Integration of CAD Software with DSS for Engineering and Architectural Project Design

Satakhun Kosavinta[1], Pizzanu Kanongchaiyos[2] and Pinyo Jinuntuya[3]

[1]Architecture, Faculty of Architecture and Planning, Thammasat University, beer1525@gmail.com
[2]CG&A Laboratory, Department of Computer Engineering, Faculty of Engineering, Chulalongkorn University, pizzanu@cp.eng.chula.ac.th
[3]Architecture, Faculty of Architecture and Planning, Thammasat University, pinyoji@gmail.com

ABSTRACT

CAD software is a necessary tool for the engineering and architectural design of a visible object or model. Therefore, project development and management of such objects needs an estimation of time/cost corresponding to the design in order to complete its successful construction. Most project management software, however, lacks the ability to share this information with CAD software which provides one of the requirements for engineering and architectural projects. This research proposes an integration of the CAD software with DSS based project management software. The integrated system extends the original CAD system with the traditional triple constraints of the project management (time, cost and scope) which allow users to either manage their project with the estimated change of design or design the product and estimate the result for supporting their decision. The implementation of an integrated system of CAD and DSS is conducted for sample housing projects. The experimental results show that the system enables the collaborative work between architectures and project managers to explore their decisions in the design processes.

Keywords: Decision Support System (DSS), Project Management, Estimation, CAD, Housing, Design tools, Computer-aided Design.

1. INTRODUCTION

Computer-aided design technology seems to be the best solution for problems that usually occur in the early design phase. It has been adopted widely as a useful tool for speeding up and improving the design process [3]. Today CAD systems are being used more often as a drafting package, but fail in the action of design and decision support system because they are not actually concerned with the requirements of the project. So they can't improve the design approach and develop the computer aided design goal. Housing project design involves collaboration between multiple disciplines and interests such as project planners, architects, and cost estimators. Each party comes with a different agenda, design criteria, and respectively its preferred representation of pertinent housing project data. The different points of view become a fundamental characteristic of collaborative work and hence necessitate the use of multiple representations to resolve design decisions from different perspectives. (Fig. 1)

Proposed DSS is also tested and verified with some information from sample past projects of the National Housing Authority. From the experimental results, the DSS allows designers to improve the design of the project in real-time by inspecting the result of their design via the architectural design-oriented GUI called NAVIGATOR and Clipboard tool. The NAVIGATOR consists of three parts corresponding to laws, design standards and specific parameters of the project. The Clipboard tool speeds up the dividing building type number process. Moreover, the DSS also supports three dimensional interfaces as a virtual reality (VR) system for the collaborative project design. Together with planning, Automation in Feasibility Analysis is focusing on financial analysis The four main financial parameters that show the feasibility of the project are: Net Present Value (NPV), Benefit-Cost Ratio (B/C), Internal Rate of Return (IRR), and Payback Period. Estimating performance is the decision making activity that the computer offer the most. The computer can be used to predict performance with respect to a large variety of performance aspects, which are usually prohibitively expensive due to the magnitude of required computations.

One of the main features of software is the relationship modeling of essential factors such as number of residential area, utility area, green area, and building types. Our core system was developed on Java, Swing, JSP, XML, JavaScript, and AJAX Technology, empowered by 3D game engine. In addition, "Virtools" as our authoring tools was applied to improve interactive 3D virtual environment and explore rapid online system prototyping.

This research aims to recommend a method of user interface that can support the decision making process in design and project feasibility. The GUI consists of four windows representing (1) working space, (2) Clipboard tools, (3) Standard NAVIGATOR, and (4) financial-based NAVIGATOR. As a result of the methods and standards that were researched from the National Housing Authority of Thailand, we used their data as a default of the program then added more design standard information and flexible user adjustments. We intend to create a program or method which can help designers to design and develop their concrete housing projects.

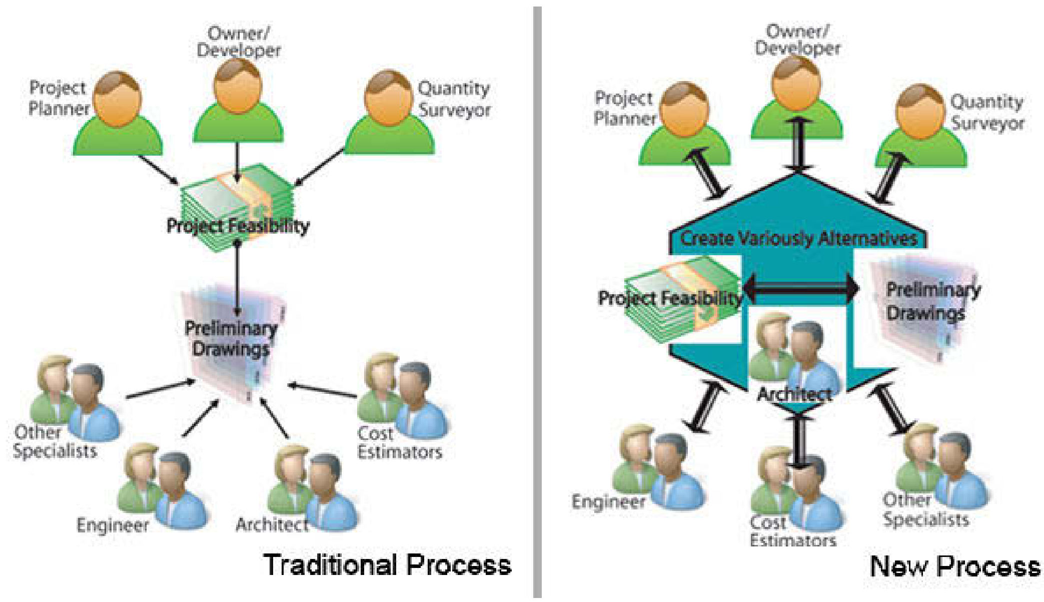

Fig. 1: Traditional Process and New Process.

2. DECISION MAKING IN THE EARLY PHASE OF A HOUSING PROJECT

Decision-making, standards, and a feasibility study are the necessary factors in the early phase of the project that affects design, cost and project initiation. The housing design process is a complex and very chaotic process with many methods. Designers always waste their time in the process of finding the law and standard that suits the project, or fix it after the design. All problems should be solved by the power of CAD which can improve the method of design and increase his/her creative thinking. The most interesting method is detected by eye-sight which we decided to use with NAVIGATOR representing Standard and Financial Analysis.

First, we put it all together in one single adjustable gauge (Called NAVIGATOR) that is separated into sub-navigators which present law, design standards, and specific parameters of the project. We set the gauge for each necessary factor that the designer is concerned with when he/she starts to create preliminary planning.

Second, each gauge responds to the action that happens in a working space by showing its value in red, yellow, and green (referring to minimum to maximum quality order). It emphasizes that you will produce a successful housing project design with a good or fine standard when you can reach all green lights (or as much as you can).

2.1 Decision Making in Housing Management

The main reason that we need and produce information at the early phase of design is so we can make a decision about what can be in the project and if it can continue or not. Understanding the decision-making process is necessary to develop an integrated tool to meet the project requirements and lead the user to the right way in the project initiation process.

2.1.1 Decision-making Process

Decision-making can be abstracted to choosing among options. The generation of options is based on the performance problems that we have identified and/or performance goals that we try to meet [5]. There are many options that come together that the designer has to decide what is the best for the project, sometimes in a very chaotic situation. Some designs are better than the others in his/her judgment. The final decision comes with a compromise of 2 major variables: possible available options, and desirable performance considerations. The process involves the repetition of four major activities: identifying problems or setting goals, identifying options toward resolving problems or meeting goals, estimating performance of the identified options, and evaluating the estimating performance. We agree with Papamichael that the decision-making can also be seen as a process of answering questions which can be modeled as an argumentative process, as Kunz and Rittel (1970) [6] and McCall et al (1998) [7] have said.

The use of data in decision making can be classified into three main characteristics: [5]

- Design characteristics, which are parameters that affect performance and can be controlled directly by the decision-makers, e.g., building, geometry, materials, equipment, operation, etc.
- Context characteristics, which are parameters that affect performance and cannot be controlled directly by the decision-makers, e.g., weather conditions, building codes and regulations, characteristics of humans, animals and plants, properties of materials, etc.
- Performance characteristics, which are functions of design and context parameters and serve as performance indicators during the evaluation of design alternatives, e.g., images, comfort indices, energy requirement, cost., etc.

The controlling of these three main characteristics is the process that we use to define how the optional designs are created, and use other factors which include (Cost and Financial Analysis) in the planning process, and exclude (meeting conclusion from the other parties) from the planning process in the software to choose what should be the conclusion of the project's conceptual initiation. Virtual Reality (VR) is used to replace the factors excluded from the planning process in the software.

2.1.2 Speeding up Decision-making Process in the Early State of Design

Most theories of the design process are based on a variation of the Analysis-Synthesis-Evaluation cycle. The theories differ in the number of steps used in each cycle and in the number of phases in the process. The basic idea is that the cycle is repeated until the design is completed. These theories cannot adequately describe the early phase of the architectural design process. They describe design processes with objective and fixed requirements that are fairly well structured. None of this applies to the architectural design process. A theory to describe the architectural design process in the early stages must be less rigid and include mechanisms to state goals and criteria during the design process. We completely agree with them: the fastest and innermost cycle is the "decision" cycle. Most design decisions are made in this cycle. The outermost cycle is the "development" cycle, in which the development of the design is controlled. Between these two is the "structuring" cycle [3]. We use that cycle as the basic structure to develop the next process of our software. In these three cycles the designer can figure out the result or decide what to do in the midst; or use the brain to calculate it which sometimes takes time. With the new technique that we propose, it will speed up and give enough time to create more optional preliminary designs to ensure that the designer will meet the goal of his/her project.

2.2 Standards in Housing Project Design

The necessary parameters that affect the design are standards. The standards (Architectural Codes, Design Standards, and Specific Parameters of the Project) should be the supporting part of the project, but they always obstruct or slow the project down. The advantage of the computer is that it can help the designer by storing the design standard database in the complexity process but still make it easy for user to use as the necessary part of the design.

For this research we use the Thai Architectural Code as the basic evaluation, but we are still searching for an international standard to compare with Asian country standards which are Thai-based with Japanese, Singaporean, Hong Kong, and Malaysian housing standards.

2.2.1 Should Know them Wells

In every country, there are specific perspectives and situations which depend on culture, environment, attitude, etc. So in many conditions, these important rules are necessary to control or help their people so they become their laws. The architect who works within each country should know them wells-- not only the law, but also the living quality which residents need or want to live in. The laws should be the least important factor that the designer should be concerned about, but it is still the rule that everyone has to follow. So it becomes the minimum of the sub-navigator showing the standard we deal with; a convenient process that the computer can give (completely accurate information). That part of the program is editable by using a customized option to suit the unique project.

2.2.2 Design Standards

After researching about the law, one of the most effective parameters is the design standard. What can prove that it is a good design? That is the most popular question for everyone. Looking for international or research standards seems to be the first choice which can support or lead the project to the goal of a good design. The design standard is the long term study that is developed from the experience and real research study. Starting with it can ensure you that the way that you chose is the right way with expert grantee. As we said before, this second sub-navigator uses the data that was collected from four Asian country housing standards which are based on Thai Human comfort against international living criterion.

2.2.3 Specific Parameters of the Project

In every project, there are specific parameters that are goals or objectives or special requirements of the project. In the sense of improving the architectural practice or raising the living quality, the tools that are used to support it should be easy and convenient for the user to adjust. This third sub-navigator should be the maximum value of the gauge. Sometimes it can be a lower value than the design standard value, but it has to be higher than the legal limit. (Tab. 1)

Area	Law (%)	Standard (%)	NHA Standard (%)
Residential Area		62	60-70.
Open space, Street-Pedestrian & Green Area	30	22	17-22.
Public Utility Area		8	8-18.
a resident per square meter	40-60 (m^2)	51.62 (m^2)	40-60 (m^2)
Type of building	m^2	Va^2	
Detached House	240	60	
Duplex House (semi-detached house)	160	40	
Row House (terraced house)	80-120	20-30	
Apartment			
Village is the main focus with 300-500 Residential Units and 12,500 residents			

Tab. 1: Laws and Standards Limit.

2.3 Financial Analysis for a Feasibility Study

Performance characteristics are functions of design and context parameters and serve as performance indicators during the evaluation of design alternatives. Financial analysis is one of those. The four main financial parameters that show the feasibility of the project are: Net Present Value (NPV), Benefit-Cost Ratio (B/C), Internal Rate of Return (IRR), and Payback Period. Estimating performance is the decision making activity that the computer offer the most. The computer can be used to predict performance with respect to a large variety of performance aspects, which are usually prohibitively expensive due to the magnitude of required computations. The method that Henriques, Maver, and Retik (1996) [4] used in their research has the same sense as the way that our program intends to be developed. As the supporting process for the architect in construction cost estimation, in which they aim to increase the efficiency and precision of the model, in addition to simplifying and developing the exchange of information between the architectural project and the cost estimate study. But we expand the project scale into the housing project development through appropriate computer-based simulation processes. Through the capability of the computer, that can greatly facilitate such computation to produce values for both quantitative and qualitative performance variables, it will be represented through the NAVIGATOR's gauge and changeable value number. It is flexible by adaptable matters that have changed the physical nature and value of the project. For those values --Construction Cost, Develop Cost, and Land Cost-- they were contained in Building model data base which related to the model that designer created in visual space.

Through the collaborative work of designer and financier, there are several inputs which have to calculate before designer can start to design the project. Those inputs are Units Sold, Unit Build, Land Plot Size (wide x long), Income, Initial Cost, Capital Expend, Duration, Inflation ratio, and Discount Rate. Then architect can create the project base on basic financial assumption through the outcome from those inputs. After that process of design the designer can estimate the feasibility of project through financial evaluation charts which consist of pie chart, bar chart and graph.

- Pie chart illustrates volumes of designed area.
- Bar chart illustrates comparative of design standard area and present designed area.
- Graph illustrates time of break even point.

The net present value (NPV) of a project is defined as the present value of all future cash flows produced by an investment, less the initial cost of the investment: (2.1).

$$NPV = \sum_{t=1}^{n} \frac{X_t}{(1+r_p)^t} - 1 \tag{2.1}$$

Where n is the number of cash flows generated by the investment and rp is the required return on the investment project. In determining whether to accept or reject a particular projected, the NPV decision rule is:

- Accept a project if its NPV > = 0;
- Reject a project if its NPV < 0;
- Indifferent where NPV = 0 (but for this research we will accept a project).

The Benefit-Cost Ratio (B/C) or the profitability index, is used when firms have only a limited supply of capital with which to invest in positive NPV projects. This type of problem is referred to as a capital rationing problem. Given that the objective is to maximize shareholder wealth, the objective in the capital rationing problem is to identify that subset of projects that collectively have the highest aggregate net present value. To assist in that evaluation, this method requires that we compute each project's profitability index PI.
The formula for Benefit-Cost Ratio (B/C) is: (2.2).

$$PI = \frac{NPV}{I} \tag{2.2}$$

We then rank the project's PI from highest to lowest, and then select from the top of the list until the capital budget is exhausted. The idea behind the profitability index method is that this will provide the subset of projects that maximize the aggregate net present value. However, this is not always the case.

The internal rate of return, IRR, of a project is the rate of return which equates the net present value of the project's cash flows to zero; or equivalently the rate of return which equates the present value of inflows to the present value of cash outflows. The internal rate of return (IRR) solves the following equation: (2.3).

$$\sum_{t=1}^{n} \frac{X_t}{(1+IRR)^t} - 1 = 0 \tag{2.3}$$

In determining whether to accept or reject a particular project, the IRR decision rule is

- Accept a project if IRR > r_p
- Reject a project if IRR< r_p
- Indifferent if IRR = r_p
- For mutually exclusive projects accept the project with highest IRR if IRR > r_p

The payback period, PP, is the length of time it takes to recover the initial investment of the project. To apply the payback period criterion, it is necessary for management to establish a maximum acceptable payback value PP*. In practice, PP* is usually between 2 and 4 years. In determining whether to accept or reject a particular project, the formula for Payback Period is: (2.4).

$$\text{Payback Period} = \frac{\text{Costs of Project / Investment}}{\text{Annual Cash Inflows}} \tag{2.4}$$

The payback period decision rule is:

- Accept if PP < PP*
- Reject if PP > PP*
- Indifferent where PP = PP*
- For mutually exclusive alternatives accept the project with the lowest PP if PP<PP*

3. THE USER INTERFACE AND IMPLEMENTATION

The four parts of user interface represent: (1) working space, (2) Clipboard tools, (3) Standard Navigators, and (4) Financial-based Navigators. (Fig. 2)

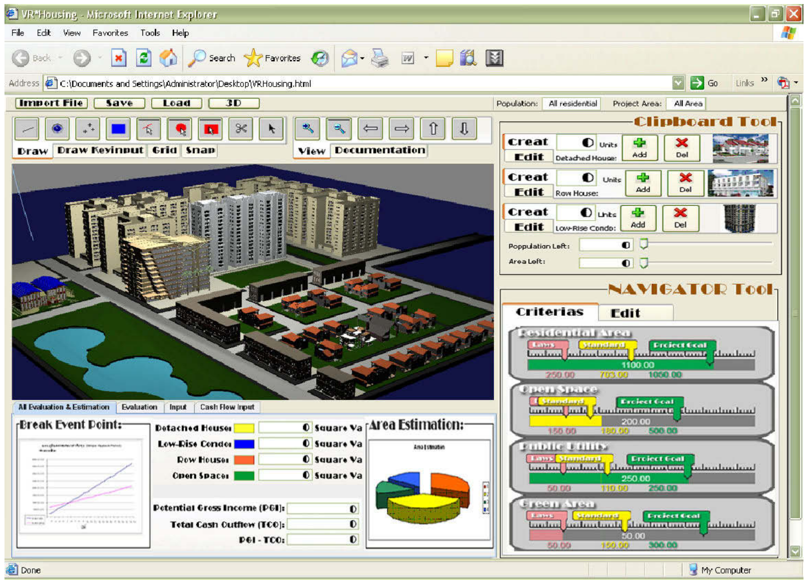

Fig. 2: Graphic User Interface.

Property \ Software	ArchiCAD	Revit	AutoCAD	3D Studio max	Microsoft Excel	Developing Software
Project Planning	o	o	o	-	-	o
Viewing 2D to 3D	o	o	o	o	-	o
Monitoring	o	o	-	-	-	o
Feasibility Evaluation	-	-	-	-	o	o
Collaborative Design	o	o	-	-	-	o

o = Potential

- = None Potential

Tab. 2: the Potential of Developing Software.

3.1 Working Space

The area of the program that is used for planning the housing project can switch between a 2D and 3D view, which is a requirement of the planning method. Toolbars, on the top and the right of the window, are used to control, create, and modify objects in the working space. The working space is the first place where the designer starts the new project. Starting the new project begins with the program asking to define site area and shape. Then fill in the residential population or density (if specific values are required, the user can customize a code of planning in this process). Finally, the software will generate a preliminary gross area to show the density of the area (Residential area, Public utility area, and Open space including the Street-Pedestrian & Green Area) and how much area or floors that the target group basically requires.

3.2 Clipboard Tool

The Clipboard tool will relate between the preliminary gross area and building numbers. The clipboard tool, or determined Building type number tool, is based on the Trill and Error method which supports the designer to divide the residential requirement area into NHA's building types (House, Row house, and Apartment) and determined the number of them. The way to distribute residential gross area into each building type number depends on the designer's decision which can create alternatives in the short period. After that the designer can drag and drop building models onto the site plan and arrange them by him/herself. In each NHA's building type they will store construction costs, residential population, and the building area which are presented in NAVIGATOR. (Fig. 3)

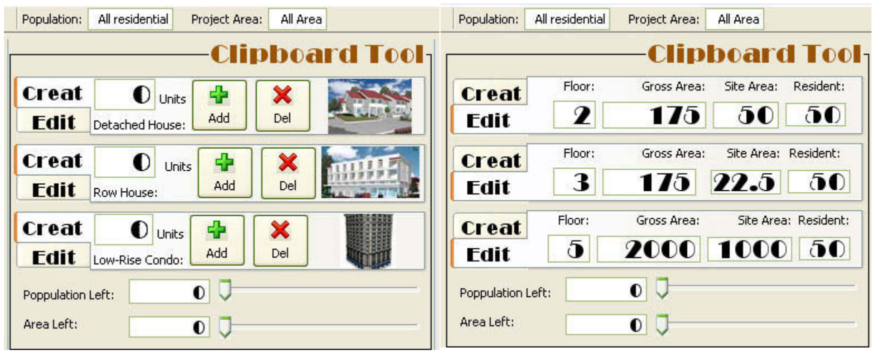

Fig. 3: Clipboard Tool was applied for easy usages and simplified interface.

3.3 Standard Navigators

The DSS allows designers to improve the design of the project in real-time by inspecting the results of their design via the architectural design-oriented GUI called Navigator. The Navigators combine three main standards (Laws, Design Standards, and Specific Parameters) of the Project. The main standards are shown in order of colors which come from everyday intimately acquainted signs -- red, yellow, and green. We fixed laws and design standards value with the Thai Code and NHA Standard which can be customized by using the customize option. Specific Parameters of the Project as a Specific Standard option can be adjusted for the personalized opinions or goals of the project. (Fig. 4)

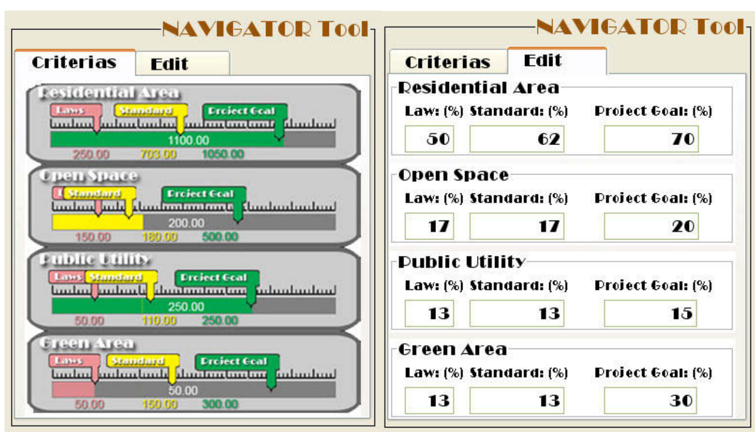

Fig. 4: Standard NAVIGATOR was applied for easy usages and simplified interface.

3.4. Financial-based Navigators

The NAVIGATOR gauges that represent the four main financial parameters that show the feasibility of the project are: Net Present Value (NPV), Benefit-Cost Ratio (B/C), Internal Rate of Return (IRR), and Payback Period. This tool can calculate the feasibility assumption that helps the designer decide (present in pie chart, bar chart, and graph) and present the conclusion of the first preliminary design to generate possible alternatives. The feasibility assumption came from those several inputs which are Units Sold, Unit Build, Land Plot Size (wide x long), Income, Initial Cost, Capital Expend, Duration, Inflation ratio, and Discount Rate. (Fig. 5)

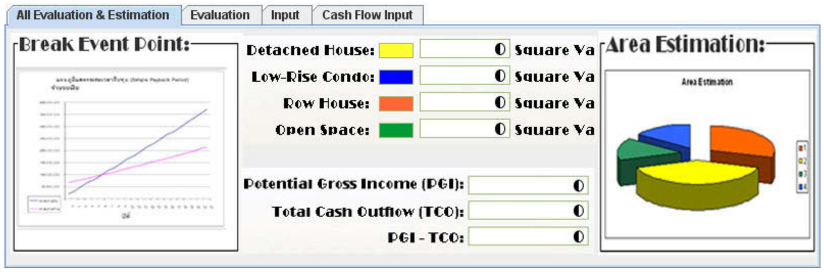

Fig. 5: Add Financial-Based NAVIGATOR.

4. CLIPBOARD TOOL, NAVIGATOR AND VIRTUAL REALITY SUPPORT TECHNIQUE

In the process of initiated project, the designer will know or receive the requirement of the project. In a particular process of a Government Housing Project, they will set the goal of the project which comes with factors of requirements --land site, population, residential density, budget, and living building standards. As Segers, De Vries, Achten, and Timmermans (2001) [8] have stated, personal interest, intuition and critique play an important role. Therefore it is important to develop a tool that can be personalized. As we said before the way that can obviously speed up and make the decision process accurate and immediate, is the navigator gauge.

What can the computer do? This question is always asked. From the answers that people always seek, there are many ways that many researchers have tried to provide. The computer is the best in determining the values of performance variables and the designer is the best in creating aesthetics. So the best negotiation is between what humans do best and what the computer does best. From our research, the possible processes that are suitable and appropriate for housing planning are using trial and error with the NAVIGATOR and Clipboard tools.

4.1 Trial and Error by Clipboard Tool and Navigator

This work explores real time hypothesis. It is our contention that the computer user should not be hindered or devotes a significant amount of mental energy to the translation of basic ideas into computable form. The machine must be a useful support of dynamic thought before it can radically alter the practice of design thinking [1]. Trial and Error is the method that is suitable for the early phase of design but it always uses a lot of time and energy to initiate the first capable preliminary design of a project because there are a lot of methods, principles, and parties involved. We propose the NAVIGATOR and Clipboard tool to make the complex simple and accurate.

NAVIGATOR is the tool that, based on the trial and error method, supports the designer to detect what he/her is doing right or wrong by Colors.

The Clipboard tool is the tool that, based on the trial and error method, supports the designer to divide the residential requirement area into NHA's building types (House, Row house, and Apartment) and determine the number of them.

4.2 Virtual Reality for Communication and Collaboration

The application of Virtual Reality until now is mainly restricted to the realistic visualization of shapes. VR software (such as World Tool Kit and Device) is optimized for generating pictures of a building model consisting of objects with a shape representation and a texture mapping, while navigating through the model. Moreover, objects can exhibit some behavior like gravity and collision detection. With these capabilities a very realistic impression can be created of a building which only exists in the mind of an architect. The architect himself/herself or the principal can use VR to judge a design on its esthetical and its functional qualities. The display of the design in VR is dynamic, but the design itself is static. To take VR one step further, the designer must be able to interact with the design by creating, modifying and deleting design objects and by evaluating the design to certain aspects [9]. Virtual Reality of this program will support: (1) zooming, (2) panning, (3) camera navigation, (4) dynamic model display, and (5) making comments-- the same approach as de Vries, Buma, and Jessurun (2006) [2] used in their research, but we add more functional options (making comment) to comment on what should be done in the next step of the design. To create a robust and easy to operate system, it was decided to limit the operation of virtual world to only walkthrough, flythrough, and drive-through, which cannot move or edit anything in the project after the designer decides to finish the creation process. VR is only for presentation or communication with other parties in the project. Other parties or designer teams can comment on what they think and what to do next for the next process of the design phase.

5. CONCLUSION AND FUTURE WORK

This research explores trial and error methods and real time hypotheses in the housing planning project by using Clipboard tool, NAVIGATOR, and Virtual Reality. The experimental results show that the system enables the collaborative work between architects and project managers to explore their decisions in the design processes. The DSS allows designers to improve the design of the project in real time by inspecting the result of their design via the architectural design-oriented GUI called NAVIGATOR and Clipboard tool. The navigator consists of three parts corresponding to laws, design standards and specific parameters of the project. The Clipboard tool speeds up the dividing building type number process. Moreover, the DSS also supports a collaborative design system for developing a 3D virtual community. (Fig. 6, Fig. 7)

Future work will support other kinds of projects such as private housing projects, Condominiums, and single house or resort projects, and then continue to the other phases of project delivery. Finally we will create more flexible, updatable software with a complete database.

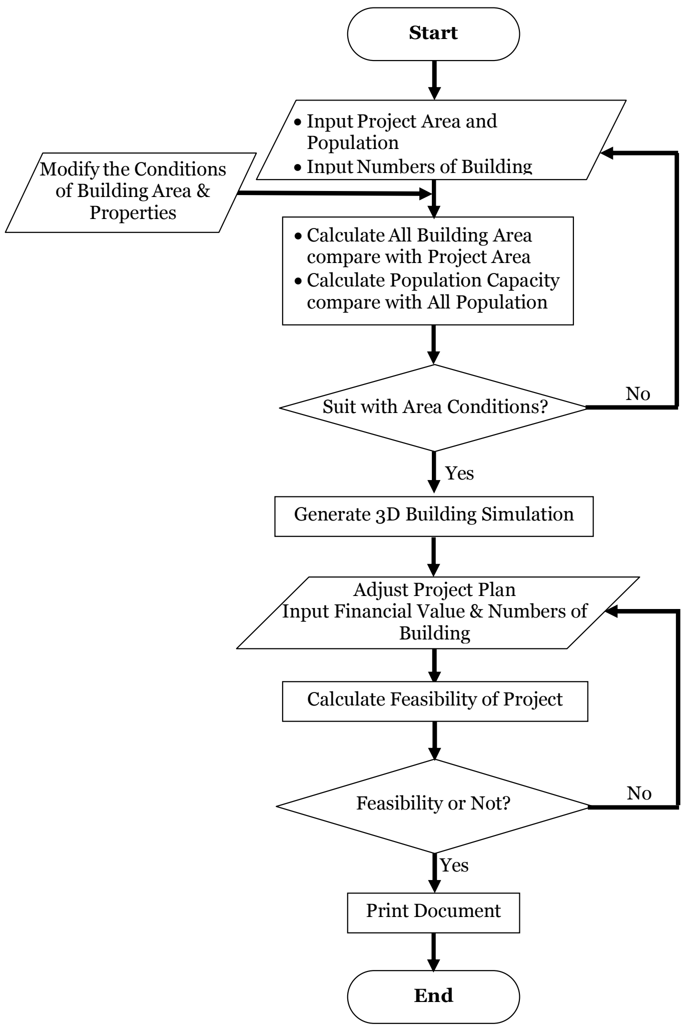

Fig. 6: Proposed System Flow Chart.

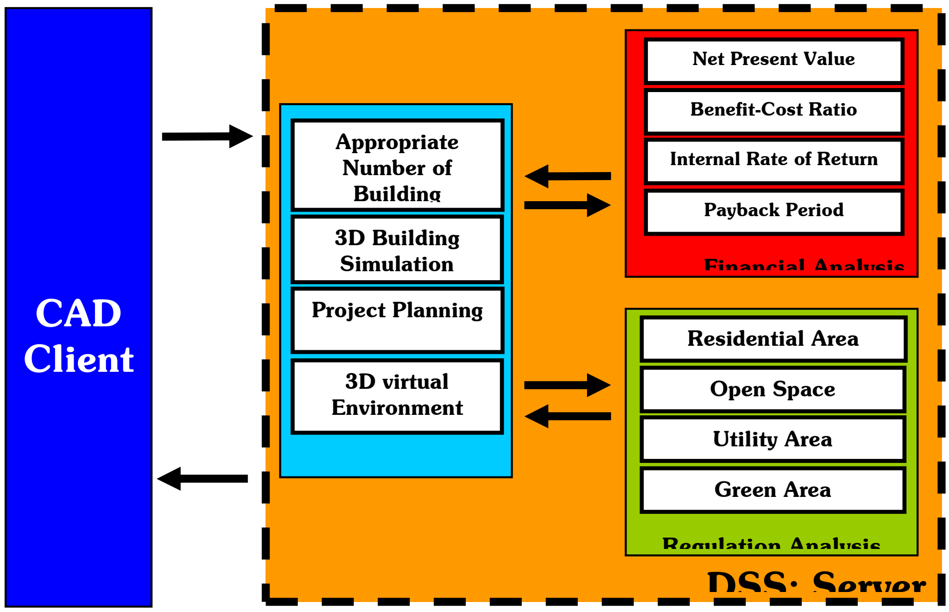

Fig. 7: Proposed System Architecture.

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