valid only limited users, automation provided in the project doesn't fully ensure the reduction of stress because of extensive labor and limited time. For this purpose, it is aimed to create a cooperative working environment for users, who have different programing knowledge level, in the new workflow like BIM. In the present case, there aren't comprehensive studies because of that it is aimed to prepare an approach plan for standardisation of new workflow in order to spread the usage among the employees and to provide comprehensive optimisation in the project phases. The approach is tested with a case study to show the effects on a project phase. As a result of the analysis, it is concluded that algorithms reduce the tension arising from the heavy workload in the projecting process but for the comprehensive optimisation, algorithm is not sufficient. Algorithm should be standardized to increase the company-wide usage, reduce the dependence of users on each other and pauses, caused by lack of information. In the absence of standards, in spite of being able to optimize, it is monopolized by the limited user and it is difficult for new users to understand and adapt. Therefore, in addition to the algorithms, used to reduce stress due to heavy workload and time loss during the projecting phase, the use of a common language or standards are necessity for companies.

Keywords
Algorithm aided BIM, BIM, Parametric modelling.

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1. Introduction

Building Information Modeling (BIM) has become widespread with supplying integrated environments for different disciplines. One of the pivotal goals of BIM environments is to build a virtual construction model of the building by incorporating everything into a single source model. Depending on object-based logic, BIM consists of multidimensional digital representations and features of various facilities. The objects used in BIM programs are smart components that contain data and parametric rules. By means of the database used in BIM programs, relations with different objects can be established. In this view, building components can be modified in a single place, allowing differentiation in all dimensions. Since all phases of a project can be executed through a single model, BIM provides opportunities to organize workflows that will increase efficiency in the project phase. Moreover, problems that can be encountered in the design and construction process can be predicted from the beginning and resources can be managed correctly and controlled by the stakeholders.

One of the common problems in the context of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) approaches to architecture offices today is the lack of communication between different disciplines. As a result, conflicts can arise between different actors and problems could be more dramatic because of causing a costly change in the progressive stages of the project. However, advancing by adopting the integrated design approaches from the first stage of the project process, problems that may be encountered in the future can be reduced. As a result, BIM supports both the design and construction phases of the project and offers better analysis (for the building life cycle), control and testing as opposed to produce by conventional CAD environments. The increasing level of complexity and the data load in computer aided design models such as vast number of parameters, variables, assumptions, relations among geometries necessitate a new perspectives to handle the complexity.

Aish (2013) approaches CAD in three eras: the 2D drafting era of early 1980s, BIM era consisting of 2D drawings and 3D models of buildings and later the design computation era (Aish, 2013:5; Humppi and Österlund, 2016). Aish's term of design computation era points out multidimensional generative and relational 3D building models which are coded and executed by using data through graphs or scripts. Generating a 3D building model through graph or scripts provides opportunities for merging design, analytical and fabrication models in one model and also design automation. In other words, different phases of a project can be represented in one model through parameters and relations. Investigations on ways for expanding the boundaries of BIM towards design computing led to led to the emergence of the concept of Algorithm-Aided BIM (Humppi and Österlund, 2016).

Further to the theoretical discussions on the integration of algorithmic approaches and BIM, today in practice as well, it is possible to generate 3D building models in BIM environment based on constraints, rule sets, and requirements of project to achieve more efficient solutions. It can be considered as the reflection of object-oriented low-level programming logic onto computer-aided design representation. In a broader sense, depending on the efficiency of the algorithms, the efficiency and overall performance of the project phases can be improved. However, in this case it becomes important to investigate what kind of algorithms and at which extend the algorithms improve the efficiency in the project phases. For example, when the designers do not have experience in coding, would traditional way of using BIM become more efficient?

In the scope of this research, collaboration of different disciplines through Algorithm Aided BIM approaches is investigated. Moreover, the potentials and limitations of Algorithm Aided BIM are discussed in the context of complex optimisations during the project phase. We argue that Algorithm Aided BIM approaches accelerate the adaptation of users to different levels of knowledge through algorithmic workflow in collaborative design processes in which different disciplines involve.

The preliminary results show that without standardisation in collaborative environment, optimisation merely coming with algorithmic approaches does not fulfil the overall efficiency expectations. Due to the fact that, standardisation of Algorithm Aided BIM project process is investigated for comprehensive optimisation. In the current situation, there is any standardization for the Algorithm Aided BIM project stages. The aim of this study is that standards for the new approaches are prepared with the help of the subway design project which is undergoing the design process and literature review.

2. Algorithm aided BIM

Algorithm allows users to find a solution efficiently with his/her own recipe. In order to make the project process algorithmic, firstly, a problem needs to be identified, and the solution is abstracted according to the problem context. This abstraction is based on translating a nonlinear process into a linear logic, defining infinite number of possibilities through finite number of steps by using variables, functions, operations and relations. The relations involve organisation and automatisation of repetitive actions, iterations and recursions. Further to the constitution of algorithms, in most of the cases the variables are differentiated, and the solution is tested. This very basic description of algorithms can be applicable and elaborated in different contexts and cases.

When it comes to BIM, certain associations allow the entire system to be managed by a limited number of users under network control with algorithmic approaches. Algorithms have potential to reduce the workload and time spent in the project development, particularly in repetitive tasks. Moreover,, since the entire system is related to each other, the data network can be visualised more clearly through visual scripting environment. Therefore, changes in the data network and the new design decisions become trackable by different actors

BIM programs are based on the interrelationships between the objects controlled by the variables. Modifying the variables give alternative model results. As expressed by Eastman et al. (2011), there is algorithmic infrastructure at BIM programs. While the entire system is under control in the algorithmic modeling, the object-based singular control is observed in BIM programs. Therefore, as the model variables become complicated, difficulties of adapting to changes and the number of errors is increasing. Because of that, the relationship between BIM and the Algorithmic Modeling is investigated and attracted much attention (Janssen, 2014).

In algorithmic modeling, users develop a general logical scenario and controls the entire system. This gives the user a very comprehensive and automated process. However, in BIM programs, parameter control can not go beyond the object base, and systems in this context differ from algorithmic modelling. According to Boeykens (2012), many users use algorithmic modeling software to produce complex models and transfer them to BIM programs after model reaches a certain level of maturity. After the model transfers to the BIM environment, there is no return. Furthermore, for programs aiming to create a rich database like BIM, only the introduction of geometric representations from the early phase of design is causing serious information loss.

Within the scope of this research, it is suggested that the user should adapt to algorithm aided approaches in order to reduce the workload, to control the process more and to design the possible events in a short time.

Algorithm aided approaches provide users with the ability to automate tasks, generate parametric geometries, and giving ability using model to perform various engineering analyzes. Users are constantly working on different alternatives to reach the best solution. However, in order to achieve more efficient solutions, algorithm provides the programming of decisions based on constraints, rule sets and project requirements. This provides a transition from more traditional solutions to a wider range of possibilities.

In traditional BIM project steps, users, who need to work intensively and

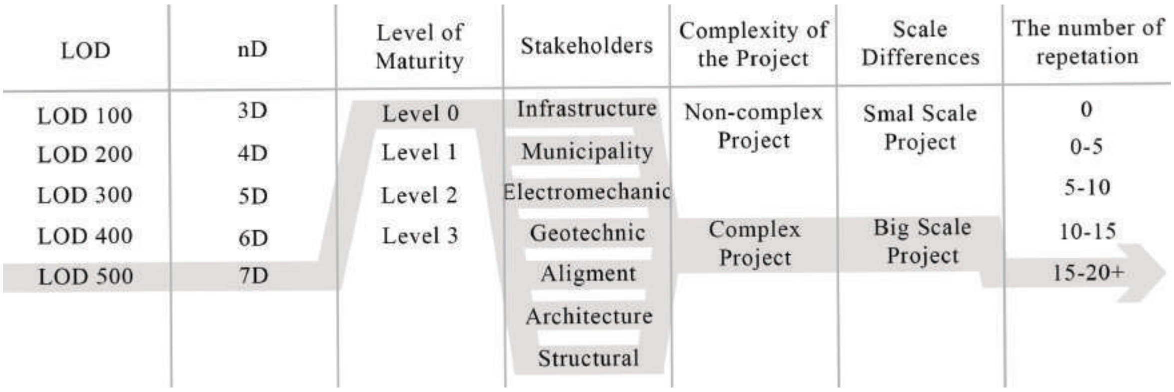

Figure 1. *Factors that push the user in the process of BIM.*

spend a lot of time, are searching new project steps. This study aims to examine which project steps might need more time and effort in the modeling process. These steps, at which algorithmic definitions become more efficient in comparison to traditional way of BIM usage, are defined as breakpoints. At the breakpoints it is considered that transformation of the BIM processes into algorithmic processes would be more advantageous. In the scope of the study, seven breakpoints are determined based on the individual experiences of the author and literature review.

Controlling the data load and finding the required information from the desired layer are some of the crucial problems facing the user. These lead to breakpoint in the project workflow. As shown in figure 1 below, there are seven factors which cause the breakpoint. The increase in LOD (Level of Development), nD (dimension of model), the maturity level of the model, the number of disciplines, the complexity of the project, the scale differences, and the number of repetitions of similar operations push the user into new workflows because of increasing the number of data loads and variables in the model. More integrated systems are needed to strengthen the parametric infrastructure of BIM so that all expected operations can be done correctly and accurately at a limited time.

3. Application method for algorithm aided BIM

BIM allows many disciplines to cooperate in a single database. In this way, all disciplines can follow and control the process from the first stage of the project. As a result of the integration of algorithm aided approaches and BIM, new project steps need to provide possibilities to work within unity. Otherwise, there may be information loss between project phases due to the disunities. This study aims to prepare a cooperative working plan for different disciplines in the visual programming environment (algorithm aided environment). However, it is difficult to make a general plan that defines algorithm aided project steps because the method to be followed is various even though the goal is only one. While defining new workflow, it is aimed to present a proposal to give the users a general idea about algorithm aided project steps.

The process can be converted algorithmic to solve the problem. However, it is also important to develop an algorithm in a standardisation to work in cooperatively because the established logic can be changed with the arrival of a new business decision. At this stage, changing the algorithm against the new problem may cause purpose to change. This could cause moving away from the solution, or even uncontrolled progression. It may also need efforts to reestablish the logic of the algorithm. As a result, other users need to be able to understand and interpret the flow of the algorithm when it is examined. For this purpose, it should be made orderly and understandable.

A remarkable amount of study has been done to improve the usability and intelligibility of prepared algorithms. For this purpose, visual programming is developed to meet this need. Visual programming is an easier language than script language (Crafai, 2015). In visual programming, codes are also modular. When the user indirectly creates a program graphic, it generates programming codes hidden in the nodes of the graph. The level of complexity could be reduced with the algorithm being modularized. Moreover, according to a survey of 25 participants by Woodbury et al. (2007), designers have observed that the small changes in the algorithm have increased the clarity of the script. Woodbury et al. (2007) mentioned that it is necessary to group the script in modules that do similar works. In this way, scripts can be represented in groups so that the design intent is more clearly conveyed to the other users. In addition, for the grouping of patterns according to Alexander's (1977) definition, it is necessary to clearly define the problem, the abstract solution and the results. Therefore, the process shouldn't be limited to only grouping of modules. Woodbury (2010) also mentioned coloring scenarios. This coloring ideas was produced by him based on Christopher Alexander's design patterns. It is colored by similar commands or problem solutions, making it easier for users to understand the pattern.

Today's object-oriented programming foundation reflects onto the way of creating logic in the graphical user interfaces as well. The objects incorporate their own design philosophy into their own pattern of their own worldview at the structural level within the group they belong to. The coloring scenarios have potential to improve clarity while coloring creates bridges between script, operations and the 3D building model.

The standards related to visual programming which are examined in this study can be adapted to Algorithm Aided BIM tools. In the scope of the study one specific program was chosen to be used due to avoid potential differences caused by program limits. Standards are established according to the most widely used BIM tools in program selection. According to a study by BIPS (2014), the most commonly used software in architecture, engineering and construction was found Autodesk Revit program. Therefore, Algorithm Aided BIM is being implemented through Autodesk Revit which is preferred by applications and standards generally. As a visual scripting environment, Dynamo which is an open source add-on for Autodesk Revit was used. On the other hand, it is possible to use Dynamo outside of or in Revit. Dynamo provides diverse possibilities for object creation, object modification and data management. In terms of expanding Revit's capacities towards computational design tool, Dynamo enables customization in design processes.

Currently there is no commonly accepted standard for the use of Algorithm Aided BIM. The work of White Research Lab has been observed, indicating that these tools are designed to promote wider use at the office regardless of the level of experience among employees (Ondejcik, 2016). According to the firm standards, the functional part of Dynamo is divided into two sections: the user interface and the background. The partitioning provides for the distribution among users with various visual programming skills. Users with very basic skills can interact with the interface without ever having to worry about ruining the backface function. The interface is supported by color coding to describe the functions of the algorithm. The bright colors are open to user interaction and the gray colored groups are related to the back face. The back face is used among the users, who have advanced level of knowledge about algorithm.

It is considered that Algorithm Aided BIM environments need to allow different users with different programming knowledge level to be used. For this purpose, Christopher Alexander's patterns are set out to show how different users would include an algorithm for classification and what kind of information is needed for a better understanding. Since there is no specific standard in the present case, limited amount of published standards were examined. In order to achieve a standardization in Algorithm Aided BIM, the following items are assumed to be defined as minimum requirements:

- Group definitions and project description,
- The purpose of the algorithm,
- Algorithmic way of design descriptions,

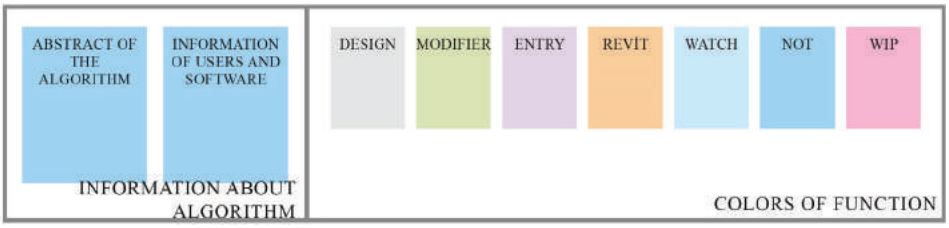

Figure 2. *Dynamo usage template.*

- Problem should be prepared by grouping the algorithms for the solution purpose.

The above mentioned 4 items are the logic of establishing the algorithm that should be standardized by the users at different levels apart from the the program focus. The standards to be created in the program are examined with the sample works produced in the project process. The advantages and deficiencies are tested and an alternative standard is proposed for project firms.

A template was created as shown in Figure 2, using Woodbury's (2010) algorithm to classify algorithms, Alexander's (1977) idea of design patterns, grouping methods used in Grasshopper visual program software, and standards established by White Research Lab using Dynamo software. Groups are colored according to their functions so that different users can understand the algorithm and their functions are settled and their functions can be easily understood.

In the information section (Figure 2), a brief summary of the algorithm is described containing the name of the person who prepared the algorithm and the information about which version of the software is used. In this way, other users would know who to consult when they want to get information about the algorithm. Specifying the information for each module of the algorithm reduces the information loss. Therefore, when a part of the code will be changed, the change history would be trackable. Specifying the version is crucial. Otherwise, the same code may not work due to changes or removals of functions in a short time.The information section is expressed in blue color.

In order to increase the intelligibility, the blocks in the algorithm are grouped by their functions. This way of grouping also provides a better understanding for the users who do not have programming experience. The gray color refers to the part that makes up the design, is defined as the background and is not open to all users. By differentiating the access permissions to the background code, the program code is protected from potential errors made by novice users. The green group is the modifier of the algorithm, which allows assigning new information on the objects. Invalid information seen in the database can be checked by the control groups because it is the last place the data was stored before it was written. Purple group includes geometry and other limitations. The orange group refers to the groups associated with the Revit program. It includes commands such as obtaining information from the project, selection procedures, writing information. The light blue group is the part used for data surveying in the algorithm. Commands such as data extraction from outside are included in this group. The dark blue groups refer to information parts. Algorithm descriptions, user information and writing information are included in this section. The pink groups refer to the code being studied.

The necessity of the created template, its deficiencies and developments are examined by case study.

4. Assessment of standards with case study

In order to reduce the tension caused by intensive workload and time-consuming during the project phase in BIM environment, it is aimed to establish an approach for the companies that want to switch their projects and workflow into Algorithm Aided BIM process. Creation object-based database in BIM makes it possible to work more efficiently and synchronously at every step of the project process in comparison with the conventional usage of BIM. Unlike the conventional methods, the users can focus on design decisions, rather than spending time on documentation. However, the integration of BIM with algorithm aided approaches can be achieved by the end of project planning, automation and optimization by consuming less labor and time. If multiple disciplines are considered to work at the same model in BIM, relatedly a similar approach needs to be followed in the case of the Algorithm Aided BIM. In order to test the validity of the assumptions on algorithm aided approaches in BIM, a case study was established. Users with different backgrounds in one construction company have attended to the case study. The following questions were investigated through the case study based on design and development of one subway project:

- What can be the need for algorithmic approaches to BIM environment?
- Is it possible for the project stakeholders involved in the project planning process to work in a coordinated and collaborative way in Algorithm Aided BIM processes?
- How can users who have different programming knowledge levels adapt to the Algorithm Aided BIM process?
- What method should be used in the process of model development for users who go to Algorithm Aided BIM processes?

The reason for choosing subway project is that the author has a desire to benefit from professional practice and experience and is more dependent on the collaborative working environment and information exchange, which is important because of the important role of the other stakeholders same as the architects.

For the collection of data, the individual experience of the author in the subway design,the information collected from the construction company through informal interviews, objects, materials and equipment purchased from the project company, design decisions taken in the process, the collaborative studies with other disciplines in the project process were used.

As a result, it is aimed to develop an implementation method for Algorithm Aided BIM in order to minimize user-focused time consuming and labor-intensive tasks with investigation of the case study. With the help of algorithm, users reduce this tension in the project planning environment. However, the algorithm needs to be managed and implemented by different users. For this purpose, the breakpoints, application approach and method for the transition to the algorithm aided workflow in the project phase are examined in the case study.

The case study is conducted by an empirical test method. Theoretical assumptions were developed as algorithm aided workflow and tested with case study. A particular workflow planning and implementation method were developed for Algorithm Aided BIM. Breakpoints in BIM workflow were determined with the number of repetitive tasks in the project process, introduced by Reseller's (1998) complex model definition and the list of repetitive tasks were expanded based on the author's observations in relation with the the representation levels of BIM and the number of disciplines involved in the project process.

In the beginning of the case study, , the intensive workforce in the project planning phase and time-consuming workflow are defined as breakpoints. Further to the definition of the initial breakpoints, involvement of each new breakpoint and their impact on overall efficiency were evaluated. Assessment of the subway project processes were considered as preliminary, final, and application respectively. The project processes were evaluated according to the 6 factors that can cause the breakpoints, which lead to transition to algorithm aided workflow. These factors were examined in terms of LOD, nD, maturity level of the model, number of disciplines, complexity of the project and number of repetitions in the project process. Based on the evaluation results, it has been assumed that either repetitive, iterative, recursive operations or the design model need to be reconstructed through algorithms where a tension was emerged causing the need for a breakpoint. Algorithm Aided BIM workflow were prepared in Dynamo software. However, it was not

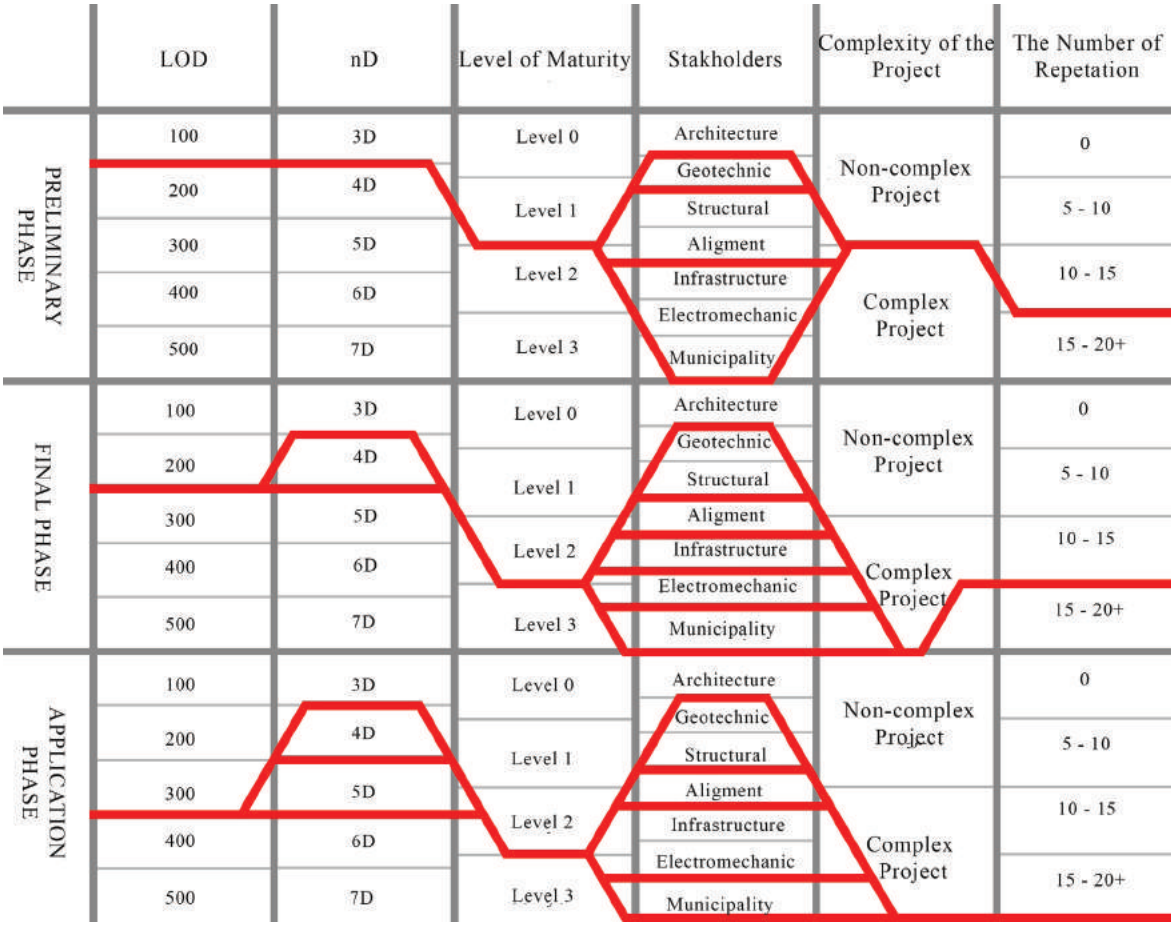

Figure 3. Factors pushing users in subway design processes in BIM environment.

considered sufficient to use merely algorithms, provide optimization in the project process. Apart from those,there had been a necessity to integrate the Algorithm Aided BIM for the usage of different stakeholders. This is because the standards were generated to be open to any use in the selected construction company.

When the preliminary project phase has been evaluated based on the above mentioned Figure 3 according to 6 breakpoints, the decisions in the earlier phase of the project were limited. Therefore, it was difficult to capture similar patterns according to design decisions. Furthermore there were few breakpoints in the modeling process that push the user to initiate new workflows. Algorithm aided workflow was not needed at the preliminary stages in the subway project because model components were consisting of low level of detail. Along with the increase of the data load in the project process, the need for algorithm aided workflow was started.

The steps at the final project were evaluated according to the 6 breakpoints as well. The final project phase was depended on collaborative works by users from various disciplines. Moreover, the level of detail of the objects was complicated, so the databased was enlarged. In the modeling section, the objects were encoded in the visual programming interface. The coarse layout plans have been differentiated after the inclusion of the electromechanical team in terms of equipment layouts, equipment coding, room entrances and exits, door directions and locations. Therefore, as the number of decisions taken in the project increased, the data and workload in the project have been also increased. To update the database, each object in this phase has been used with their own code, which were modeled in the relevant standard. However, there have been a lot of tasks that were repeating in the final project phase with new design decisions. There has been a need for controlling the data during repetitive operations. Otherwise, since it was not a geometric representation, mistakes were observed in the uncontrolled workflow. As a result, the number of breakpoints, the number of disciplines working on the project are causing serious workload and waste of time, which lead to adherence to algorithmic workflow at this stage. Furthermore, in order to be able to draw the project, it was necessary to translate BIM programs in accordance with the workflow and parameters. With 4D modeling, controlling different parameter and validation of the data were required as well as completing on time. For an efficient project process, regular checks and adjustments needed to be done.. However, as the project process has become more complex, it became more difficult to control. In the cases when controlling the code and the model became difficult, the user has searched new workflow in modelling process. This led to breakpoints in the workflow.

Further to the evaluation of the application phase based on the specified 6 breakpoints, it has been observed that the detail levels of the objects were increased. Identification of the companies and writing these information into the objects and information complexity increased workload on the user. As the cost estimates and analyzes were made with 5D modeling in the application phase, the accuracy of the information in the database has also played an important role Although at the maturity level of 2, the data flow between different users appeared to be more efficient and easier, it took time and effort for a few stakeholders to learn and understand basics of BIM and algorithmic definitions. Coordination was difficult with project stakeholders in the further phases where shared data got more details. Moreover, the increase in data load have brought additional need for changes in the project and also accelerate the workload through repetition of the similar jobs. The more the complexity of the model has been increased in the application phase, the more control need has been occurred in each change. However, in large infrastructure projects involving thousands of entities, it has been very difficult to control the model in each change. Parametric workflows were needed to overcome the difficulties regarding the control problem in BIM program. In a broader sense, when the application phase was evaluated, it has been difficult to transfer the system details of the identified companies and review the model, control the data load and process the information in the database. Each discipline worked in more detail at this stage. As a result, when the application phase was evaluated, it was the phase where stakeholders have needed the most algorithm aided workflow. In addition, improvements in the project process and software cause less labor and time spent in the project process of BIM tools.

In the project development phases of the subway project, it has been observed that an integrated environment was needed in which Algorithm Aided BIM processes can be implied and executed. In order to reduce the heavy workload of the project process, not only algorithms but also standardisation for the stakeholders were needed to work in cooperative environment. The validity of the standards has been tested in BIM project processes. According to the result of the analysis, algorithms should be standardized in an environment that is open to business cooperation. Otherwise, discontinuities in communication among different users have been observed. In order to increase the adaptation of users with knowledge of different programs, clarity of algorithm needed to be improved by informing and separating function groups. In this way, the generated algorithm relatively has become more efficient and more open platform for articulation. Inferences from the subway project process and the platform, on which the algorithm was built, should be split into two parts: information and functions.

As shown in Figure 4, information sharing and function sections of the algorithm are used to express company wide workflow clearly and spread the usage of the algorithm between different users.

Information section:

- The name of the person who prepares the algorithm,

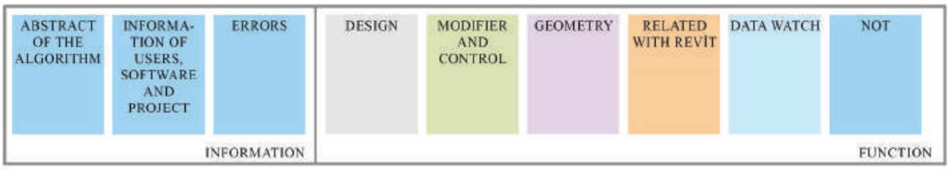

Figure 4. *Companywide usage standards.*

- The version prepared by the algorithm,
- If additional package is used,
- A short text in which the algorithm is created,
- If there is a file exported from outside, the extension of this file,
- If the prepared algorithm is specially prepared for a project,
- An informative article explaining how to solve the mistakes in the use of the algorithm,
- If the existing algorithm has been developed, a summary of who has developed and the new logic should be written.

Whenever there has been a change in the algorithm, other users automatically were informed about the about who made the change. In this case, the version of the Dynamo became important. This is because, there were different applications in the different version of the software which has caused confusions. When an error has occurred in the code execution, the version needed to be changed, users were aware that there might be changes in the blocks. Moreover, in the cases that additional package was used, the relevant information has been updated in the infornatiıın section so that other users could learn what additional packages to install before running the code. In this way, the disruption caused by the fact that the package was not in that user has been removed. It has been necessary to write a brief note for informing the logic of the algorithm.

The changes might be forgotten even by the creator of the algorithm, when it is not used in the long run. The observations derived from the case study shows that to avoid reestablishment of the algorithm resulting from the loss of information in the process, a brief description and an approach to the problem should be clearly stated. Some algorithms are specially defined to the specific project or specific problem. It is necessary to write the information about which project and when these algorithms are not used in the whole company. Users with different levels of programming knowledge are able to solve specific problems without the need for advanced users, as they are involved in the process. For this purpose, if the solutions of the mistakes is informed, users are solved without help of advanced user who has high programming knowledge. As algorithms are used in the process, they are modified or improved due to changes in new requirements or project decisions. If the summarizer of the algorithm and the summary of the innovations are included in the information section of the algorithm, the information loss between the development process is also prevented. As a result, Errors and reference for external file path in the information section is seen as necessity to decrease dependency of users to each other, when the project phase samples are tested from the logic of classifying algorithms, the idea of design patterns of Alexander (1977), the grouping methods used in Grasshopper visual program software and the standards prepared by White Research Lab's Dynamo software. For this purpose, it is necessary to explain what the user should do in response to the error in parameters. In this way, the need to users who know advanced programming could be reduced. Thus, the ability of the users to generate a solution against a certain level of error can reduce the pauses in the process. For this purpose, as the project principle is guided, the solution should be expressed clearly in the guidance section as the error arises. Specifying the source of the file to be exported is to ensure that the relevant file is available without consulting each time to the people who have contributed in the process of preparing the algorithm. With this type of comprehensive information writing, stakeholders are trying to be adhered to new business steps by reducing the need of users with different levels of programming knowledge to other users.

Function section:

In the part where the algorithm is established, grouping and coloring of modules in according to the aims are effective approach as seen in case study. When user looks at algorithms, they could be read easily. As shown in figure 5.39 above, although inside of algorithm groups is not understood by users, purpose of groups could be understood clearly. The coloring and naming of the groups increase clarity to convey the purpose. In particular, explaining what to choose in the selection blocks makes it easier to adapt algorithm. As a result, when the samples at the projecting stage are tested according to the criteria of Woodbury's (2010) classification algorithm, Alexander's (1977) idea of design patterns, the grouping methods used in Grasshopper visual program software and the standards prepared by White Research Lab's Dynamo software, the presence of the block at WIP is considered unnecessary and confusing. The code that is studied may be inaccurate or incorrect. It will be more accurate to work in a new folder instead of going through the same code. With the division of the function groups into interface and back sides, users with the low level of programming knowledge level is separated from the advanced user. In this way, different stakeholders can attend the process without breaking the code of logic. In addition, with the grouping of blocks in the interface, users with a low level of programming knowledge can more easily understand and contribute to the algorithm.

As a result, it is observed that the workload can be reduced by algorithm aided approaches. Working on the joint project by different stakeholders in BIM shows that planning new workflow is also necessary. Otherwise, the new workflow move more independently in BIM process and there may be breaks in the project phases. Standards must be established so that new workflow can be used by other stakeholders. In order to test the validity of the prepared standards, the project process is still being investigated through the ongoing subway project during the period of the survey. As a result of the analysis, it is concluded that algorithms should be created in the new workflow to reduce the tension arising from the heavy workload in the projecting process. Moreover, algorithm should be standardized to increase the adaptation of different stakeholders in the company like BIM processes. In the absence of standards, in spite of being able to optimize, it is monopolized by the limited user and it is difficult for new users to understand and adapt because of lack of standards. Algorithms are used to reduce stress due to heavy workload and time loss during the projecting phase, and the use of a common language within the company reduces the dependence of users on each other and reduces the pauses in the process. It is prepared for example of project offices that want to pass on algorithm aided workflow with the created approach method.

5. Conclusion

The impact of using algorithm-aided approaches in the BIM environment were investigated through a case study with a particular focus on efficiency in project design and development process.

- Algorithm aided approaches appear to reduce the time and effort of the user in the project development process. However, it has been observed that algorithm aided workflow conducted with BIM might cause a limited amount of stakeholders to become more dominant in the process than others which contradicts with the very basic idea of collaboration. Asynchronous access to the shared BIM model or accessing but not understanding the repetitive and recursive operations defined via visual algorithms might create gaps between the designers and the BIM model.
- It is necessary to reduce the stress caused by the heavy workload in the project process and spread the companywide standards from the very beginning of project design in order to increase efficiency. Otherwise, the efficiency is provided either for the limited user, or it de-

pendents on the users who have advanced programming knowledge.

- There is a need for users with advanced level of programming knowledge to establish new project steps that come with algorithm aided approaches. Otherwise, learning both programming and building a system can be more difficult and challenging than traditional approaches.

This study aims to present highlights for the companies that intend to implement algorithm aided approaches in BIM during project design, development, management and construction processes. In terms of switching the core database and workflow from CAD to BIM, and/or from BIM to computational BIM, one of the most common problem for companies is the lack of standards. With this in mind, in the scope of the study an algorithm based model was proposed to be adapted and used in different contexts by various companies. The validity of the proposed model was tested through a subway project.

The subway project was selected as a case study subject due to its containing repetitive operations and its level of complexity, the increasing need for coordination between different users and the frequent changes. Due to stakeholder's contribution to the project in different phases and dominance of some actors to others, the need for spreading standards across the company is a necessity, regardless of infrastructure, superstructure project differences. It is shown that companies that use BIM programs will be able to pass on an efficient business process, and after the detection of the pattern that causes unnecessary and repetitive work in the project planning process, algorithm aided approaches and company-wide standards are expected to reduce the load on the user.

Standardisation of algorithm aided workflow to have potential improve the adaptation and motivation of the users to new business steps. According to BIM manager of company, algorithms in standardisation prepared in the subway project become more understandable with the use of some of them. Acceleration of the process in the projecting process with the participation of other users and the decreasing dependency of the users to each other in the informing part and grouping of the algorithm and decreasing time loss for obtaining information in the process is seen. It is determined that the quality of the model increases with the decrease of error rates with more controlled project process.

As a result, it has been observed that the spread of algorithm aided approaches throughout the company has prevented the loss of time and unnecessary workloads. Integration of the algorithms into the project phases is not a surprise that automation will be achieved in the process, but with the standards established within the company, time and unnecessary works are reduced, so cost and repetitive tasks are reduced and more comprehensive automation and efficiency are provided in terms of more controlled progress. Similar to the algorithm aided approach of BIM working environment, the cooperative environment for multiple stakeholders is important in terms of putting them through the metro project as much as possible in such integrated systems.

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