DEVELOPMENT OF A HEALTH FACILITY BUILDING INFORMATION MODEL, MINISTRY OF PUBLIC HEALTH FOR MEASUREMENT AND IMPROVEMENT OF ENERGY PERFORMANCE

NUTTASIT SOMBOONWIT

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....
Mr. Nuttasit Somboonwit
Candidate

....
Lect. Vimut Prasertpunt,
Ph.D. (Environmental Information System Management)
Major-Advisor

....
Lect. Vasan Iamsupasit, B.Arch.,
Co-Advisor

....
Prof. M.R. Jisnuson Svasti,
Ph.D.
Dean
Faculty of Graduate Studies

....
Assoc. Prof. Anuchat Poungsomlee,
Ph.D. (Human Ecology)
Chair
Master of Science Programme in Information Management on Environments and Resources
Faculty of Environment and Resource Studies

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on
May 10, 2006

....
Mr. Nuttasit Somboonwit
Candidate

....
Lect. Vimut Prasertpunt,
Ph.D. (Environmental Information System Management)
Chairman

....
Lect. Vasan Iamsupasit, B.Arch.
Member

....
Mr. Wattana Suthiranart,
M.U.P. (Urban Planning)
Member

....
Prof. M.R. Jisnuson Svasti,
Ph.D.
Dean
Faculty of Graduate Studies
Mahidol University

....
Assoc. Prof. Anuchat Poungsomlee,
Ph.D. (Human Ecology)
Dean
Faculty of Environment and Resource Studies
Mahidol University

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Nuttasit Somboonwit

DEVELOPMENT OF A HEALTH FACILITY BUILDING INFORMATION MODEL, MINISTRY OF PUBLIC HEALTH FOR MEASUREMENT AND IMPROVEMENT OF ENERGY PERFORMANCE

NUTTASIT SOMBOONWIT 4437373 ENIM/M

M.Sc. (INFORMATION MANAGEMENT ON ENVIRONMENTS AND RESOURCES)

THESIS ADVISORS: VIMUT PRASERTPUNT, Ph.D., WATTANA SUTHIRANART, M.U.P. (URBAN PLANNING), VASAN IAMSUPASIT, B.Arch.

ABSTRACT

The main purpose of this study was to develop a health facility building information model from a health facility building template design for measurement and improvement of energy performance for the Design and Construction Division (DCD), Ministry of Public Health. The integration of tools used in this study included Autodesk® Revit® Building chosen as the Building Information Modeling (BIM) system to develop a health facility building information model. Green Building Studio™ was chosen as the tool to measure and analyze the building energy performance.

A template design of the OPD building DCD number 3130/2526 was chosen to be the research example. Its drawings and specifications have been defined, translated and created into the Revit Families and implemented in a project to complete the health facility building model. The research example information model and its seven-rotated orientations were measured for their energy performance by Green Building Studio™. The rotation which had the best energy performance results was further building energy performance tested by changing building components and adding sunshading devices.

The results reflected that even the same building placed in different ways of orientation causes extensively different building energy performances, and the orientation that positioned the most opaque and narrowest side facing the sun-tempering direction was the one that had the best building energy performance. Changing the building envelope components and materials caused just a little better result, but adding the sunshading devices produced a massively better result, which was the largest reduction of energy usage. In conclusion, two types of information systems that need to be studied and implemented diligently are Building Information Modeling (BIM) systems and building energy analysis tools. Custom-built systems for Thais will be useful, convenient, precise, and greatly beneficial in environment-conscious building design for Thai architects.

KEY WORDS: HEALTH FACILITY / BUILDING INFORMATION MODEL / ENERGY PERFORMANCE MEASUREMENT

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การพัฒนาแบบจำลองสารสนเทศของอาคารสถานบริการสุขภาพ กระทรวงสาธารณสุข เพื่อการตรวจวัดและปรับปรุงสมรรถภาพด้านพลังงาน (DEVELOPMENT OF A HEALTH FACILITY BUILDING INFORMATION MODEL, MINISTRY OF PUBLIC HEALTH FOR MEASUREMENT AND IMPROVEMENT OF ENERGY PERFORMANCE)

ณัฐสิทธิ์ สมบูรณ์วิทย์ 4437373 ENIM/M

วท. ม. (การจัดการสารสนเทศสิ่งแวดล้อมและทรัพยากร)

คณะกรรมการควบคุมวิทยานิพนธ์: วิมุติ ประเสริฐพันธุ์, Ph.D.,
วัฒนา สุถิรนาถ, M.U.P. (URBAN PLANNING), วสันต์ เอี่ยมสุภาษิต, B.Arch.

บทคัดย่อ

วัตถุประสงค์หลักของการศึกษาครั้งนี้คือ การพัฒนาแบบจำลองสารสนเทศของอาคารสถานบริการสุขภาพ อันมุ่งเน้นที่แบบมาตรฐานของกองแบบแผน กระทรวงสาธารณสุข เพื่อการตรวจวัดและปรับปรุงสมรรถภาพด้านพลังงาน การเลือกใช้เครื่องมือในการศึกษานั้นเป็นการบูรณาการของเครื่องมือหลากหลายชนิดอันได้แก่ การเลือกใช้ Autodesk® Revit® Building เป็นระบบในการพัฒนาแบบจำลองสารสนเทศ และเลือกใช้ Green Building Studio™ เป็นระบบสำหรับตรวจวัดและวิเคราะห์สมรรถภาพด้านพลังงาน แบบมาตรฐานที่ถูกเลือกเพื่อเป็นตัวอย่างในงานวิจัยคือ แบบมาตรฐานของอาคารผู้ป่วยนอก หมายเลขแบบกองแบบแผน 3130/2526 โดยแบบก่อสร้างและข้อกำหนดในการก่อสร้างของแบบนี้ถูกนำมาแจกแจง แปล และ ถูกนำไปสร้างในระบบสารสนเทศในรูปแบบของ Revit Families และทั้งหมดได้ถูกนำไปใช้ในการสร้างแบบจำลองสารสนเทศของตัวอย่างงานวิจัยให้แล้วเสร็จในที่สุด แบบจำลองที่เสร็จสมบูรณ์ดังกล่าวจะถูกนำไปเปลี่ยนทิศทางการวางอาคารด้วยการหมุนแบบจำลองจากศูนย์กลาง อีกเจ็ดทิศ และแบบจำลองทั้งแปดจะถูกนำไปตรวจวัดสมรรถภาพด้านพลังงานด้วยระบบ Green Building Studio™ แบบจำลองที่มีผลการตรวจวัดสมรรถภาพที่ดีที่สุดจะถูกนำมาทดสอบสมรรถภาพด้านพลังงานเพิ่มเติม ด้วยการเปลี่ยนวัสดุก่อสร้างและองค์ประกอบด้านอาคารบางชนิด และด้วยการเพิ่มเติมอุปกรณ์กันแดดแก่แบบจำลอง

ผลจากการตรวจวัดสะท้อนให้เห็นได้อย่างชัดเจนว่า อาคารแบบเดียวกัน แต่เมื่อนำมาจัดวางในทิศทางที่ต่างกัน ก็ส่งผลให้มีสมรรถภาพด้านพลังงานที่ต่างกัน และการจัดวางอาคารให้หันด้านทึบแสงที่สุดและแคบที่สุดเข้าสู่ด้านรับแดด จะส่งผลให้อาคารนี้มีสมรรถภาพด้านพลังงานที่ดีที่สุด การเปลี่ยนวัสดุก่อสร้างและองค์ประกอบอาคารนั้นส่งผลให้สมรรถภาพด้านพลังงานของอาคารดีขึ้นเพียงเล็กน้อย ต่างกับการเพิ่มเติมอุปกรณ์กันแดดแก่อาคาร ซึ่งมีผลการตรวจวัดสมรรถภาพด้านพลังงานที่ดีขึ้นเป็นอย่างมากในสัดส่วนที่มากที่สุด

จากการศึกษาพบว่า เครื่องมือที่ใช้ในการศึกษาครั้งนี้ ทั้งระบบ BIM และ ระบบสำหรับตรวจวัดสมรรถภาพด้านพลังงาน นั้นมีประสิทธิภาพอย่างมาก ถึงแม้ว่ายังมีความบกพร่องและความไม่เหมาะสมกับการใช้งานในประเทศไทยบางประการ แต่หากมีการศึกษา การพัฒนา และการนำมาใช้อย่างจริงจัง ให้ระบบดังกล่าวทั้งสอง เป็นระบบที่มีความเหมาะสมต่อการใช้งานในประเทศไทย ทั้งในส่วนของระบบข้อมูล และส่วนของระบบการทำงาน จะก่อให้เกิดประโยชน์เป็นอย่างมากต่อการสร้างความเข้าใจด้านสิ่งแวดล้อมและด้านพลังงาน แก่ผู้ออกแบบอาคาร เพื่อการนำไปใช้ในการศึกษาและออกแบบอาคารเพื่อความยั่งยืนต่อไป

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CHAPTER I
INTRODUCTION

1.1 Background and Statement of Problem

Thailand's energy consumption has been growing at a phenomenal pace since 1980. In 2001, the country's energy consumption was 2.90 quadrillion Btu (quads), nearly six times higher than just two decades previously, when Thailand consumed just over 0.5 quads. Strong economic growth and the rapid industrialization of the "East Asian tigers" were both the cause and effect of huge increases in energy consumption across the region. (EIA, 2004)

While Thailand's energy consumption growth continues to grow unabated, Thailand is highly dependent on imported commercial energy. This high dependency is the main reason why Thailand prioritizes energy efficiency and conservation as a main energy strategy, especially the building sector that on the average consume around 20 – 25 percent of the final energy consumption throughout the country. This sector shares a very large portion of the national electricity consumption. Reflecting Thailand, in the United States, commercial and residential buildings consume close to 40 percent of the total energy, 70 percent of the electricity, 40 percent of the raw materials and 12 percent of fresh water supplies. They account for 30 percent of greenhouse gas emissions and generate 136 million tons of construction and demolition waste (Autodesk, Inc., 2005b).

Design and Construction Division (DCD) of the Ministry of Public Health was established in 1967 to operate the health facility building design, construction and providing services of health facility building design and construction information to interested individuals and parties. More than ten thousand of building designs have been created and much more than hundred thousand buildings have been constructed under the DCD supervision, half of them are building template designs. **A building template design** is created from the concept of "One size fits all" and it is widely used by hospitals and health facilities all over the nation which are in the template design criteria of its type, size and work load capacity, which is aimed at reducing time consuming during feasibility studies and programming stage and design and construction documentation stage for every new building design process.

Unfortunately, almost entirely of the building template designs have been constructed without optimization of the building placement, orientation and configuration on the site to minimize energy use by means of daylighting, solar heating, natural ventilation and shading from vegetation or other buildings. The conventional way to place a building, particularly a template building, is based on just the ease of the building linkage to other buildings, facilities and infrastructures. And actually, most of the DCD architects who perform the tasks by concerning the building energy efficiency issues are depending on their professional experiences, partly based on conjecture, rarely have a thorough knowledge of energy-efficient building design. The problems must be solved by the using of Building Information Modeling (BIM).

One of the major problems in considering energy-efficient strategies and technologies in buildings is the lack of tools to assess their performance, analyzing, understanding the complex conditions and counseling approach the energy-efficient building, during the building design process, especially during the schematic phases of building design.

However, the application of simulation in building design itself is problematic because the tools are complicated and building designers are not familiar with their properties and limitations. (Zeller, 2000) Most of the tools require significant time investment both in user learning and in their actual use because of using simulation models for building design has its limitations as existing models fail to tackles issues regarding data preparation in the face of uncertainty in the design environment. The limitations include (Hui, 1998):

- The program input is voluminous and scientifically detailed. Data, which is usually unavailable during early design stages, has to be assumed when doing the analysis.
- Program output consists of bulky computer printouts that confuse the user. Understanding and interpretation of the simulation results is difficult.
- Many detailed design tools are research oriented. Learning to use them is difficult and along time is required to come competent.

- The user interface of the tools is often neglected. Architects who are trained to express themselves graphically become frustrated by the strict data structure and requirements.
- The software does not allow users the flexibility to do any programming easily to meet particular needs.
- Program validation and accreditation are lacking. People are confused and uncertain about which programs will give better simulation results.

Another especial problem, during design processing, it is an important problem to transfer the essentials of the complicated results from simulation tools into action, supporting designers to scrutinize and understand the causes of energy-efficiency shortcoming occur to the building designs. (Carrara, Fioravanti, and Novembri, 2001)

At present, Building information modeling (BIM) is the paradigm that commercial CAD (Computer-Aided Design) developers are finally turning on today (Bentley, 2003). The most sophisticated of CAD tools delivers continuous and immediate feedback on a far greater range of characteristics than conventional design tools. Material quantities and properties, energy performance, lighting quality, site disturbance and comparisons between new construction and renovation are some types of information that are available from this tool (Autodesk, Inc., 2005b). It is the latest generation of OOCAD systems in which all of the intelligent building objects that combine to make up a building design can coexist in a single 'project database' or 'virtual building' that captures everything known about the building. A building information model (in theory) provides a single, logical, consistent source for all information associated with the building.

Conventional health facility building design relies heavily on computer-aided design systems to convey form and function, but the latest generation of CAD, the BIM, with many additional features that provide robust design models containing the necessary level detail for the analyses. Pertinent design data can be easily extracted from building information model and input to various analysis programs, especially to aid in the building energy performance measurement. Even though BIM is a powerful and very helpful tool for building designers but a core barrier of the use of BIM is building objects inadequacy. More direct participation from the designers is expected in BIM modeling or the quality of the model information will be in question (Tse, Wong, and Wong, 2004). To acquire the merit of BIM, a development of sufficient and rectified building information model is very important and it will support the integrated use of energy analysis tools that would be useful to support architects more effectively evaluate building energy performance to achieve the energy efficiency goals.

1.2 Objectives

1.2.1 To develop a health facility building information model from a health facility building template design for energy performance measurement for the Design and Construction Division, Ministry of Public Health.

1.2.2 To infer the recommendations for new health facility building template designs

1.3 Scopes of the Study

1.3.1 **The scope of target user:** the architects of the Design and Construction Division, Ministry of Public Health.

1.3.2 **The study areas of this work:**

1) A Building Information Modeling (BIM) system: Autodesk Revit Building 8.1
2) A building energy simulation tool: Green Building Studio™ from GeoPraxis, Inc.
3) Building information model: the Revit Elements and Families
4) Building materials and components of a health facility building template designs which was designed by Design and Construction Division, Ministry of Public Health.
5) The energy usage comparing of a health facility building template design according to its different orientation.

1.4 Expected Results

1.4.1 The prototype of a health facility building information model for a Building Information Modeling (BIM) system.

1.4.2 Transfer the knowledge of integration of a Building Information Modeling (BIM) system and a building energy simulation tool for building energy performance measurement to the architects of the Design and Construction Division, Ministry of Public Health.

CHAPTER II
REVIEW OF LITERATURES

2.1 Energy Performance Measurement

2.1.1 Energy

The word *Energy* was coined by Thomas Young in 1807. It is form the Greek and means roughly "work within", as we shall use it, energy is the capacity to do work (Aubrecht, 1995)

Energy is the driving force for the universe. Energy is a quantitative property of a system which may be kinetic, potential, or other in form. There are many different forms of energy. One form of energy can be transferred to another form. The laws of thermodynamics govern how and why energy is transferred (8).

- *The Three Laws of Thermodynamics*

There are three laws of thermodynamics. The first law of thermodynamics, also called "Conservation of Energy", states that the total amount of energy in the universe is constant. This means that all of the energy has to end up somewhere, either in the original form or in a different from. We can use this knowledge to determine the amount of energy in a system, the amount lost as waste heat, and the efficiency of the system.

The second law of thermodynamics states that *the disorder* in the universe always increases. As the disorder in the universe increases, the energy is transformed into less usable forms. Thus, the efficiency of any process will always be less than 100%

The third law of thermodynamics tells us that all molecular movement stops at a temperature we call absolute zero, or 0 Kelvin (-273 °C). Since temperature is a measure of molecular movement, there can be no temperature lower than absolute zero. At this temperature, a perfect crystal has no disorder.

When put together, these laws state that a concentrated energy supply must be used to accomplish useful work.

2.1.2 Building Energy Performance

Energy performance of a building is the amount of energy actually consumed or estimated to meet the different needs associated with a standardized use of the building, which may include heating, hot water heating, cooling, ventilation and lighting. This amount shall be reflected in one or more numeric indicators which have been calculated, taking into account insulation, technical and installation characteristics, design and positioning in relation to climatic aspects, solar exposure and influence of neighboring structures, own-energy generation and other factors, including indoor climate, that influence the energy demand. (EEA, 2005)

2.1.3 Energy Simulation

Computer simulation is the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer, and analyzing the execution output. Simulation embodies the principle of ``learning by doing'' to learn about the system, it must first build a model of some sort and then operate the model. The use of simulation is an activity that is as natural as a child who *role plays*. Computer simulation is the electronic equivalent of this type of role playing and it serves to drive synthetic environments and virtual worlds. Within the overall task of simulation, there are three primary sub-fields: model design, model execution and model analysis.

To simulate something physical, the first need is creating a *mathematical model* which represents that physical object. Models can take many forms including declarative, functional, constraint, spatial or multimodel. A multimodel is a model containing multiple integrated models each of which represents a level of granularity for the physical system. The next task, once a model has been developed, is to execute the model on a computer that need to create a computer program which steps through time while updating the state and event variables in the mathematical model.

Simulation of a system can be done at many different levels of fidelity so that whereas one reader will think of physics-based models and output, another may think of more abstract models which yield higher-level, less detailed output as in a queuing network. Models are designed to provide answers at a given abstraction level (the more detailed the model, the more detailed the output). The kind of output which is needed will suggest the type of model the developers will employ.

2.1.4 Energy Analysis Tools

Energy analysis tools have been developed over the past 20 years to help designers determine the annual energy consumption and the cost of various building designs, and compare the energy savings resulting from different design strategies. (Jacobs and Henderson, 2002)

2.1.5 DOE-2

The DOE-2 program was developed by the Simulation Research Group at Lawrence Berkeley Laboratory, with substantial funding from the U.S. Department of Energy. The origins of the DOE-2 program go back to 1976, with the development of the Cal-ERDA program. The first version of DOE-2 was released in 1979. The program has been modified and developed through 1999, when development was stopped in favor of the DOE-2.2 and EnergyPlus programs. The current version is DOE-2.1E. Within the DOE-2.1E version, there are 133 versions or “releases.” DOE-2.1E release 110 contained a long list of new features for modeling variable flow and primary-secondary pumping loops not available in earlier versions of the program. DOE-2 is a detailed hour-by-hour simulation program designed for simulating the performance of a wide range of commercial buildings. It is the most popular public-domain whole building energy analysis tool currently in use.

DOE-2 utilizes its own text-based input language, call Building Description Language (BDL). BDL input files are English Language based, such that it is possible to get some understanding of the program inputs from reading an input file.

2.1.6 Trane TRACE

TRACE 700 (Trane Air Conditioning Economics) is part of the C.D.S. software suite from the Trane Corporation. C.D.S. is a collection of software tools created specifically for the HVAC system designer. Included in the suite are programs to assist in heating and cooling load estimating, duct system design and layout, piping design, annual building operating cost estimation, ASHRAE Standard 62 compliance analysis, and an “Engineering Toolbox.” Many of these tools are listed in the practitioner tools chapter.

TRACE 700 is Windows-based software that provides heating and cooling load estimation and HVAC system sizing. Annual energy analysis, which was previously available in the TRACE 600 for DOS, was incorporated into the 700 series software in March of 2001. TRACE has two options for energy analysis. In the first option, TRACE does calculations for an average day of each month. Hourly weather data are converted into a “typical day” of each month, and the calculations are performed for the 24 hours of each typical day. The program uses three daytypes per month: workday, weekend, and holiday. The results for each daytype are multiplied by the number days of each type in the month, and the results are summed to obtain the monthly result. In the second option, calculations are carried out for a full 8,760 hours, consistent with the general approach taken with other hourly simulation programs covered in this chapter. The first option is compatible with TRACE 600; the second option requires additional weather data files, so users may be slow to adopt the more rigorous approach.

2.1.7 eQUEST

eQUEST is a simplified DOE-2.2 simulation environment. This freeware tool is designed to allow detailed analysis without requiring extensive experience in DOE-2 modeling. This is accomplished by combining a building creation wizard, an energy efficiency measure (EEM) wizard, and a graphical results display module with the DOE-2.2 program. eQUEST has two input modes – wizard mode and a detailed input mode, allowing the user access to the full set of DOE-2.2 commands if desired. The eQUEST wizard requires a greatly reduced set of input data to describe a building. The remaining building inputs are developed from the experience of simulation experts coded into the tool. At a minimum, building type, location, floor area, number of floors, cooling system type, and heating system type are defined. Additional detail, addressing building footprint, general construction type, windows, internal load densities, schedules, and HVAC system information can be supplied if desired. eQUEST can be of great use during initial design phases, when the level of detail about the building is not well known. It can provide design direction with minimum effort and reasonable cost, while retaining the analytical rigor of a detailed simulation.

2.1.8 EnergyPlus

EnergyPlus is a new-generation building energy simulation program based on DOE-2 and BLAST, with numerous added capabilities. Released in April 2001, the program was developed jointly by Lawrence Berkeley National Laboratory, the University of Illinois, the U.S. Army Construction Engineering Research Laboratory, Oklahoma State University and others, with support from the U.S. Department of Energy, Office of Building Technology, State and Community Programs. EnergyPlus builds on the most popular features and capabilities of BLAST and DOE-2 and includes additional simulation capabilities including time steps of less than an hour and modular systems simulation modules that are integrated with a heat balance-based zone simulation. Other planned simulation capabilities include solar thermal systems analysis, multi-zone air flow, and and fuel cell analysis.

EnergyPlus employs a simultaneous load / system / plant simulation, utilizing a user-selectable time step for the loads calculation. Normal time steps are in the range of 10 to 15 minutes. Shorter time steps for the HVAC system are automatically made when required for better convergence. The program uses a conduction transfer function (CTF) wall model and a heatbalance room model. Convection, radiation, and moisture exchange are calculated from interior surfaces and furnishings at each time step. The program calculates the temperature of the internal surfaces, allowing the simulation of radiant heating and cooling systems, and the assessment of thermal comfort.

EnergyPlus input data structures are text-based files which are fairly cryptic and not intended to be the main interface for typical end-users. The long range goal is to leave the development of full-functioned graphical user interfaces to the private sector. For the initial release of EnergyPlus, a simple “launch” program is provided to handle file management, input file editing and results viewing using a combination of simplified tools and existing third-party applications.

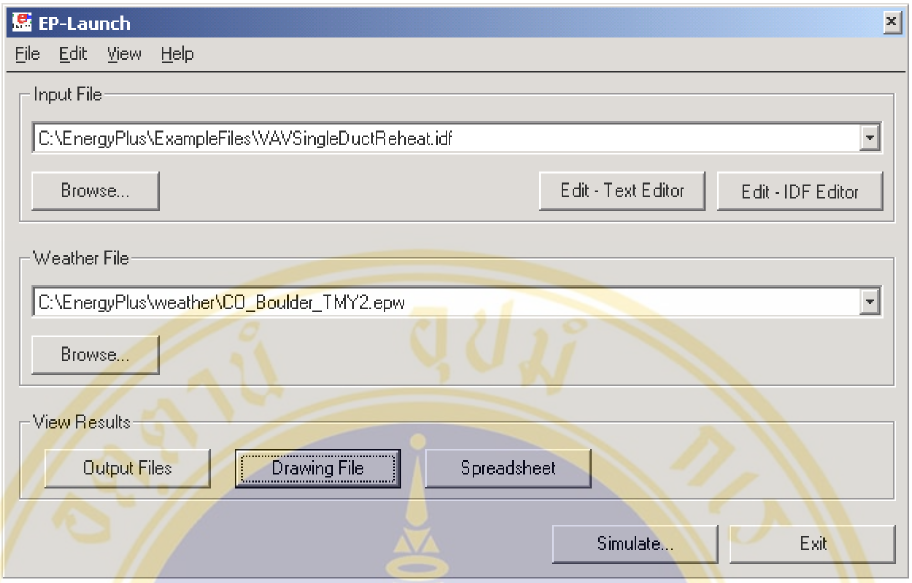


Figure 2.1 EnergyPlus Launch Program

2.1.9 Green Building Studio™

The Green Building Studio web service was developed by GeoPraxis, Inc. supported by funding grants from the California Energy Commission Public Interest Energy Research (PIER) Program, and the California Utilities (PG&E, SCE, SDG&E, and the Gas Company) supporting the non-residential new construction program called Savings By Design.

Green Building Studio, Inc. introduced the Green Building Studio web service to the A&E user community on April 21, 2004. It is available at no charge and is being aggressively marketed by the major CAD vendors, Autodesk, Graphisoft, and soon Bentley.

GBS provides the following functionality to the architecture and engineering design teams.

- ***Whole Building Energy Analysis***. GBS is accessed from within the design team's 3D-CAD or BIM software, and used the wide range of building design information in that model to create a geometrically correct thermal model of the building, with appropriate zoning and orientation. This model is developed using regional building standards, and codes for intelligent assumptions for the appropriate space type. The building is then run through the DOE 2.2 hourly simulation model using typical year weather data for the building's location. Annual energy consumption, costs, and a wide range of data on the building heating and cooling loads, spaces, and systems is summarized and presented within the 3D-CAD or BIM tool environment.

- ***Project Information Sharing with Design Teams and Manufacturers.*** Every building project is given the ability to "opt in" and share detailed project and building data with other team members and building product manufacturers (BPMs) at the earliest stages of design. This means that the design team can share detailed building data directly with engineering firms running analysis programs, and with BPM sales teams and bid preparers. The information includes detailed data about constructions, geometry, and spaces in the building, and is available at the planning and schematic design stages. This data goes well beyond the project summary data currently collected by lead services like Dodge Project Information and can be used to precisely market building products to the right persons in the right projects at the right time in the decision cycle, well before plans are finalized and bid packages prepared.

- ***Design Alternative Comparisons***. There are two ways to use GBS to compare the estimated energy consumption of alternative building designs. First, each building design configuration can be submitted to GBS as a separate run within a single project. When each run is successfully completed, the results are summarized in a GBS table and can be reviewed. Currently, detailed result comparisons are not available, but have been designed and are planned for a future release.

- ***Additional Information Services***. Using gbXML and GBS, detailed DOE-2 and EnergyPlus model input files are created, in minutes, and at no charge to the design team (EnergyPlus requires a scaled fee).

- ***Product Advisor***. Each building project run through the GBS places relevant product information in front of the design team as early as the planning and schematic design stages. Using a "Google-like" bidding and paid placement approach, and a building relevance filter, highly targeted advertisements are placed in front of the building designer in the GBS Product Advisor. These advertisements are linked to the Building Product libraries on-line, providing a high ROI advertising placement for BPMs and appropriate information for the design team.

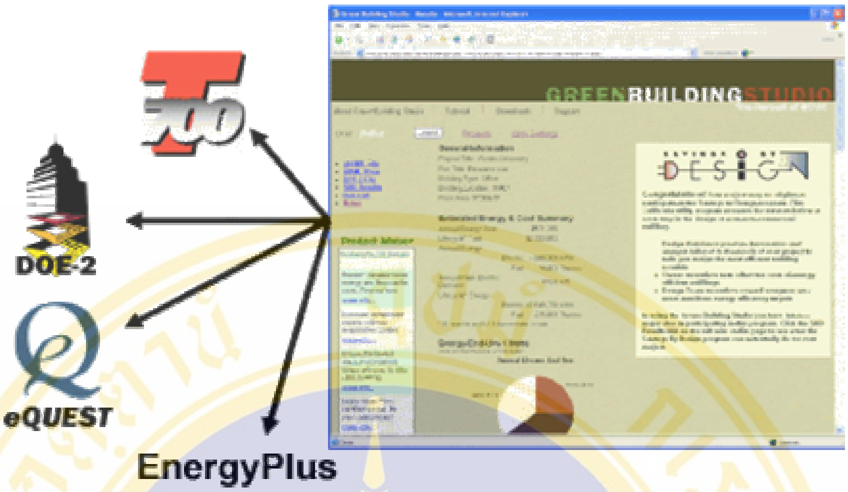


Figure 2.2 Green Building Studio Functionalities

2.2 Building Information Modeling

2.2.1 Building Information Modeling (BIM)

The term Building Information Modeling is used to refer to the process of creating 3D objects in the BIM software environment. These models, which do also exist in 3D CAD systems as well, can be classified into three distinct categories:

- Wireframe Models

Representing objects by its edges only. Therefore, wireframes cannot hide objects that are behind them.

- Surface Models

Having an infinitely thin computer-calculated surface between their edges. In other words, they can be described as an empty shell. Surface models often use wireframe models as a frame for their surfaces. Unless a hidden-line removal command has been invoked, surface models can be mistakenly thought to be wireframed due to their transparency.

- Solid Models

Solid models are surface ones, plus computer-calculated mass under their surfaces. The BIM program can report mass property information, such as volume, centre of gravity, and mass moments of inertia-for the solid. As with surface models, solid models look like wireframes, unless a hidden line removal command is in action.

The core of Building Information Modeling concept is comparatively new programming paradigm known as Object Oriented Programming (OPP), although OPP can be used in 2D CAD systems as well but it plays major role in BM systems functionality. This is built on four basic definitions of object orientation. These four concepts are outlined as follows:

- Procedural and data abstraction.

In traditional procedural computer models, data is moved through a series of procedures which act upon it. An object oriented model, on the other hand, consists of a set of autonomous objects, each containing their own data, which communicate through strictly defined interface. When an object receives a message, it acts upon its own data using its own procedures or methods. So in that case both the data and the methods which characterize a particular type (or class) of object are identified.

- Encapsulation.

The hiding of private data and methods within an object, leaving only chosen properties visible. That causes changes made to data or classes of objects, which are already in use, much faster and secure. The concept of abstraction with encapsulation ensure larger and more complicated models to be built, modified and maintained than with traditional procedural approach, since the effect of changes to data and methods has been localized.

- Inheritance.

Inheritance is used to create class hierarchies. A set of objects that differ only in their data values is said to belong to the same class. Classes are arranged in inheritance hierarchy, where a child class may inherit both data and methods from its parent class, or classes, but still also has its own, specialized, data and methods. One of the major benefits of inheritance is the opportunity for reusing existing classes in new contexts.

- Polymorphism.

That is the property of an object responding appropriately, according to its class, to a standard message (or method invocation). An example of abstract concept that could usefully be represented as standard message is multiplication. A message sent to an integer will cause it to multiply itself by itself should perform integer multiplication. In a polymorphic implementation, the same message when received by a matrix would perform a matrix multiplication, and so on. Polymorphism can be particularly helpful when combined with late-binding in object oriented programming, where the exact class of an object is not known until the runtime, the same piece of code can be invoked on different classes of object and each will respond appropriately. For example, if a program is required to calculate total area of a set of different shapes, selected at runtime from a pick-list by the user, the high level code sends a standard message to each shape instructing it to return its area, and simply adds the result. This will usually reduce the amount of code required and also aids legibility because the high level code is not cluttered with details of how to calculate the different areas of different shapes. Furthermore, if a new shape is added, no need to alter the code. (Alyazjee, 2002)

2.2.2 Autodesk® Architectural Desktop®

Autodesk Architectural Desktop (ADT) provides a transitional approach to BIM, as an intermediate step from CAD. ADT creates its building model as a loosely-coupled collection of drawings, each representing a portion of the complete BIM. These drawings are aggregated through various mechanisms to generate additional views of the building, reports, and schedules as though there was a single BIM at the center. One overhead of this approach is complexity in managing this loosely-coupled collection of drawings and the opportunity for errors if the user manipulates the individual files outside the drawing management capabilities provided in ADT.

2.2.3 Bentley Systems® Microstation®

Bentley Systems interprets BIM differently as an integrated project model which comprises a family of application modules that include Bentley Architecture (which is still also sold in some international markets under its original Microstation Triforma name), Bentley Structures, Bentley HVAC, etc. Bentley describes this approach as an evolutionary path that allows its Microstation users to migrate work practices that still have their origins based on using CAD. Access to project data is provided with DWG and IFC file formats both being supported. However, the highest levels of interoperability are only achieved when the entire family of Bentley products are deployed on a project.

2.2.4 Graphisoft® ArchiCAD®

Graphisoft's approach to BIM is to create a virtual building model, meaning their ArchiCAD application is viewed as one of many satellite applications orbiting a virtual building model rather than being seen as the central repository for the entire model. In addition to ArchiCAD being conceived as a BIM system from its inception over 20 years ago, Graphisoft is now working with a consortia of application partners to deploy EPM Technology's IFC-based model server as a virtual building repository, possibly the most innovative technical approach to the future of BIM. (Howell, and Batcheler, 2003)

2.2.5 Autodesk® Revit® Building

Through building information modeling (BIM), architects today can efficiently simulate high-performance buildings as an integral part of their form-making process. Design for energy conservation, needs not depend solely on engineers focused on mechanical solutions any longer, to achieve sustainable design that seeks to mitigate this negative impact through the use of environmentally sensitive design and construction practices.

Ever since 2000, a building information modeling system called Revit has been launched in various versions. Autodesk® Revit® Building is a building information modeler for architectural design that integrates views, annotations, and components into a single building information model. It is one of the leading BIM solutions available today (Khemiani, 2005). It supports the continuous and immediate availability of information relative to project design scope, schedule, and cost that is high quality, reliable, integrated, and fully coordinated (Smedley and Hoeflinger, 2005) through these two critical ideas:

- Keeping critical project information in digital form within a **single model database**.
- Creating real-time, consistent relationships between digital design data with parametric modeling technology. **Parametric Modeling** is the process of constructing a "virtual building" manifest in a 3D computer model where each component is created once thus providing bi-directional manipulation that occurs instantly and universally.

Autodesk® Revit® Building is based upon family groups "family based" which are all of the building elements information that the users put into their drawings that will be collected in the Revit Elements and Families database. A Family is a collection of objects, called types. A family groups elements with a common set of parameters, identical use, and similar graphical representation. Each Family element can have multiple types defined within it, each with a different size, shape, material set, or other parameter variables as designed by the family creator.

Autodesk® Revit® is perhaps the most literal interpretation of a single BIM as a central project database. The strength of this approach is the ability to coordinate every building element in one database, thus providing users the ability to immediately see the results of any design revisions made in the model, have them reflected in the associated views (drawings), as well as to detect any coordination issues. Revit® is a proprietary data model which does not currently support IFC import/export, although future IFC support has been promised. For software developers, ODBC links provide limited access to the building model information and a limited application programming interface has been provided in the most recent release. (Howell, and Batcheler, 2003)

The Autodesk® Revit® platform for building information modeling is a complete architectural design and documentation solution supporting all phases of design and all the architectural drawings and schedules required for a building project. (Autodesk, Inc., 2005a)

Revit Building provides a whole new concept in the architectural process. It was designed to provide the following capabilities:

- Mirrors an integrated architectural process
- Mirrors architectural thinking
- Encourages change
- Enables multi-user coordination
- Reflects what a building really is

Parametric building elements are at the heart of Revit Building and they are already provided. The building components include walls, windows, column, stairs, roofs, and doors. There is a built-in intelligent relationship between these components, and their look and feel can be easily changed by changing their controlling setting. The users can also simply design their own building components in Revit Building. Besides, Revit Building's revolutionary Family Editor allows users to graphically create their own components.

Revit Building is a CAD product made for the Microsoft® Windows operating system. Its interface resembles those of other products made for Windows. It features menus with commands, toolbars with buttons, dialog boxes, and windows in which the users complete tasks. Many of the model components, such as walls, windows, and doors, are available at the click of a button.

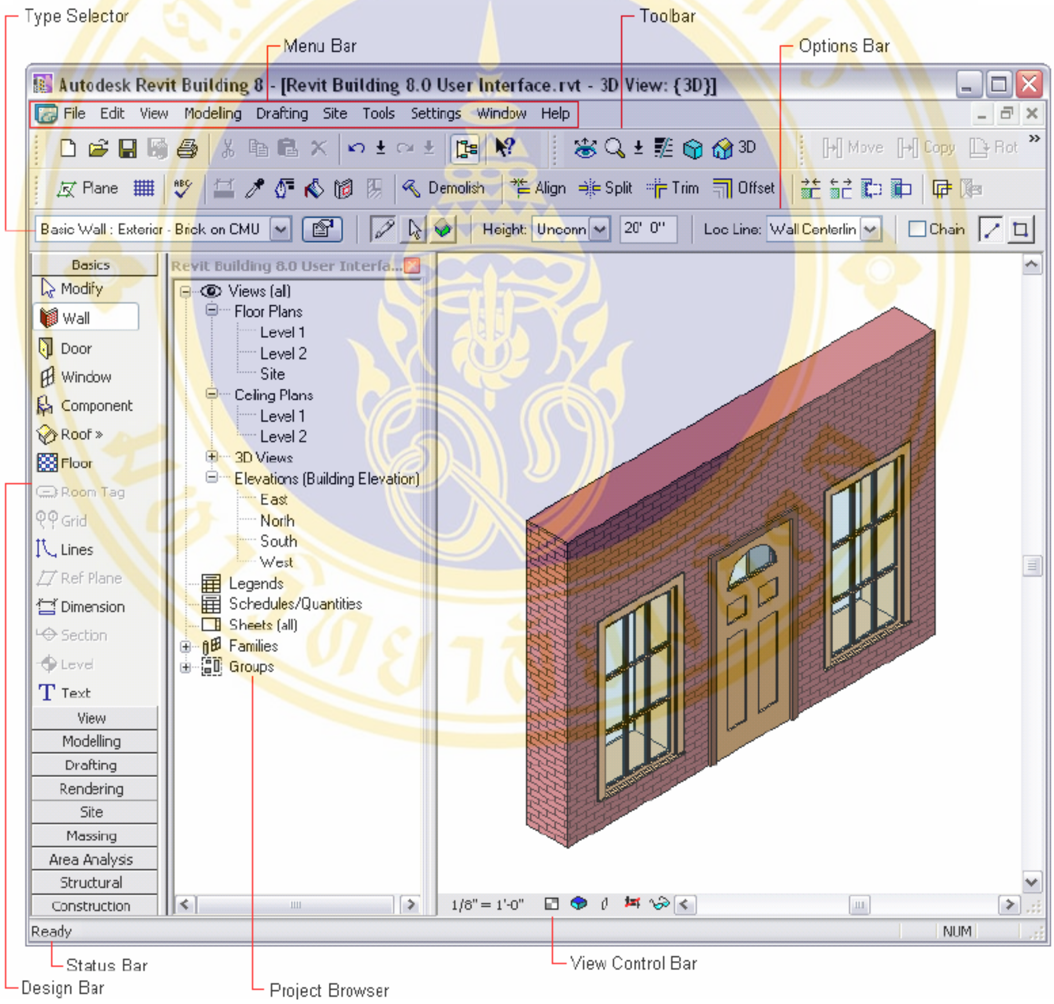


Figure 2.3 Revit Building's Interface

A fundamental characteristic of a building information modeling application is the ability to coordinate changes and maintain consistency at all times. Revit Building uses two key concepts that make it especially powerful and easy to use.

The first is the capturing of relationships while the designer works. The second is its approach to propagating building changes.

Revit Building uses five software **element classes:** host, component, annotation, view, and datum. Hosts include walls, floors, roofs, and ceilings. Components include windows, doors, and furniture. Annotations are 2D, view-specific elements that help documenting. Views are dynamic representations of the model and are always up-to-date. Datums are reference elements that help putting building together.

In Revit Building, the elements determine their behavior largely from their context in the building. The context is determined by how the users draw the component and the constrain relationships that are established with other components.

Most of the terms used to identify objects in Revit Building are common, industry-standard terms familiar to most architects. The following defines the basic terms used in Revit Building:

- **Project:** the project is the single database of information for the user's design - the building information model. The project file contains all the information for a building design, from geometry to construction data.

- **Level:** Levels are infinite horizontal planes that act as reference for level-hosted elements, such as roofs, floors, and ceilings. Most often, user uses levels to define a vertical height or story within a building.

- **Family:** a Family is a collection of objects, call types. A family groups elements with a common set of parameters, identical use, and similar graphical representation. Different types within a family may have different values of some or all parameters, but the set of parameters – their names and their meaning – are the same. All elements in Revit Building are family-based.

- **Type:** a Type is a member of a family. Each Type has specific parameters that are constant for all instance of the Type that exist in the model. These are type properties. Types have other parameters called Instance parameters, which may vary over the various instances of this type in any model.

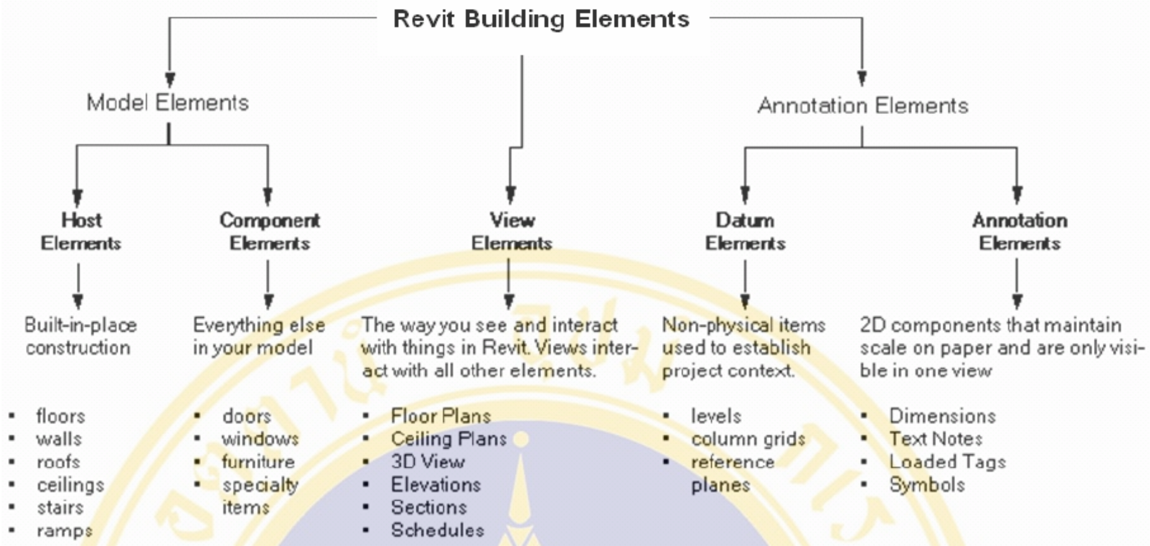


Figure 2.4 Revit Building Elements

Revit Building offers several different methods of geometry creation to use when define the user's families. User can combine these methods to create a family. The geometry forms available are lines, extrusions, sweeps, blends, revolves, and regions. User can also add text and tags to the families.

2.3 Health Facility Building Design of The Design and Construction Division, Ministry of Public Health

2.3.1 The Design and Construction Division, Ministry of Public Health

Design and Construction Division (DCD) is a division of Health Service Support Department, Ministry of Public Health was established in 1967 to operate the health facility building design, construction and providing services of health facility building design and construction information to interested individuals and parties.

2.3.2 The Building materials and components specifications of health facility buildings

The standard of building materials and component specifications of health facility buildings comprise of:

- Walls specification
- Floors specification

- Ceiling specification
- Doors specification
- Windows specification
- Roofs specification
- Construction specifications
    - Columns specification
    - Beams specification

2.4 Bioclimatic Design Data for Florida, U.S.A.

2.4.1 Florida based on bioclimatic design condition

Figure 2.5 U.S. regions based on bioclimatic design conditions

As seen above, Figure 2.5 indicates an approximate characterization of United States regions, the regional characterization offers a way to understand macroclimatic factors. (Watson, and Milne, 1998)

Florida is defined as "humid overheated" which it is less than 2,000 HDD (Heating Degree Days) and it requires little heating in comparison to cooling. The entire of Florida has mean daily humidity readings exceeding comfort limits under still air conditions. The main bioclimatic strategy of this region is thus to use shading and ventilation, to minimize if not to replace mechanical dehumidification and air conditioning, which may be required as a function of building type and climate.

Table 2.1 Tampa, Florida Temperature Data (City of Tampa, 2006)

Month	Maximum Temperature (˚F)	Minimum Temperature (˚F)	Average Temperature (˚F)
January	70	50	60
February	71	51	61
March	77	57	67
April	82	61	71
May	87	67	77
June	89	73	81
July	90	75	82
August	90	75	82
September	90	73	81
October	84	65	75
November	77	57	67
December	72	52	62

Table 2.2 Relative Humidity Data for Tampa, Florida
(Southeast Regional Climate Center, 2006)

Month	Maximum RH (%)	Average RH (%)
January	87	60
February	86	57
March	87	56
April	86	52
May	85	53
June	86	60
July	87	64
August	90	65
September	91	63

Month	Maximum RH (%)	Average RH (%)
October	89	58
November	88	58
December	88	60
Annual	88	59

2.4.2 Passive solar heating potential of south-facing windows for Florida

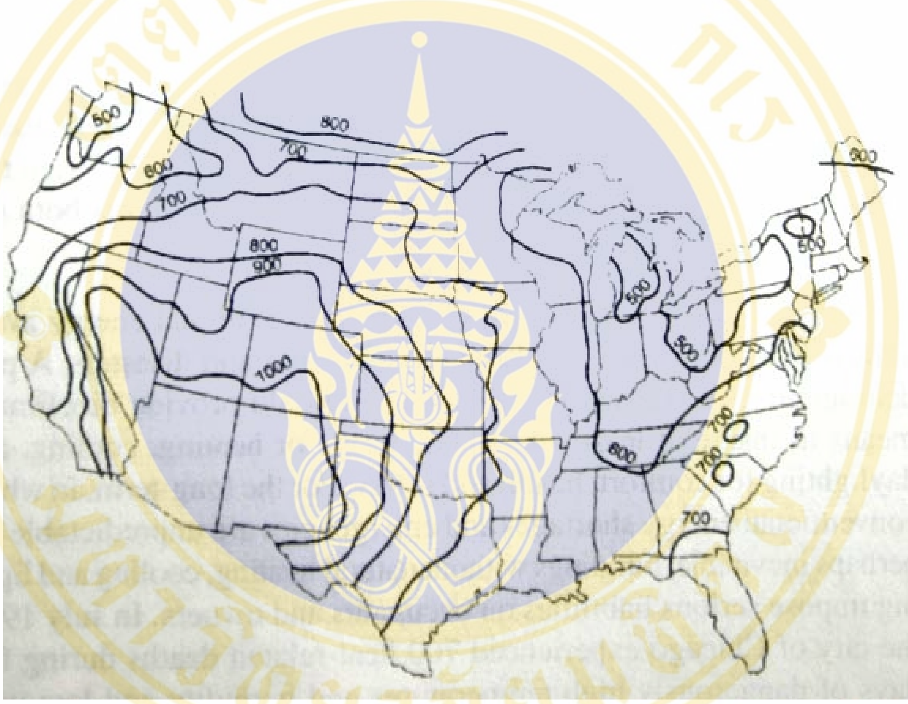


Figure 2.6 Passive solar heating potential south-facing windows (Btu/SF/day)

Florida has potential of 700 Btu/SF/day (SF: South-Facing) and it causes effects on an architectural design technique "Sun-Tempering" which may provide a substantial portion of winter heating. Otherwise, the Sun-Tempering technique needs to be careful to be used, especially of south-facing windows in any humid overheated region.

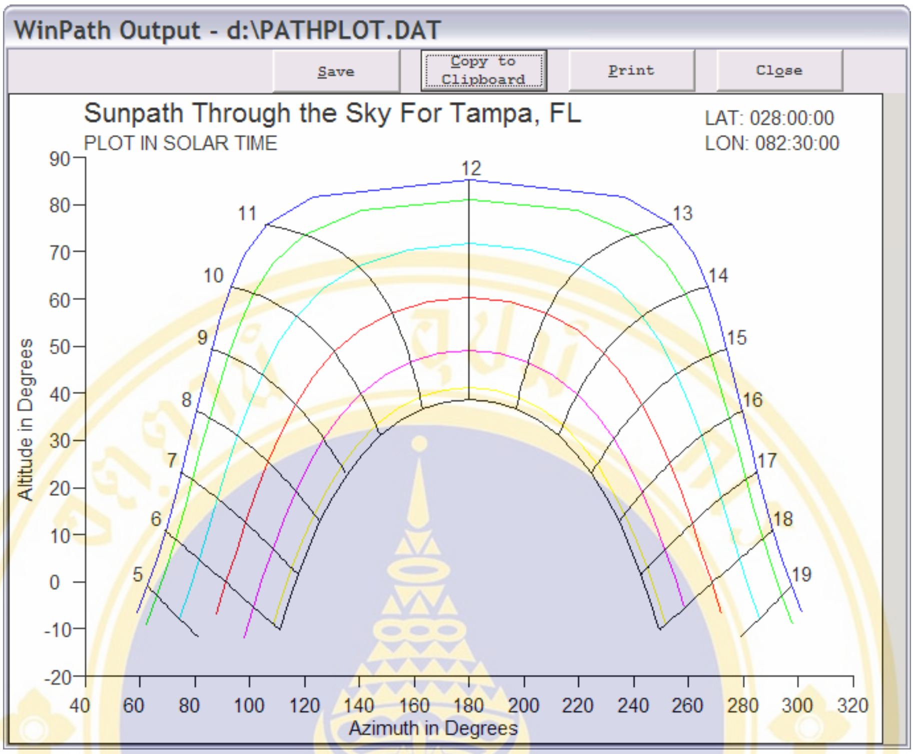


Figure 2.7 An Equidistant Vertical Sun-Path Diagram for Tampa, Florida

According the sun-path that is shown above. The blue line represents sun path line of Northern (June) Solstice which the altitude and the vertical shadow angle of the sun at the time is maximum and the sun position is most north. The red line represents the equinox days (approximately March 22 and September 22) which the sun is directly over the equator, the earth-sun line is within the of the equator, thus the declination = 0˚. The innermost black line represents sun path line of Southern (December) Solstice which the altitude and the vertical shadow angle of the sun at the time is minimum and the sun position is most south; the beam radiation of the sun can directly penetrate inside building at sharp angle in the winter season.

2.4.3 Bioclimatic analysis for Florida

Table 2.3 Bioclimatic design data for Florida, U.S.A.

Bioclimatic Conditions	% Hours/Year
1. Within comfort	18

Bioclimatic Conditions	**% Hours/Year**
2. heating is required	16
3. Cooling is required	50
4. Promote solar heating	16
5. Sun-tempering is very effective	15
6. Restrict solar gain (shading)	84
7. Promote ventilation	35
8. Promote evaporative cooling	7
9. Utilize thermal mass for "coolth"	9
10. Beyond passive cooling effectiveness	31
11. Dehumification alone will provide cooling	16

Climatic data indicated in Table 2.1 are read for representative climatic locations across the Florida. Some of the data indicate that:

- 18 percent of annual hours fall within comfort zone in which one is comfortable under a shade of tree.
- 31 percent of annual hours in Florida are beyond passive cooling strategies and
- 50 percent of annual hours require some form of cooling which means 19 percent of annual hours are within the effectiveness of passive cooling strategies.
- However about 16 percent of annual hours require dehumidification alone, not cooling.
- Provision shading of windows is extremely needed (84 percent of annual hours of the year).
- Contrarily, sun-tempering of south-facing windows is needed for just 15 percent of annual hours.
- Design of controlled ventilation for cooling is very effective (35 percent of annual hours of the year)

2.5 Related Research

2.5.1 Specification and Implementation of IFC Based Performance Metrics to Support Building Life Cycle Assessment of Hybrid Energy Systems (Morrissey, O'Donnell, Keane and Bazjanac, 2004)

This research developed for storage and utilization of these performance metrics through an Industry Foundation Classes (IFC) instantiated Building Information Model (BIM). The paper describes a Building Information Model (BIM) that stores or references building-specific data from various sources (see Figure 2.4).

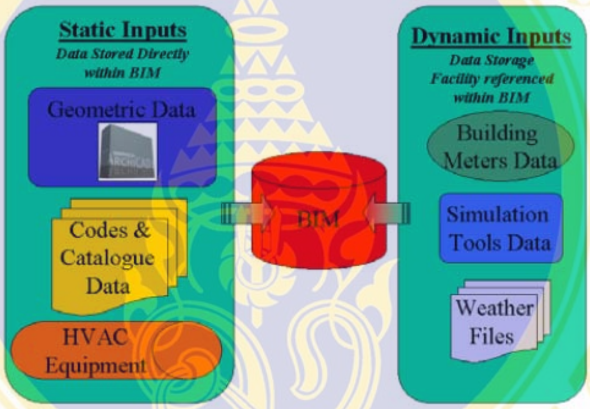


Figure 2.8 Schematic of BIM storage facility

The framework utilized for this paper is referred to as the Building Energy Monitoring, Analyzing and Controlling (**BEMAC**) framework. This non-proprietary integrated environment for obtaining, formatting, storing, retrieving and controlling data associated with the building's energy usage is employed due to its interoperability between varying software tools. The Standard for the Exchange of Product Model Data (STEP) and IFC's are employed for transfer and storage of all building related information.

In order to visualize and display these rich sets of performance data, a performance indicating software tool must be utilized. For the purposes of this work, efforts are focused on development of a beta version of BuildingPI. This software tool, currently under development, will offer the user a 'view' or a direct visualisation of the performance data for a building that is instantiated in the IFC 2*x*2 format.

The paper focuses on storage of three sets of performance data from three distinct sources, which are; Benchmark Metric: Building codes and manufacturer's catalogues, Simulated Metric: Simulation package(s), and Measured Metric: BMS. An example of a performance metrics programming hierarchy is displayed for a heat pump and a solar array. Utilizing the sets of performance data, two discrete *performance effectiveness ratios* may be computed. The first effectiveness metric ratio is the **Idealized Effectiveness Ratio** (*Ir*), which is computed by dividing the benchmark metric by the measured metric and the second effectiveness ratio is **Performance Effectiveness Ratio** (*Pr*), is computed by dividing the simulated metric by the measured metric. The 'Idealised Effectiveness Ratio' offers the ideal building, which can be used for comparison purposes; the 'Performance Effectiveness Ratio' offers a means to attain this ideal through efficient scrutiny of the installed systems.

2.5.2 Optimization of Buildings with Respect to Energy and Indoor Environment (Nielsen, 2002)

TOKE RAMMER NIELSEN carried out this Ph.D. Thesis between February 1999 and June 2002. The purpose of this project is to develop a building design methodology that supports optimization of building designs in the early stages of the design process. The purpose of building design optimization is to reach a cost effective building design with good performance. This means that the optimal building design in a given case must fulfill requirements expressed by the society and the user of the building at minimal cost.

The evaluation of cost is based on life cycle cost calculations and the optimization is performed with respect to other performance aspects such as energy use, indoor environment and daylight conditions.

The design methodology is developed based on a discussion of the building design process, performance assessment methodologies, modeling and simulation of buildings, economic theory and optimization approaches.

The researcher stated that many aspects of the overall building performance depend on decisions in the early stage of the design process. To improve the performance of buildings it is necessary to be able to assess the performance and monitor cost during the design process. This is possible if the consultants and the building user cooperate with the contractors, manufacturers and suppliers from the early stage of the design process.

The desired performance of the building is based on an early identification of the needs expressed by the user and the society. Many aspects related to the physical, energetical and environmental performance of a building design influence the life cycle cost. Therefore, the life cycle cost may be used as an objective measure of the overall building performance. Still aspects such as thermal indoor environment and daylight conditions are difficult to associate directly with cost. These aspects must be handled individually by imposing additional performance requirements.

Performance assessment of different building designs requires the use of computer simulation. With few exceptions, existing design tools may be used to evaluate the consequences of a particular building design but are generally unable to suggest a particular design solution. Using design tools, problem definition and parameter variations can be very time consuming. Also analyzing many parameter variations may not result in the optimal solution, as the influence of different design parameters on the performance can be difficult to understand. Automatic optimization can replace manual variation of different design variables and save the building designer a lot of work and at the same time guide the building designer towards a cost effective building design with good performance.

In this thesis a building design methodology is suggested that support optimization of building designs in the early stage of the design process. The design methodology is implemented in a design tool that utilizes an optimization method to perform automatic parameter variations of the design variables to find the geometry and mix of building components that minimizes the life cycle cost with respect to energy use, thermal indoor environment and daylight conditions. The building designer defines the geometric parameters, selects alternative building components from a building component database and defines performance constraints that constitute the solution space for the design problem using a graphical user interface.

The design methodology implemented in the prototype tool is tested on two case studies. The case studies consider optimization of a room in a one-family house and optimization of office rooms in a multi storey office building.

Based on the work presented in this thesis it is concluded that is possible to develop design tools that are useful in the early stage of the design process and helps the building designer minimize the life cycle cost of the building design with respect to energy and indoor environment.

2.5.3 nD Modelling in the Development of Cast in Place Concrete Structures (Jongeling, Emborg and Olofsson, 2005)

ROGIER JONGELING, MATS EMBORG and THOMAS OLOFSSON are researchers in The Swedish IT-stomme (IT-structure) project, which is aimed at applying product models in practice and developing modeling tools for cast in place concrete structures. The main focuses of the research are product modeling, Building Information Model (BIM), nD modeling and Virtual Building Environment (VBE). **A product model** refers to data models that contain both product and process data supporting a building's life cycle. **A Building Information Model (BIM)** is a computer model database of building design information, which may also contain information about the building's construction, management, operations and maintenance. **An nD model** is an extension of the BIM, which incorporates multi-aspects of design information required at each stage of the lifecycle of a building facility. **A Virtual Building Environment (VBE)** is a "place" where building industry project staffs can get help in creation BIMs and in the use of virtual buildings.

Implementations and applications discussed in this paper are mainly driven by the interests from a ready mixed concrete supplier who identified product modeling as a threat and as an opportunity for its business process.

A residential construction project is modeled in the IT-stomme project with and Internet-based product modeling system developed by Enterprixe Limited. The system uses a central database in which the product model is stored. Additional databases containing for example cost data or documents can be linked to the central database. When logged in, a project can be selected from the product model server and specific client software to view and edit the product model. AutoCAD-based software and a VRML viewer embedded in an Internet browser are used as software clients to the product model server in the IT-stomme. Exchange file import and export is used in addition to direct client-server connection to extend the product modeling environment.

A number of product model dimensions is discussed that result from combining different software applications. The objective of the IT-stomme study was to illustrate and develop the use of product models in practice beyond 3D modeling. An example of a potential n^{th} dimension of product model development and use is given, in addition to a product model's 2^{nd}, 3^{rd}, 4^{th} and 5^{th} dimension. The n^{th} dimension is illustrated by integrating a product model with results from a program used to calculate the optimal drying process for concrete slabs. This paper concludes by discussing main challenges for the uptake of product models in practice in relation to findings and efforts from the IT-stomme project.

2.5.4 ArDOT: A Tool to Optimise Environmental Design of Buildings (Mourshed, Kelliher, and Keane, 2003)

ArDOT, an Architectural Design Optimisation Tool, it was under development at IRUSE, National University of Ireland, Cork. The paper focuses on environmental design of buildings involves "finding the optimum" solution satisfying predefined objectives (e.g., reduction in operating/capital cost, maximization of daylighting etc.). A number of computer based simulation models exist to assist professionals in finding this optimum through building performance assessment. MONJUR MASUM MOURSHED, DENIS KELLIHER, and MARCUS KEANE founded that contemporary practices involving building simulation require enormous effort to prepare input, extract output, and visualize data, which restricts designers from realizing the full potentials offered. In most cases, rules of thumb are applied and experienced guesses are made; simulation software is used only to validate the assumptions, which do not necessarily lead to the intended optimum. Moreover, these tools have been developed as simulation engines, which is inadequate to visualize the compounded and interdependent effect of a large number of design variables.

The authors believe that to realize the potential offered by building simulation software, a new breed of DBSs (Decision Based Systems) is needed coupling existing simulation engines with formal optimization methods through neutral data standards (BPM – building product models) for seamless integration. This paper first elaborates on the previous attempts at solving integration issues related to the design process and simulation; also attempts at finding the limitations. Secondly, formulation of design problems as optimization has been discussed with reference to the different stages of design. Thirdly, for effective integration of activities among stakeholders and processes, the use of client/server oriented building product model has been proposed to overcome the limitations of file-based prototypes. The authors commented that combining all three aspects into one makes ArDOT unique, which is essentially an enhanced decision making tool for the design of energy efficient buildings.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Tools

3.1.1 Hardware

- Processor: Intel® Pentium® 4 1.4 GHz or equivalent AMD® Athlon™ processor
- Main Memory: 1 GB RAM
- Display: 1024 x 768 monitor and display adapter capable of 24-bit color
- Hard Disk Drive: 1 GB free disk space

3.1.2 Software

- Operating System: Microsoft® Windows® XP
- Internet Browser: Microsoft Internet Explorer 6.0
- Building Information Modeling System: Autodesk® Revit® Building 8.1
- Building Energy Analysis Tool: Green Building Studio™ from GeoPraxis, Inc.

3.1.3 Internet Connection: High speed Internet
Upstream ≥ 128 Kbps
Downstream ≥ 128 Kbps

3.2 Research Procedures

3.2.1 Data collection

3.2.1.1 Collecting the existing health facility building data

- Health facility building template handouts distributing data
  - Gather data of the building template designs which are the three most distributed for the last 5 years.

– The design serial number, name, type, size, and, amount of the design handouts

- Examine for the building template design which has the most complicated architectural function.
- Select the research example building template design for developing the building information model.

3.2.1.2 Health facility building template design drawings and specifications data

Collecting the architectural drawings and specifications which are included the building components and materials data of the research example building template design.

3.2.2 Building information model database development

3.2.2.1 Building Information Modeling System selection

The candidates of BIM systems in the selection of research tool are Autodesk® Architectural Desktop® (ADT), Graphisoft® ArchiCAD®, and Autodesk® Revit® Building.

The weightings of properties in the selection of the Building Information Modeling (BIM) System to be used in this research are:

(1) Companion to DCD architects .... 40 %

(2) Accuracy of parametric modeling .... 30 %

(3) Interoperability to building energy simulation programs .... 30 %

The maximum score will be given in each property is 3 for the system that has the maximum number in that property, 2 is given to the runner-up and 1 is given to the system that has the minimum number in that property. The scores that each system gets in every property will be multiplied by the weighting of that property. The total sum of the scores of each system will be used to select the research BIM tool: The maximum total score is the research BIM tool.

Table 3.1 Scores of the properties for the selection of the research BIM tool

	Companion to DCD architectors *Weighting 40*	Accuracy of parametric modeling *Weighting 30*	Interoperability *Weighting 30*	**Total Score**
ADT	2 2 x 40 = 80	2 2 x 30 = 60	2 2 x 30 = 60	200
ArchiCAD	1 1 x 40 = 40	2 2 x 30 = 60	2 2 x 30 = 60	160
Revit Building	3 3 x 40 = 120	2 2 x 30 = 60	2 2 x 30 = 60	240

The maximum total score goes to **Autodesk® Revit® Building** which gets total score = 240 and it is the research BIM tool.

3.2.2.2 Building Energy Analysis Tool selection

The candidates of building energy analysis tool in the selection of research tool are DOE-2, EnergyPlus and Green Building Studio™ (GBS).

The weightings of properties in the selection of the building energy analysis tool to be used in this research are:

(1) Easy to use for DCD architects .... 40 %

(2) Efficient to compare the energy performance of the research example building according to its different orientation .... 30 %

(3) Interoperability to the research BIM tool .... 30 %

The maximum score will be given in each property is 3 for the tool that has the maximum number in that property, 2 is given to the runner-up and 1 is given to the tool that has the minimum number in that property. The scores that each system gets in every property will be multiplied by the weighting of that property. The total sum of the scores of each tool will be used to select the research energy analysis tool: The maximum total score is the research building energy analysis tool.

Table 3.2 Scores of the properties for the selection of the research building energy analysis tool

	Easy to use for DCD architectects	Efficient to compare the energy performance	Interoperability	**Total Score**
	Weighting 40	*Weighting 30*	*Weighting 30*	
DOE-2	1 1 x 40 = 40	3 3 x 30 = 90	1 1 x 30 = 30	160
EnergyPlus	1 1 x 40 = 40	3 3 x 30 = 90	2 2 x 30 = 60	190
GBS	3 3 x 40 = 120	2 2 x 30 = 60	3 3 x 30 = 60	240

The maximum total score goes to **Green Building Studio™** which gets total score = 240 and it is the research building energy analysis tool.

3.2.2.3 Defining and determining the health facility building materials and components

- Defining the building components and materials specification data of the building template design research example from its architectural drawings and documents.
- Translating the building components and materials specification data into the structure of the Revit Families: Autodesk® Revit® Building BIM system.
    - Columns → Kind of family template
      Type name

Type of column (rectangular/round)
Depth x Width / Diameter
Column materials
Base level
Top level

- Beams → Kind of family template
  Type name
  Type of beam
  Beam Width x Height
  Structural usage (Girder, Joist, Purlin, or Bracing)
  Beam materials
  Reference level and Elevation
- Doors → Kind of family template
  Type name
  Door leaf width
  Door leaf height
  Door width
  Door height
  Door panel thickness
  Door panel material(s)
  Door frame material(s)
- Windows → Kind of family template
  Type name
  Window width
  Window height
  Sill height
  Window **frame** solid geometry
  – Geometry descriptions and material(s)
  Window **sash** solid geometry
  – Geometry descriptions and material(s)
  Window **glass** solid geometry

– Geometry descriptions and material(s)
Window **mullion** solid geometry
– Geometry descriptions and material(s)

- Walls → Kind of family template
  Type name
  Wall structure
  – Wall functions, materials, and thickness
  Wall base constraint
  Wall top constraint
- Floors → Kind of family template
  Type name
  Floor structure
  – Floor functions, materials, and thickness
  Level or height
- Ceilings → Kind of family template
  Type name
  Ceiling structure
  – Ceiling functions, materials, and thickness
  Ceiling grid size
- Roofs → Kind of family template
  Type name
  Roof type
  Roof structure
  – Roof functions, materials, and thickness
  Base level
  Slope angle
- Stairs → Kind of family template
  Type name
  Stairs width
  Tread properties

– Tread material, depth, nosing profile, and thickness

Riser properties

– Riser material, riser type, and thickness

Stringer properties

– Stringer material, height, stringer carriage height, and landing carriage height

- Railings → Kind of family template

  Type name

  Rail properties

  – Height, profile, and materials

- Detailing→ Room tags

3.2.2.4 Creating the health facility building material and component types and families using Autodesk® Revit® Building Family Editor

- Using the Revit Family Template Files for crating the types and families of the research example including the defined building material and components.
  - Creating door families
  - Creating window families
  - Creating wall families
  - Creating floor families
  - Creating ceiling families
  - Creating roof families
  - Creating stair families
  - Creating railing families

3.2.3 Implement the building information model

3.2.3.1 Loading the families to a health facility building project

3.2.3.2 Creating a health facility building model project

- Create **the First Prototype** of the building research example Revit Building project.

3.2.3.3 Testing and correcting the building information model

3.2.4 Building energy performance measurement testing: Exporting the building information model to a simulation tool

3.2.4.1 Building energy performance measurement testing of the First Prototype using Green Building Studio™ by GeoPraxis, Inc.

- Create a new Green Building Studio project
    - Registration
    - Enter the project name, select a Building Type and US ZIP code
- Export gbXML from Revit using Green Building Studio Client
    - Confirm the completion of project phase, room tags and ZIP code
    - Export the Revit project into gbXML format
    - Activate and login the Green Building Studio Client
    - Select the gbXML file
    - Send the gbXML file to be analyzed through the Internet
- Get the energy analysis results of the first prototype through the Internet
    - The energy analysis results will be send to the researcher's email account

3.2.4.2 Building orientation testing

- Change the orientation of the first prototype: Rotate the first prototype clockwise for seven 45° different axis using the Rotate command.
    - Select the whole of the first prototype to rotate
    - Specify the center of rotation symbol
    - Select the Angle option of the rotation

- Enter the 45° angle of rotation. Revit Building automatically performs the rotation.
- Export gbXML from Revit using Green Building Studio Client
- Repeat the Rotate command and export gbXML to the rotated prototype; 45° 90° 135° 180° 225° 270° 315° of the first prototype
- Get the energy analysis results of the rotated building model through the Internet

- Compare the results of the first prototype with the results of the seven rotated prototype building models
- Examine the GBS results. The rotated prototype which has the best energy analysis results is **the Second Prototype**.

3.2.4.3 Building components changing testing

- Create some of new material and building component Revit Families that relate to the research example building envelope
  - Creating new roof families
  - Creating new window families
  - Creating new wall families
- Implement the building information model to the Second Prototype. The building components changed prototype is **the Third Prototype**.
- Export the Third Prototype's gbXML from Revit using Green Building Studio Client.
- Compare the GBS building energy analysis results of the First and Second Prototype with the results of the Third Prototype.

3.2.4.4 Shading devices addition testing

- Create some of shading device Revit Families

- Implement the building information model the Second Prototype. The shading devices added building model is **the Forth Prototype**.
- Export the Forth Prototype's gbXML from Revit using Green Building Studio Client.
- Compare the GBS building energy analysis results of the First, Second and Third Prototype with the results of the Forth Prototype.

3.2.5 Research conclusion

3.2.6 Research documentation

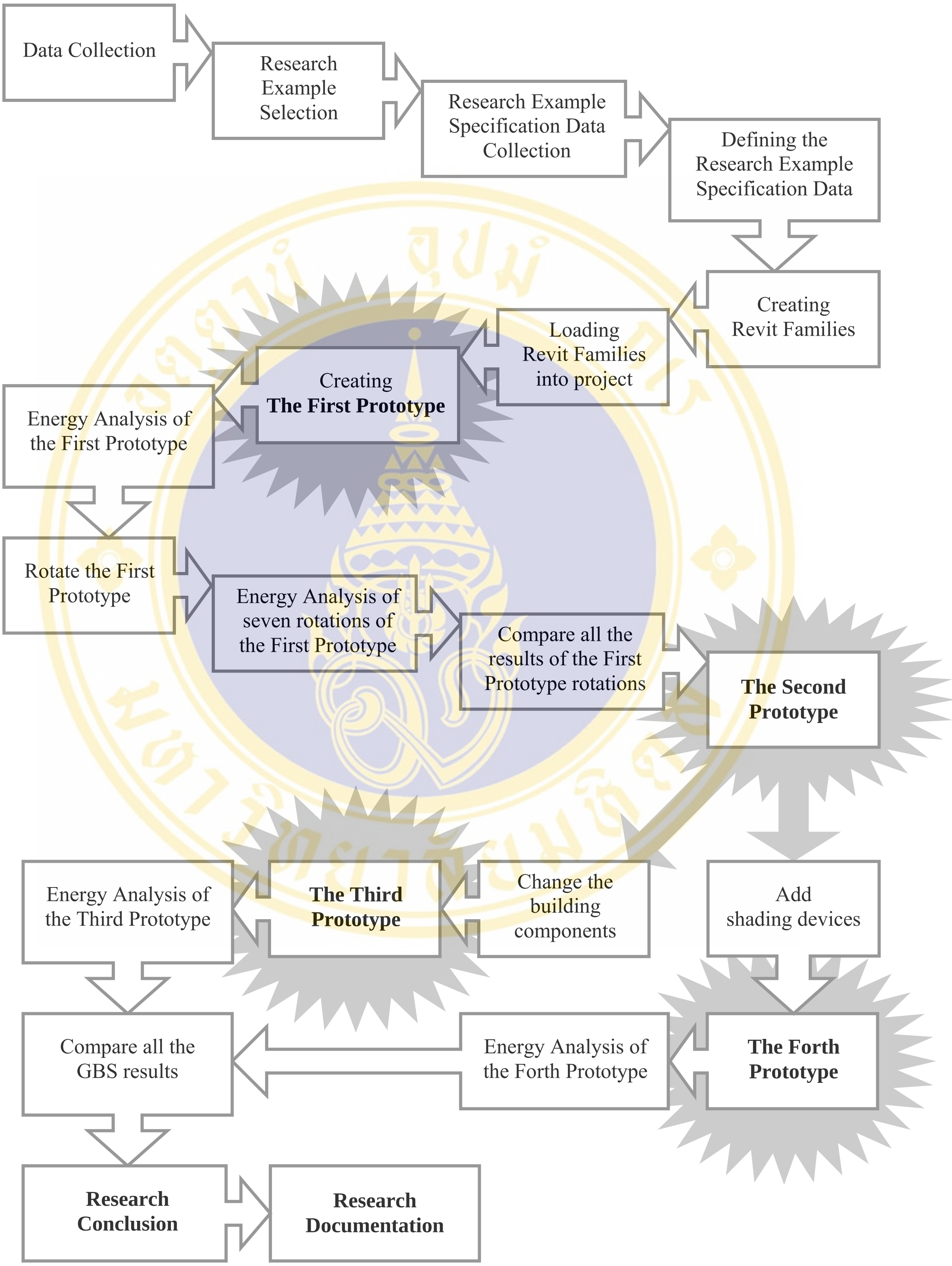


Figure 3.1 Research methodology diagram

CHAPTER IV
SYSTEM DEVELOPMENT

4.1 Research example selection

4.1.1 Collecting the existing health facility building data

- Health facility building template handouts which are the three most distributed for the last 5 years are:
  1) An inpatient ward building which has building details as following:
     – DCD number → 2731/2530
     – Building usage → Inpatient ward (**1 function**)
     – Number of floors → 1
     – Functional area → 610 m^2
     – Number of people → Hospital staffs = 20
       → Patients = 30
     – Number of handouts in the last five years
       → 122 copies for hospital's requisitions

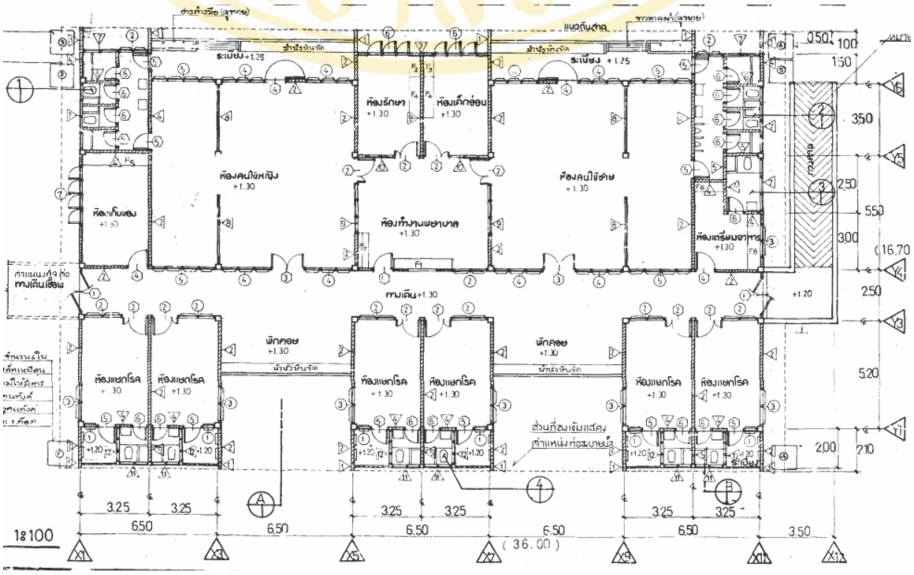


Figure 4.1 First floor plan of inpatient ward building number 2731/2530

2) An outpatient department (OPD) building which has building details as following:
   - DCD number → 3130/2526
   - Building usage → Outpatient Department (OPD), Emergency Room (ER), Diagnostic Department: Laboratory and Radiology Section, Dental Department, Pharmacy Department, Operation Rooms, Delivery Room and Medical Registration and Record Department, Health Promotion Department, Administration Department and Director's Office (**12 functions**)
   - Number of floors → 2
   - Functional area → 1,300 m^2
   - Number of people → Hospital staffs = 65
     → Patients = 200
   - Number of handouts in the last five years
     → 81 copies for hospital's requisitions

Figure 4.2 A photograph of OPD building number 3130/2526

3) An Central Supply Service Department (CSSD) building which has building details as following:

- DCD number → 5323/2536
- Building usage → Central Supply Service Department (**1 function**)
- Number of floors → 1
- Functional area → 160 m^2
- Number of people → Hospital staffs = 5
  → Patients = 0
- Number of handouts in the last five years
  → 107 copies for hospital's requisitions

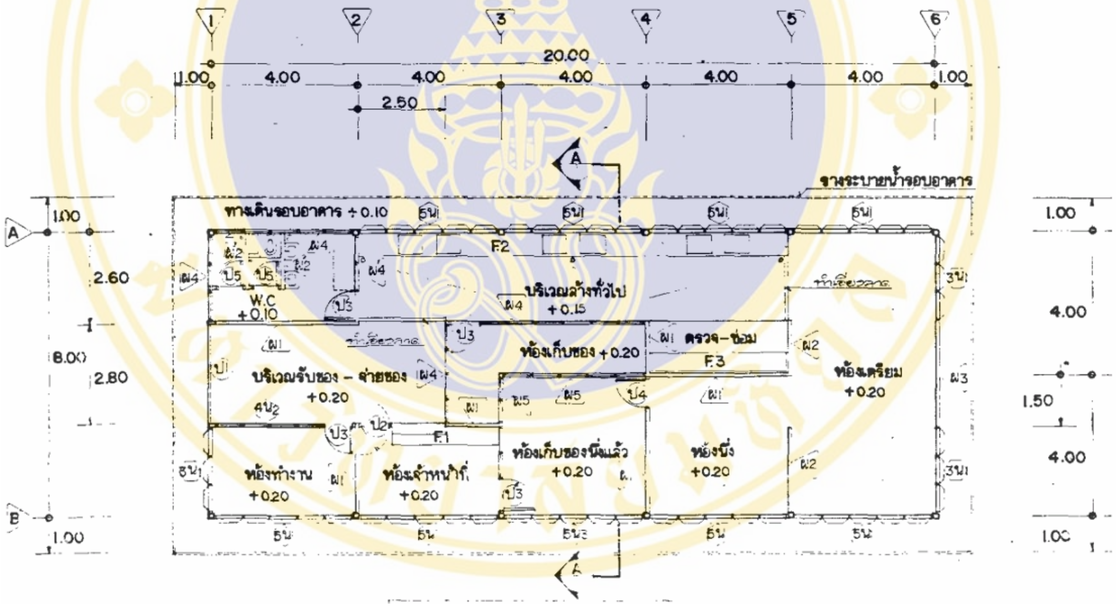


Figure 4.3 Floor plan of Central Supply Service Department (CSSD) building Number 5323/2536

4.1.2 Select the research example building template design for developing the building information model.

- The weightings of building detail categories in the selection of the research example are:

  (1) Number of handouts in the last five years.....30 %

  (2) Building usage..30 %

(3) Functional area..20 %

(4) Number of people..20 %

The maximum score will be given in each category is 3 for the building that has the maximum number in that category, 2 is given to the runner-up and 1 is given to the building that has the minimum number in that category. The scores that each building gets in every category will be multiplied by the weighting of that category. The total sum of the scores of each building will be used to select the research example: The maximum total score is the research example building.

	Number of handouts	**Building usage**	**Functional area**	**Number of people**	**Total Score**
	Weighting 30	*Weighting 30*	*Weighting 20*	*Weighting 20*	
Inpatient Ward **2731/2530**	3	2	2	2	230
	3 x 30 = 90	2 x 30 = 60	2 x 20 = 40	2 x 20 = 40	
OPD Building **3130/2526**	1	3	3	3	240
	1 x 30 = 30	3 x 30 = 90	3 x 20 = 60	3 x 20 = 60	
CSSD Building **5323/2536**	2	1	1	1	130
	2 x 30 = 60	1 x 30 = 30	1 x 20 = 20	1 x 20 = 20	

Table 4.1 Scores of the main categories for the selection of the research example

The maximum total score goes to the **OPD Building** number **3130/2526** which gets total score = 240, which means this building template design is popular and big. It contains many sophisticated medical and administration functions. And this design affects many types and number of people including the hospital staffs and patients. And finally, it is the research example.

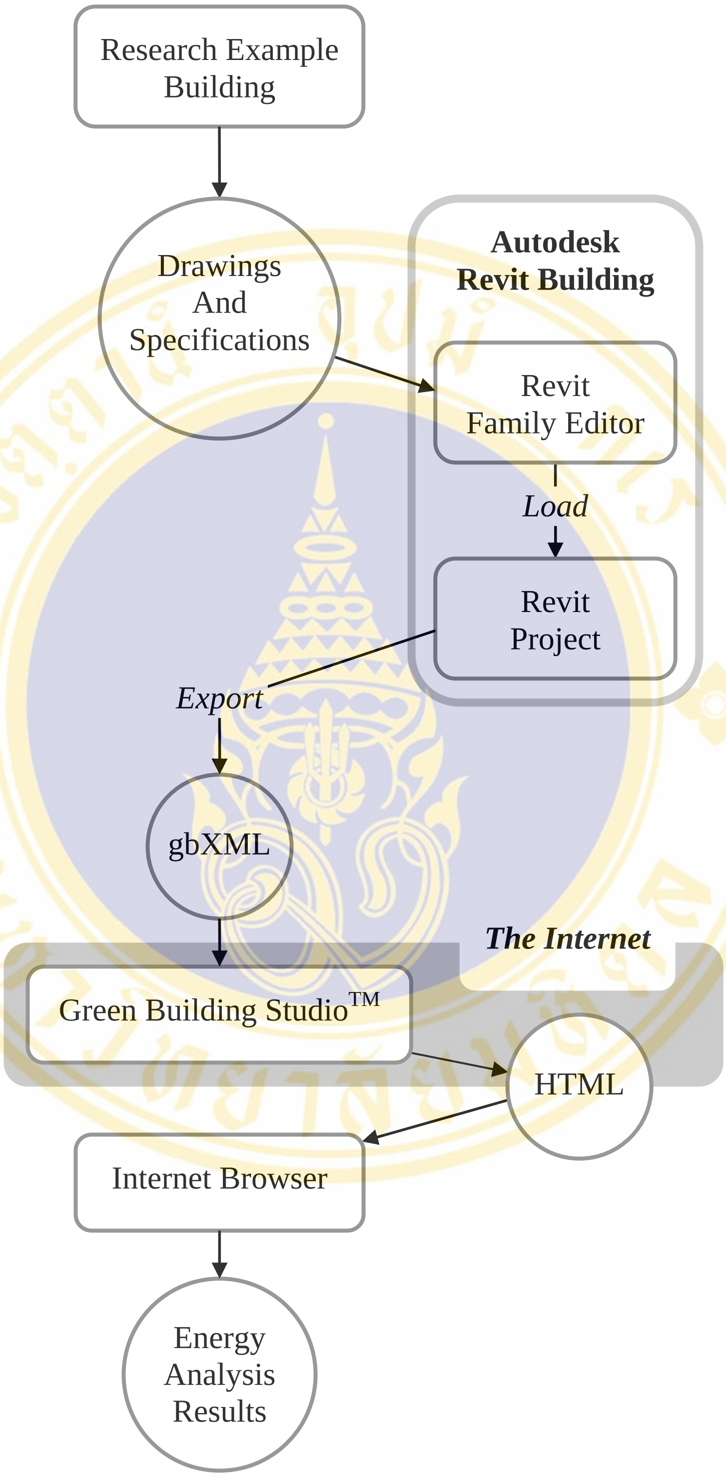


Figure 4.4 Development schematic of a Health Facility Building Information Model for Energy Performance Measurement, Ministry of Public Health

4.2 Building information model database development

4.2.1 Defining and determining the health facility building material and component specifications

There are ten types of building material and component specifications of the OPD building number 3130/2526 which are translated into the structure of the Revit Families: Autodesk® Revit® Building BIM system.

4.2.1.1 Column Specification

The following is the specification of the column:

- Column number and description
- Kind of family template
- Family name
- Type name
- Column structure

Column	**Material**	**Depth** (m.)	**Width** (m.)	**Colors**
-	-	-	-	-

- Base Level
- Top Level
- ★ (See details of the columns in Appendix B)

4.2.1.2 Beam Specifications

There are three types of beam which are used:

- Beam number and description
- Kind of family template
- Family
- Type name
- Structural usage
- Beam structure

Beam	**Material**	**Width** (m.)	**Depth** (m.)	**Colors**
-	-	-	-	-

- Reference Level

- Elevation

★ (See details of the other beams in Appendix B)

4.2.1.3 Door Specifications

There are 17 types of doors which are used:

- Door number and description
- Kind of family template
- Family
- Type name
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
-	-	-	-	-	-	-	-

★ (See details of the doors in Appendix B)

4.2.1.4 Window Specifications

There are 13 types of window which are used:

- Window number and description
- Kind of family template
- Family
- Type name
- Window structure

Window Number	Window Width (m)	Window Height (m)	Sill Height (m)	Window Frame Materials	Window Sash Materials	Window Glass Materials	Window Mullion Materials
-	-	-	-	-	-	-	-

★ (See details of the windows in Appendix B)

4.2.1.5 Wall Specifications

There are 9 types of wall which are used:

- Wall number and description
- Kind of family template
- Family
- Type name
- Wall structure

Exterior Side

Layer	Function	Materials	Thickness (m.)	Colors
-	-	-	-	-

Interior Side

- Wall base constraint
- Wall top constraint

★ (See details of the walls in Appendix B)

4.2.1.6 Floor Specifications

There are 5 types of floor which are used:

- Floor number and description
- Kind of family template
- Family
- Type name
- Floor structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
-	-	-	-	-
Interior Side				

- Wall base constraint
- Height Offset From Level

★ (See details of the floors in Appendix B)

4.2.1.7 Ceiling Specifications

There are 2 types of ceiling which are used:

- Ceiling number and description
- Kind of family template
- Family
- Type name
- Ceiling structure

Upper Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
-	-	-	-	-
Lower Side				

- Level
- Height offset from level

★ (See details of the other floors in Appendix B)

4.2.1.8 Roof Specifications

The following is the specification of the roof:

- Roof number and description
- Kind of family template
- Family
- Type name
- Roof structure

Upper Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
-	-	-	-	-
Lower Side				

- Base level
- Base offset from level
- Slope angle

★ (See details of the other floors in Appendix B)

4.2.1.9 Stair Specifications

There are 2 types of stair which are used:

- Stair number and description
- Kind of family template
- Family
- Type name
- Stairs width
- Number of risers
- **Treads** properties
  - Treads material
  - Minimum tread depth
  - Tread thickness
- **Risers** properties
  - Riser material
  - Maximum riser height
  - Riser thickness
  - Riser type
- **Stringers** properties
  - Stringer material
  - Stringer height
  - Stringer thickness
- Base level

- Top level

★ (See details of the stairs in Appendix B)

4.2.1.10 Railing Specifications

There is just one type of railing which is used:

- Railing number and description
- Kind of family template
- Family
- Type name
- Railing height
- Rail structure
- Baluster placement
- (See details of the railing in Appendix B)

4.2.2 Creating the health facility building material and component types and families using Autodesk® Revit® Building Family Editor

All elements in Revit Building are "family based". Each Family element has the ability to have multiple types defined within it, each with a different size, shape, material set, or other parameter variables as designed by the family creator. Even though various types within a family can look completely different, they are still related and come from a single source, thus the term, family.

4.2.2.1 Family Editor

The Family Editor is a graphical editing mode in Revit Building that allows the user to create families to include in any Revit project. Firstly, for start creating a family, the researcher opens a template to use in the editor; Metric Window Templates for creating a window family. It is important to the researcher to use the **Family Editor Commands** and especially **Solid Geometry Tools** for creating the actual representation of the family then use the **Load into Projects** command allows the researcher to load a family directly into any open project or family.

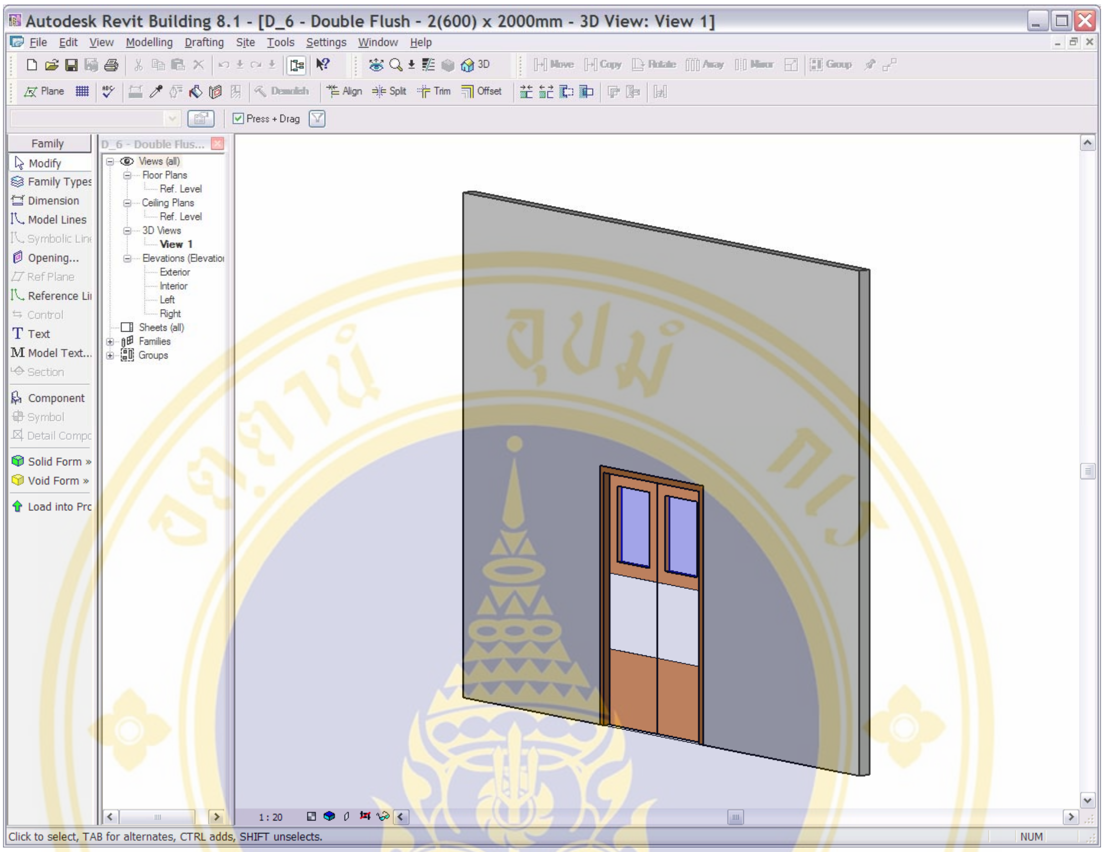


Figure 4.5 Using Autodesk® Revit® Building Family Editor for creating a door type D_6 - Double Flush – 2(600) x 2000mm

4.2.2.2 Family Types

The Family Types command applies predefined properties to different types within a family. Researcher uses this command during creation of every research example's families. The command is useful for labeling several different sizes of the same component. When researcher loads the health facility component families with the different types into a project, the researcher can then place any components of that family type. The Family Types command is enabled only while Revit Building is in the Family Editor.

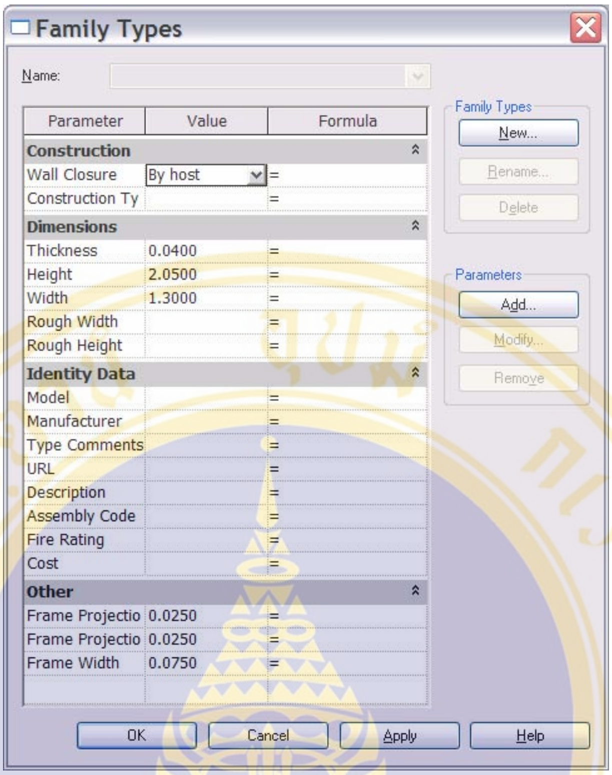


Figure 4.6 Family Types Properties of D_6 - Double Flush – 2(600) x 2000mm

4.3 Implement the building information model

4.3.1 Loading the families to a health facility building project

The completion of creating the research example's material and component types and families is meaning the completion of the project's family library. Then using Load Family command loads the entire family into a project.

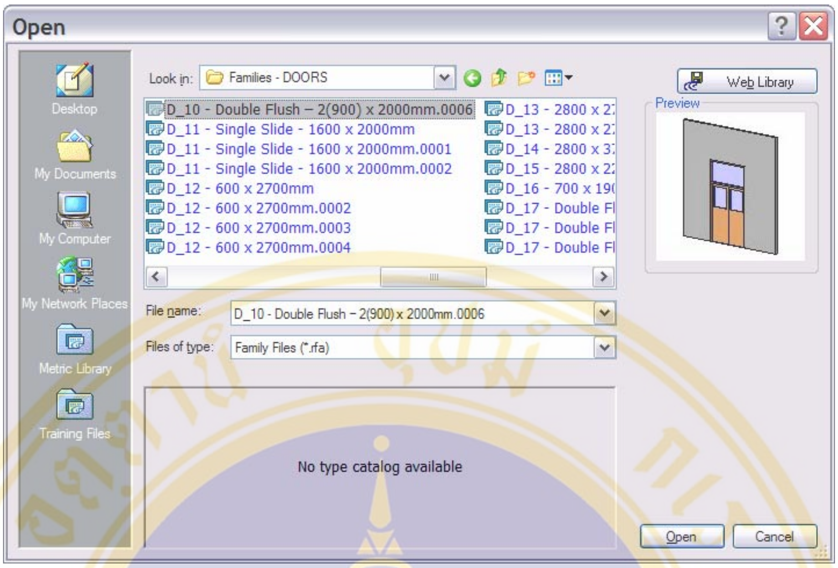


Figure 4.7 The Load Family from project library window

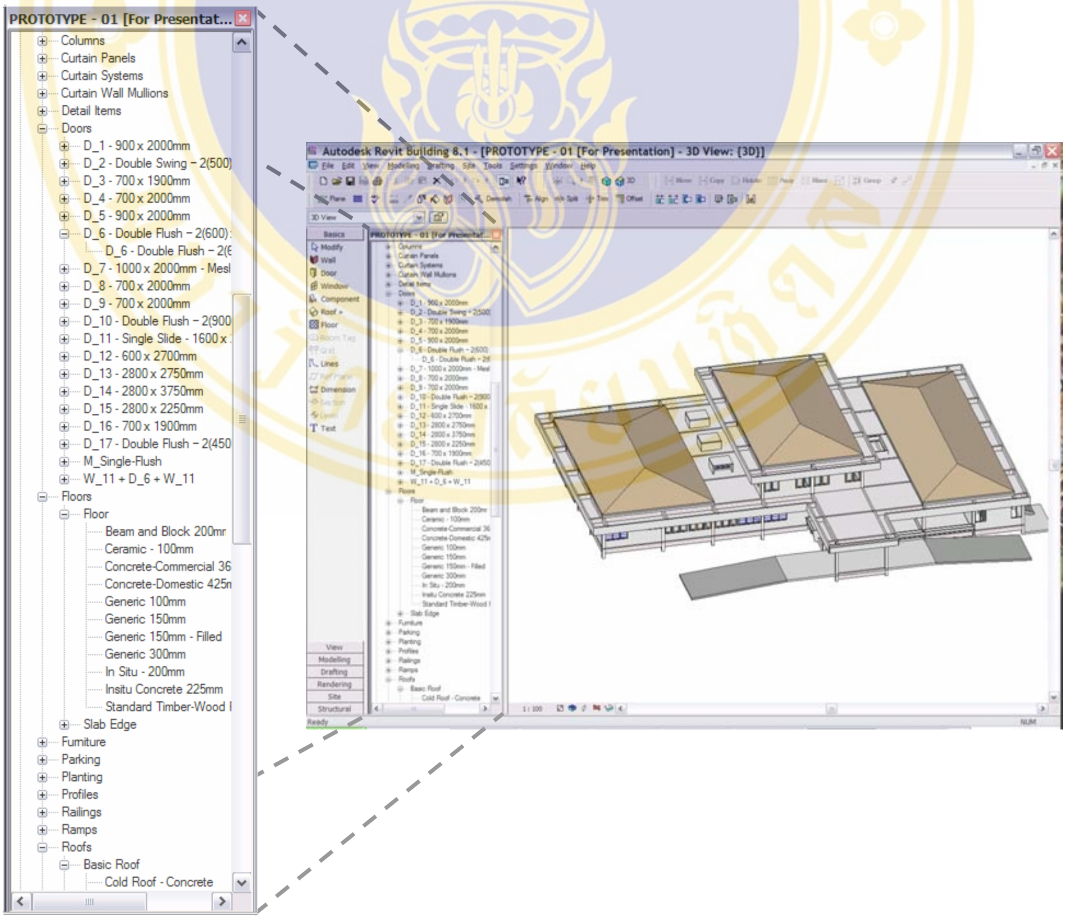


Figure 4.8 Appearance of the project families in the Project Browser

4.3.2 Creating a health facility building model project

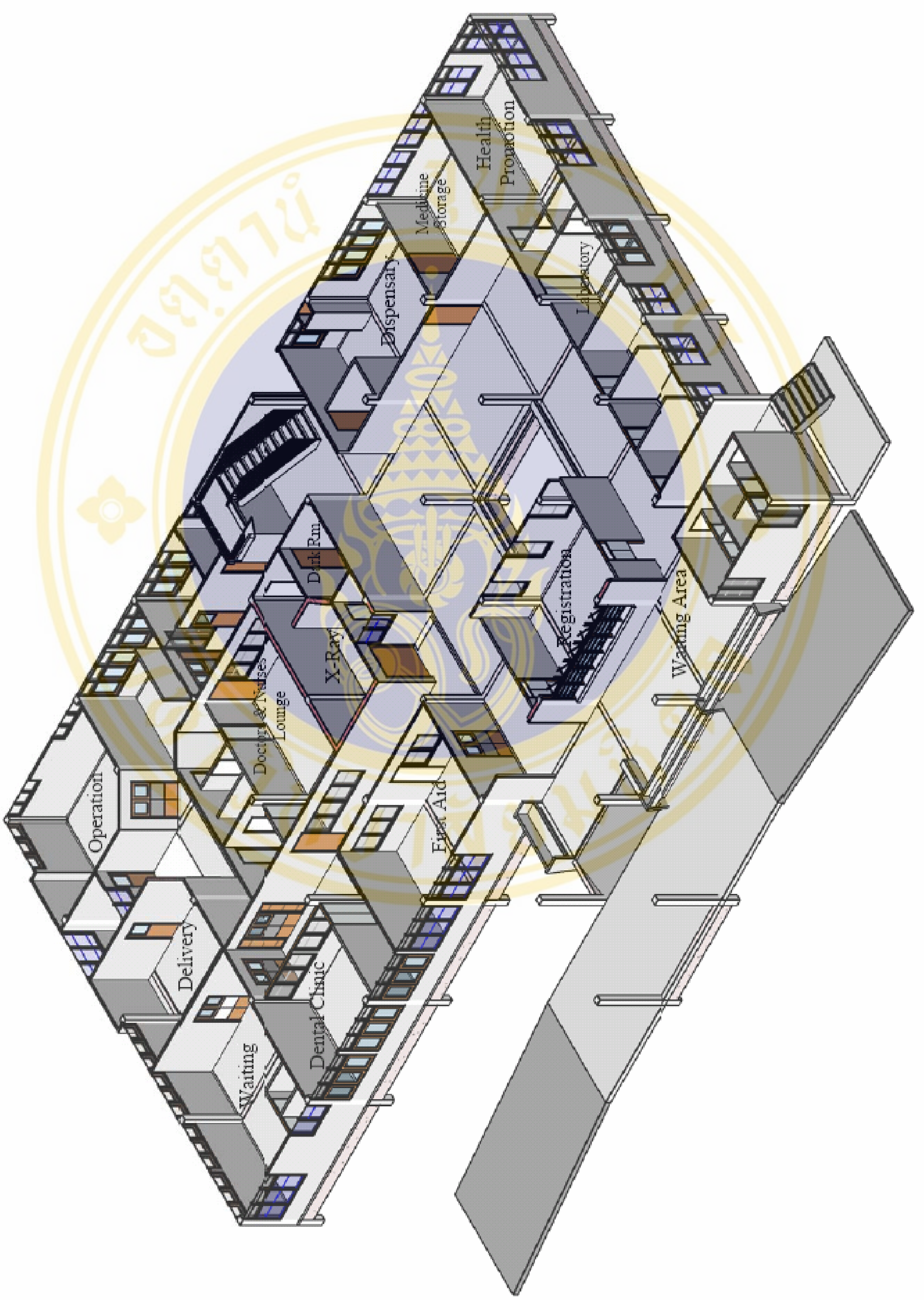


Figure 4.9 First floor building model of the research example: The First Prototype

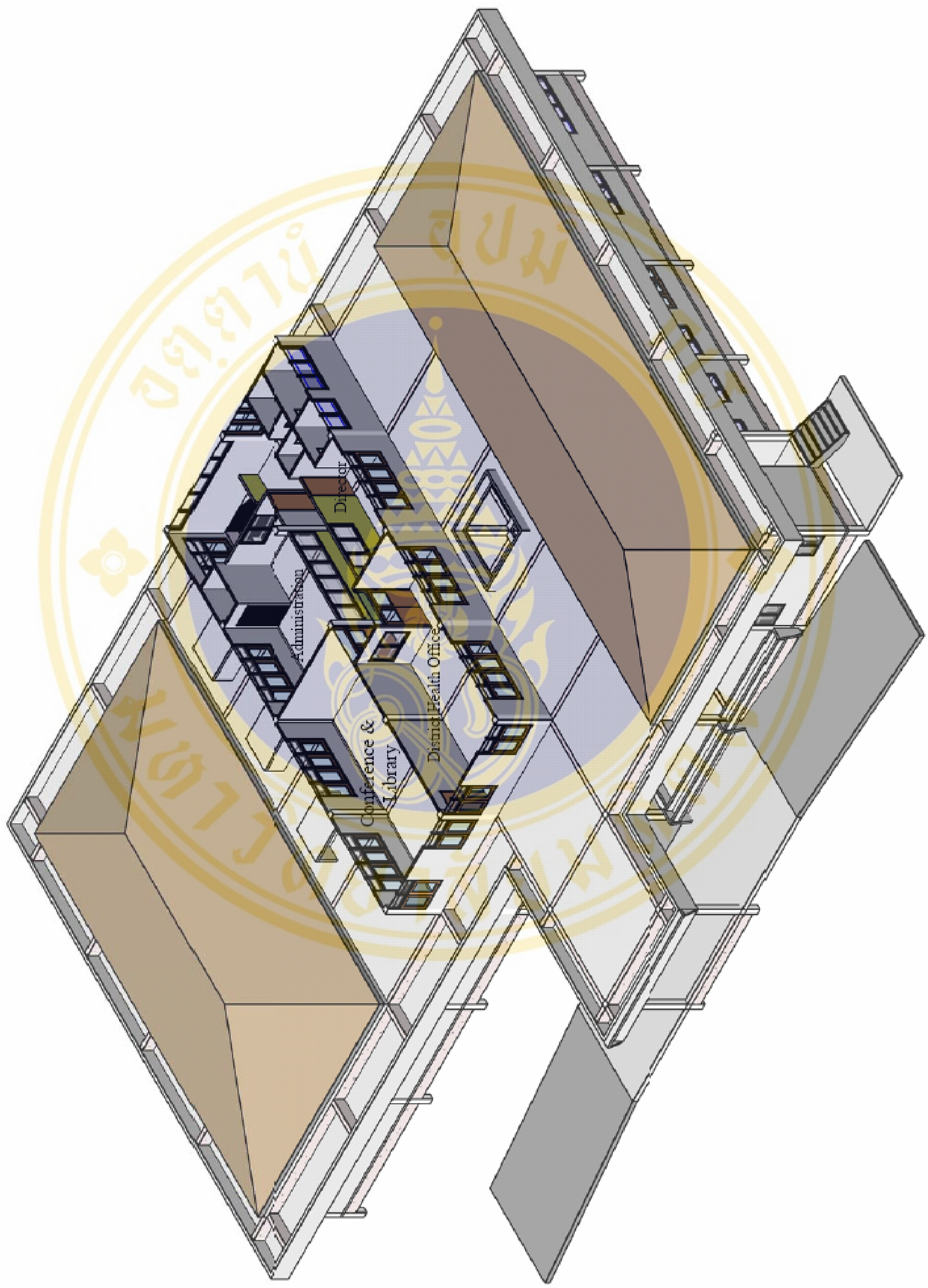


Figure 4.10 Second floor building model of the First Prototype

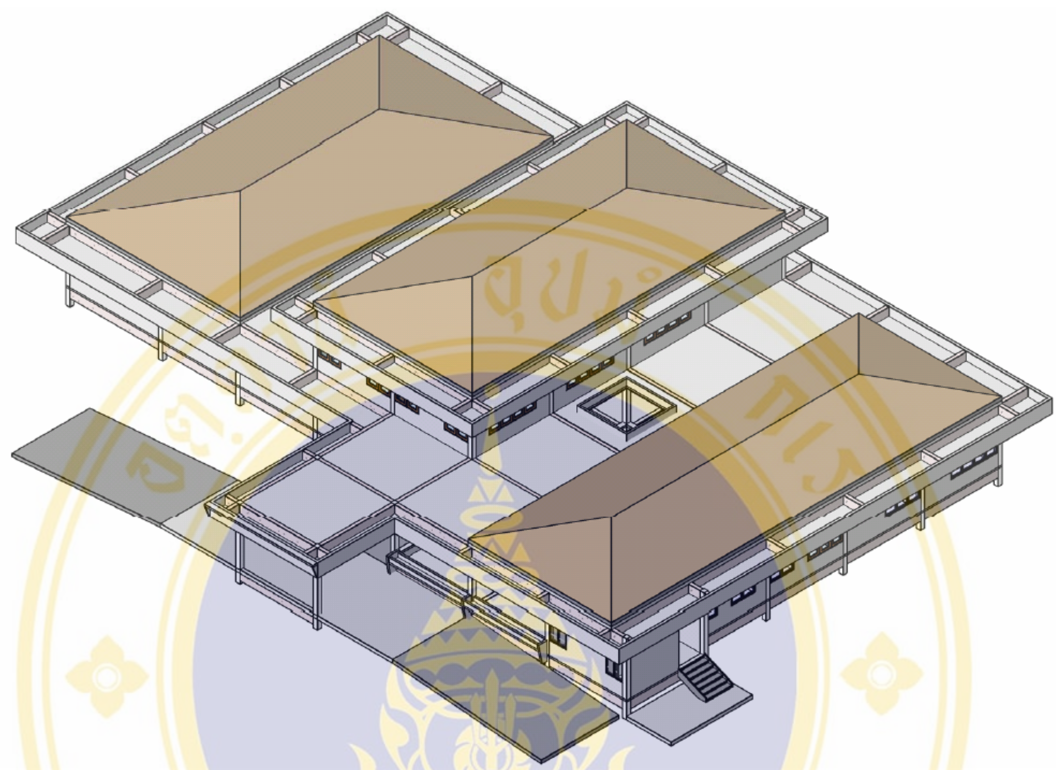


Figure 4.11 The southeast isometric view of the First Prototype

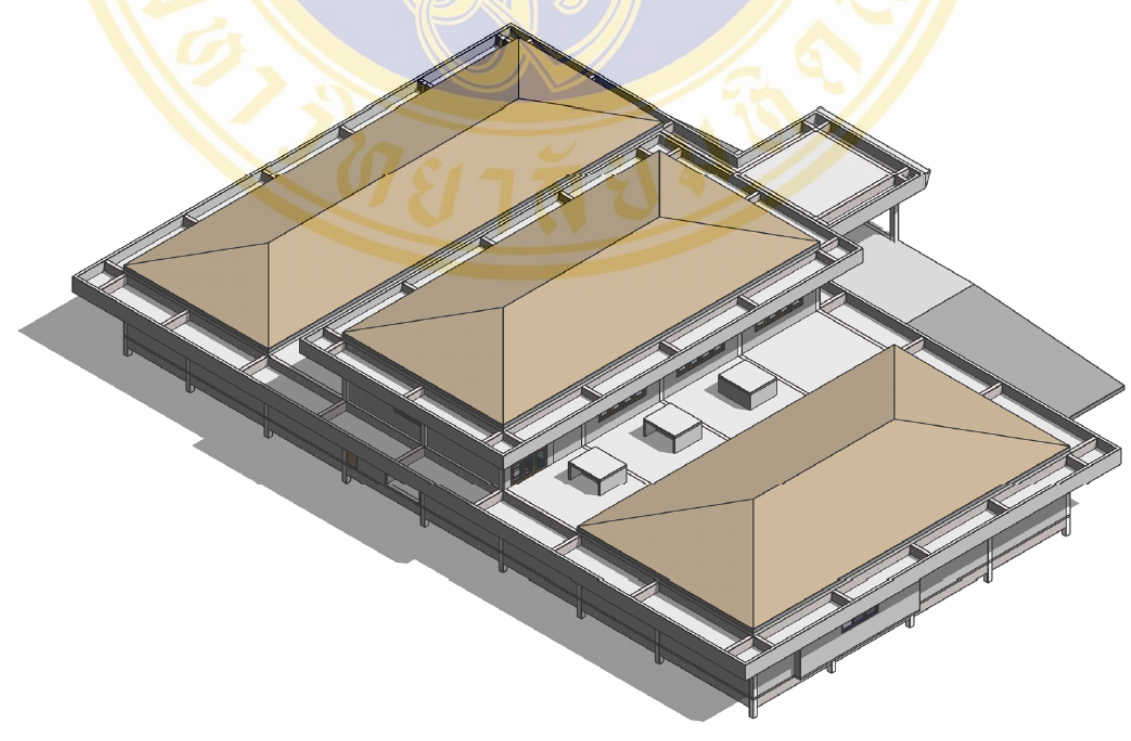


Figure 4.12 The northwest isometric view of the First Prototype (with cast shadows)

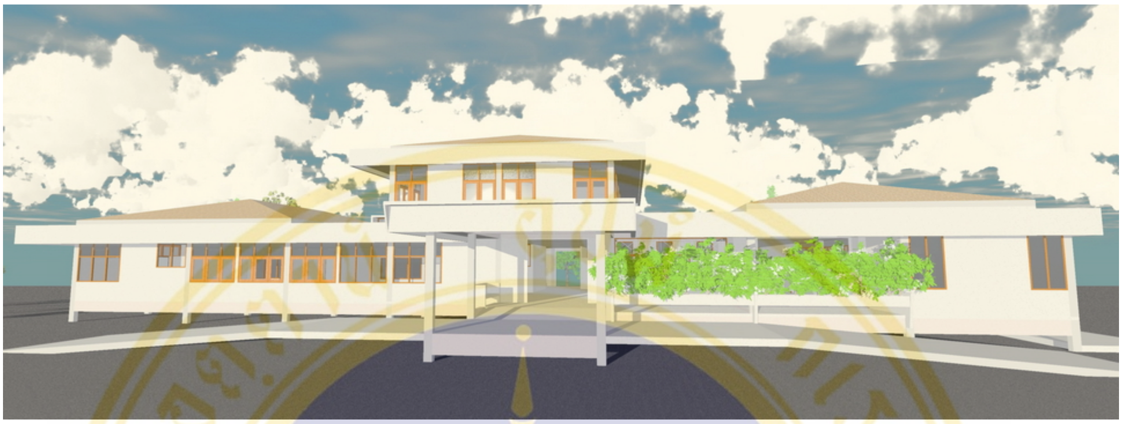


Figure 4.13 A perspective rendering of the research example: The First Prototype

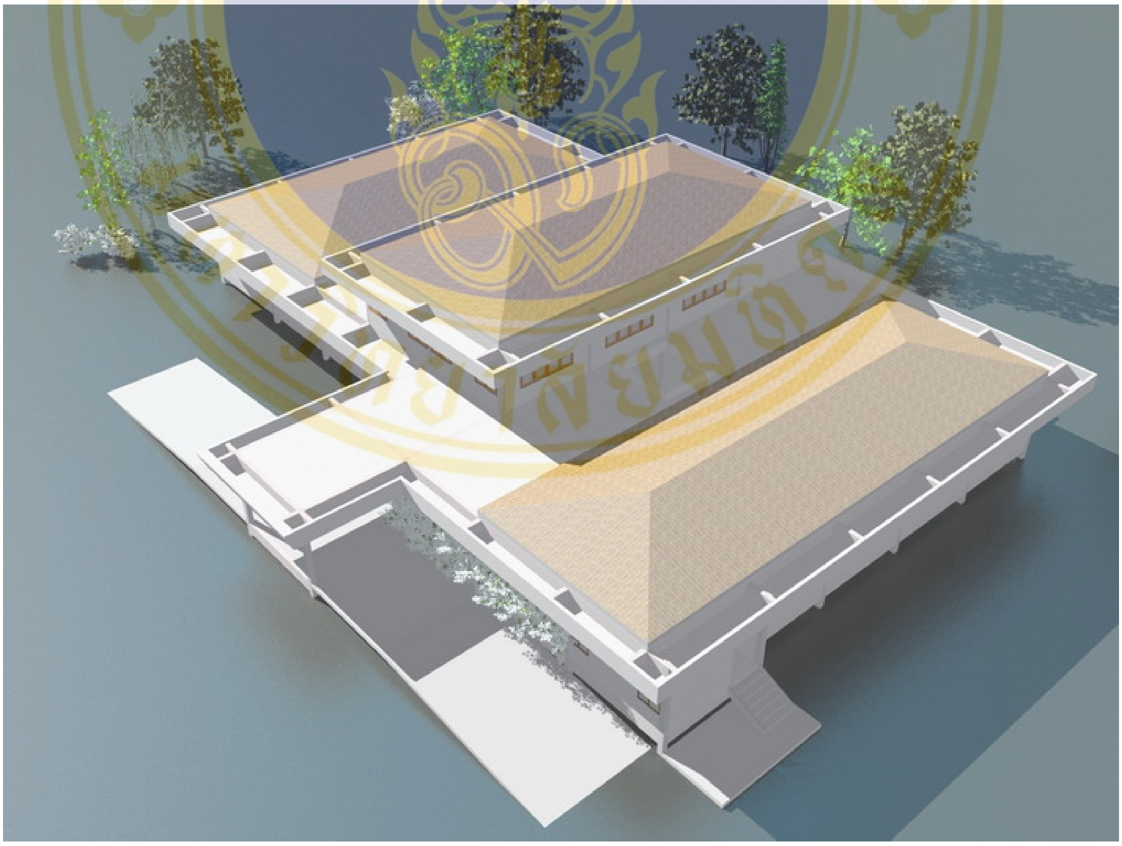


Figure 4.14 A perspective rendering of the First Prototype

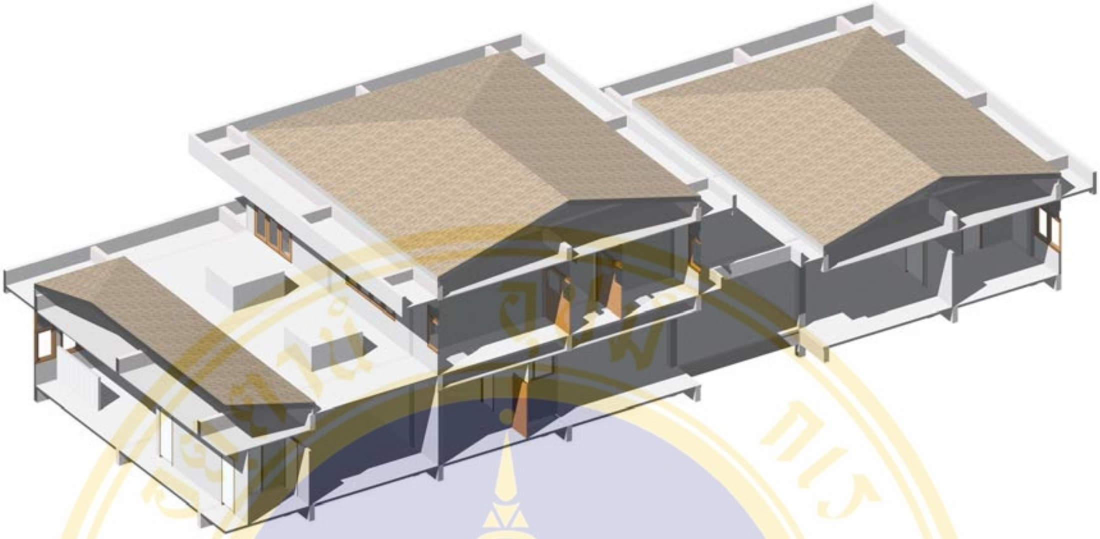


Figure 4.15 A section rendering of the First Prototype (widthwise)

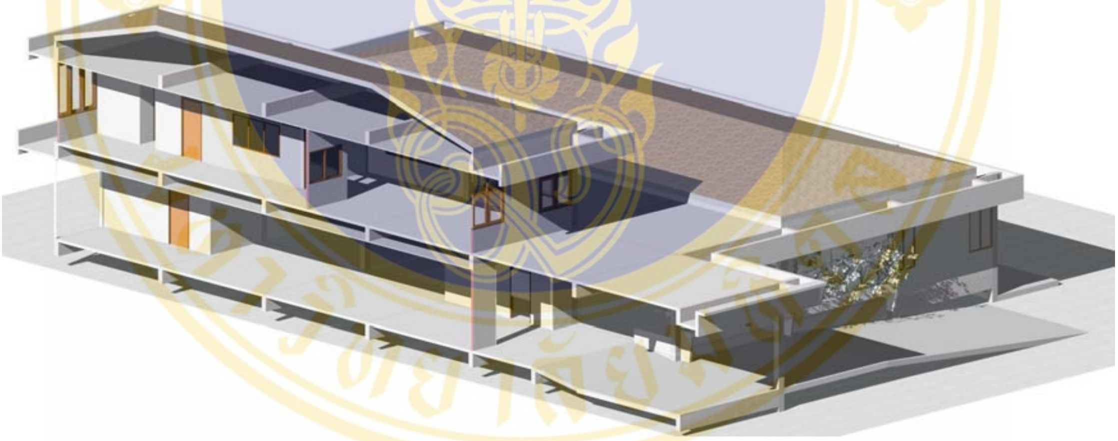


Figure 4.16 A section rendering of the First Prototype (longwise)

4.3.3 Building geometry description of the research example building

4.3.3.1 Functional area description

- First floor functional area = 900 m^2
- Second floor functional area = 400 m^2
- Total functional area = 1300 m^2

4.3.3.2 Building elevation description

- South elevation

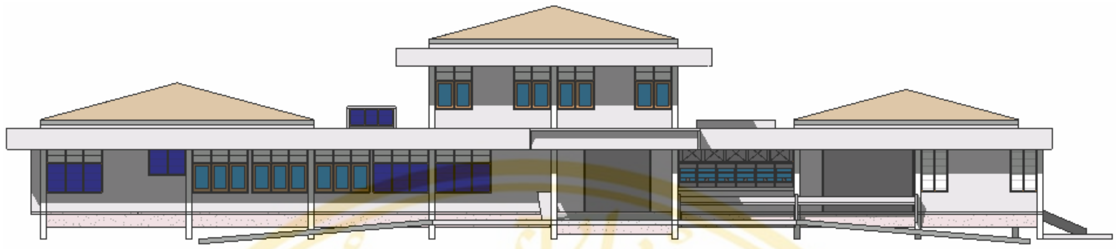


Figure 4.17 South Elevation of the First Prototype

Floor	Wall Area (m^2)	Windows and Doors Area (m^2)	Airy Space (m^2)
First Floor	49.338	36.912	51.750
Second Floor	19.972	12.028	-
Total Area of South Elevation	69.310 (40.77%)	48.940 (28.79%)	51.750 (30.44%)
	170 m^2		

- West elevation

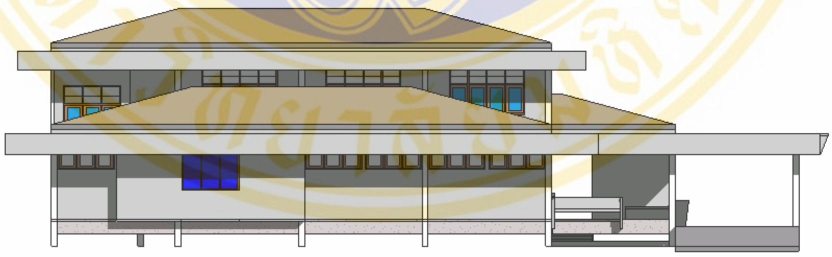


Figure 4.18 West Elevation of the First Prototype

Floor	Wall Area (m^2)	Windows and Doors Area (m^2)	Airy Space (m^2)
First Floor	48.944	20.056	17.25
Second Floor	104.332	23.668	-
Total Area of West Elevation	153.276 (71.54%)	43.724 (20.40%)	17.25 (8.05%)
	214.25 m^2		

- North elevation

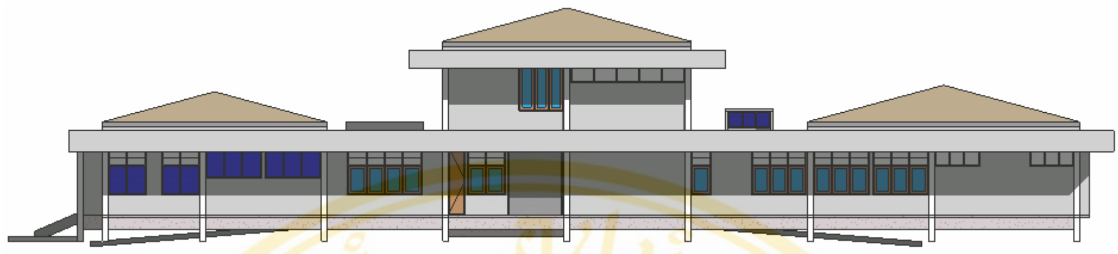


Figure 4.19 North Elevation of the First Prototype

Floor	Wall Area (m^2)	Windows and Doors Area (m^2)	Airy Space (m^2)
First Floor	97.741	43.709	-
Second Floor	20.751	11.249	-
Total Area of North Elevation	115.042 (67.67%)	54.958 (32.33%)	-
	170 m^2		

- East elevation

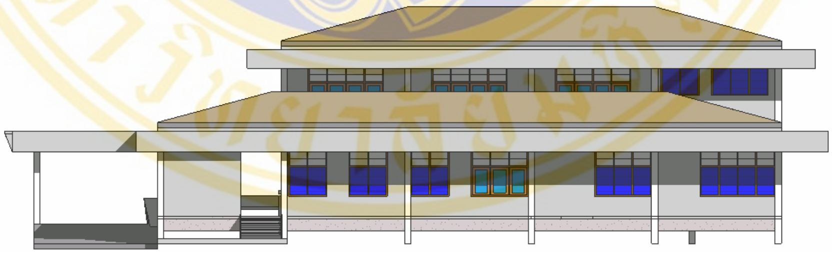


Figure 4.20 East Elevation of the First Prototype

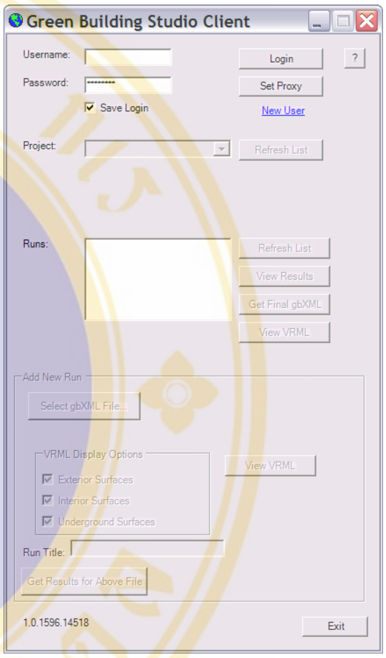
Floor	Wall Area (m^2)	Windows and Doors Area (m^2)	Airy Space (m^2)
First Floor	59.473	29.777	6.21
Second Floor	100.294	24.706	-
Total Area of East Elevation	159.767 (74.57%)	54.483 (25.43%)	-
	214.25 m^2		

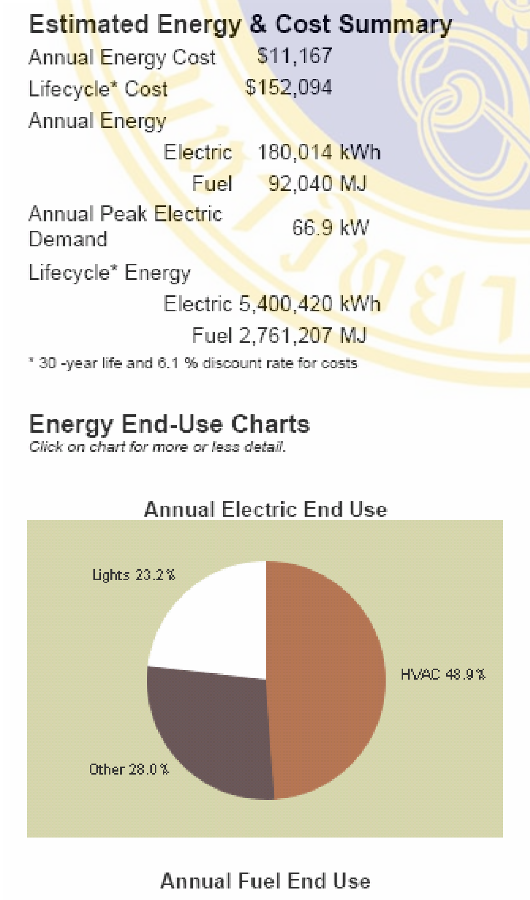
4.4 Building energy performance measurement testing: Exporting the building information model to a simulation tool

4.4.1 Building energy performance measurement testing of the First Prototype using Green Building Studio™ by GeoPraxis, Inc.

- Create a new Green Building Studio project

Figure 4.21 The interface of the Green Building Studio Client





- Export gbXML from Revit using Green Building Studio Client
- Get the energy analysis results of the first prototype through the Internet

Figure 4.22 A part of the energy analysis results of the First Prototype

4.4.2 Additional material and building component Revit Families

The essence in comparing the building energy performance of the Second Prototype and the Third Prototype is to know how different of the energy analysis results when the building envelope materials have been changed. There are three additional material and component Revit Families:

4.4.2.1 Additional Roof Specifications

หลังคา 2 หลังคากระเบื้องลอนคู่บุฉนวนกันความร้อน โครงหลังคาเหล็ก

- Kind of family template → Roof-based
- Family → Basic roof
- Type name → **Roof - 250mm (Insulated)**
- Ceiling structure

Upper Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Finish	Roofing Slate	0.005	RGB 127-127-127
2	Thermal/Air Layer	Rigid Insulation	0.050	RGB 127-127-127
3	Thermal/Air Layer	Air Barrier	0.045	White
4	Structure	Steel Bar Joist Layer	0.150	RGB 249-249-249

Lower Side

- Base level → Level 2
- Base offset from level → 0.20 m
- Slope angle → 20°

4.4.2.2 Additional Floor Specifications

6 พื้นค.ส.ล. เพิ่มฉนวนกันความร้อน

- Kind of family template → Floor-based
- Family → Floor

- Type name → **Insulated Concrete - 200mm**
- Floor structure

Exterior Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Structure	Concrete – Sand/Cement Screed	0.025	RGB 127-127-127
2	Membrane Layer	Roofing - Felt	0.00	RGB 127-127-127
3	Thermal/Air Layer	Rigid Insulation	0.05	RGB 127-127-127
4	Membrane Layer	Roofing - Felt	0.00	RGB 127-127-127
5	Structure	Concrete – Sand/Cement Screed	0.025	RGB 127-127-127
6	Structure	Concrete – Cast In Situ	0.10	RGB 192-192-192 (Concrete, Non-Uniform, Gray)

Interior Side

- Wall base constraint → Level 1/2
- Height Offset From Level → 0.00

4.4.2.3 Additional Wall Specifications

△10 ผนังก่ออิฐครึ่งแผ่น สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → Basic Wall

- Type name → **Insulated - 100mm**
- Wall structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Membrane Layer	Paint	0.00	White
2	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
3	Structure	External Wall Insulation	0.08	RGB 127-127-127
4	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
5	Membrane Layer	Paint	0.00	White
Interior Side				

- Wall base constraint → Level 1/2
- Wall top constraint → Ceiling Height (offset from Level 1/2)

4.4.3 Shading devices addition testing

Application of sunshading devices is one of widely accepted strategy of Solar Control which aims to utilize beneficial sunshine for passive heating and for daylighting and minimizes overheating. In this research, to transform the Second Prototype into the Forth Prototype is shading devices addition. Only one type of shading device has been used:

4.4.3.1 Additional shading device Revit Families

Shading device 1

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → Shading device 1
- Shading device structure

Shading device Number	Width (m)	Height (m)	Sill Height (m)	Frame Materials	Sash Materials	Glass Materials	Mullion Materials
1	0.90	0.90	0.00	**Shading Device Frame** RGB 247-247-247 (Metal, Steel, Polished, Plain)	-	-	**Shading Device Mullion** RGB 247-247-247 (Metal, Steel, Polished, Plain)

- Base level → Level 1/2
- Base offset from level → 1.65 m

Figure 4.23 An isometric rendering of the Forth Prototype
(The Second Prototype with shading devices)

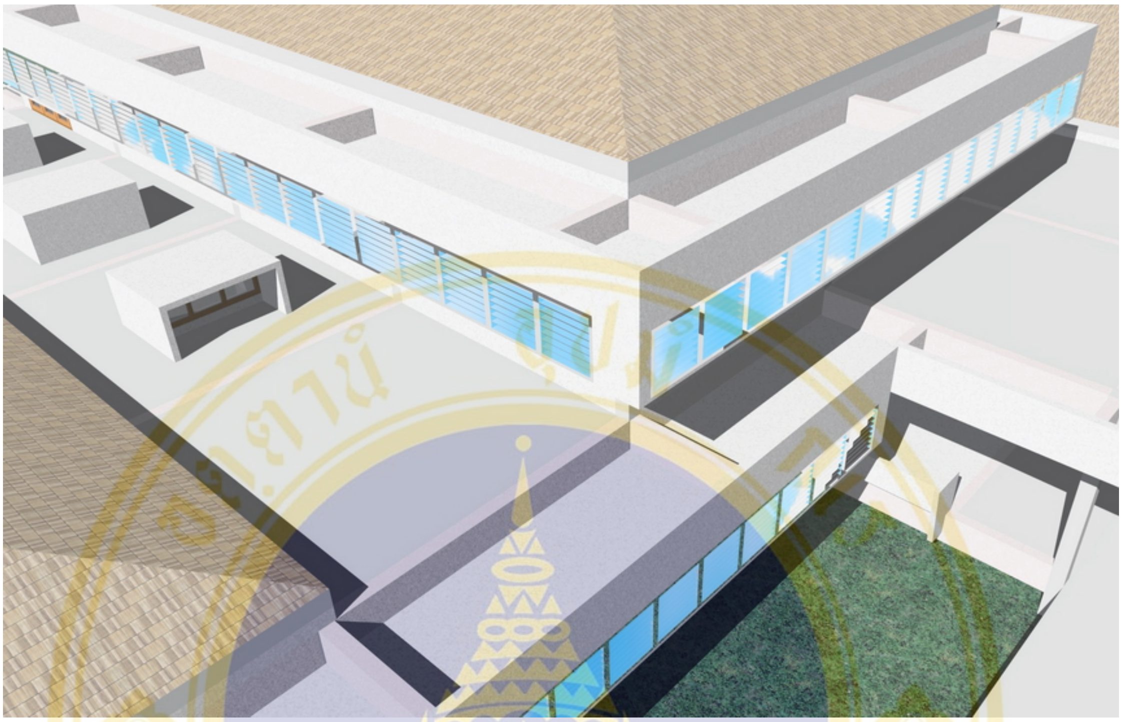


Figure 4.24 A detail perspective rendering of shading devices

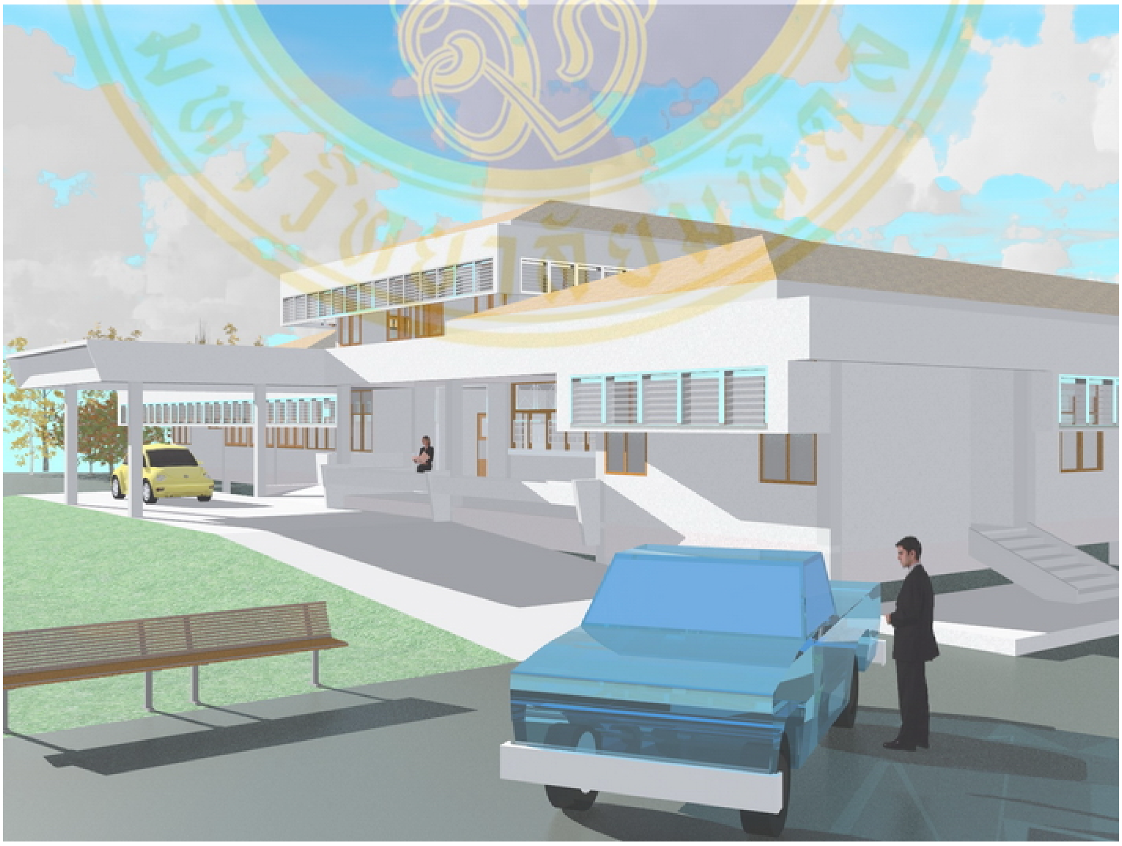
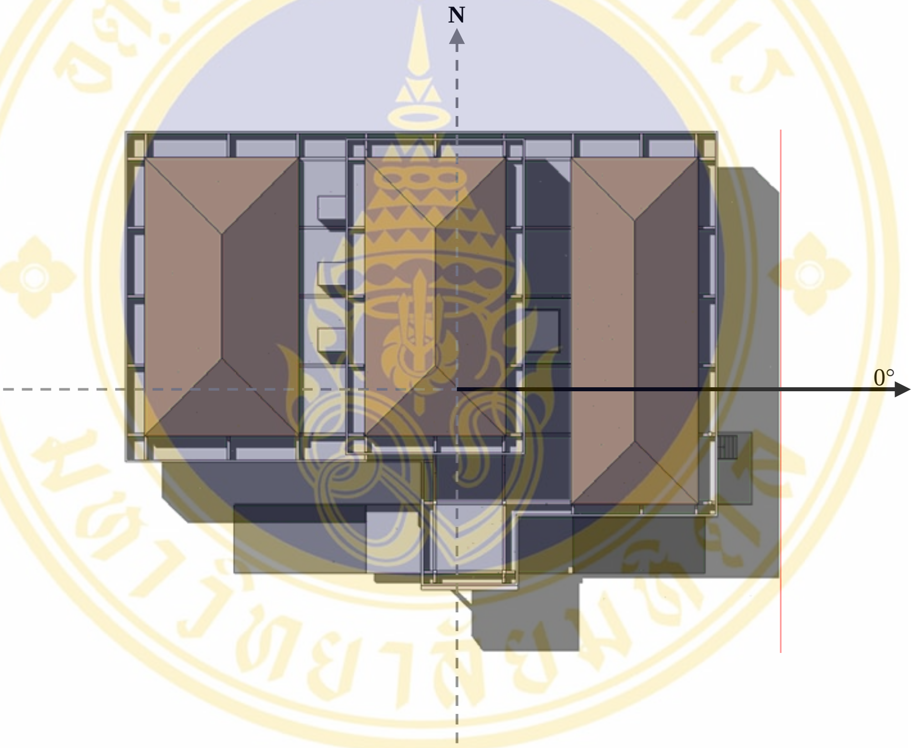


Figure 4.25 A perspective rendering of the Forth Prototype (with entourages)

CHAPTER V
RESULTS AND DISCUSSION

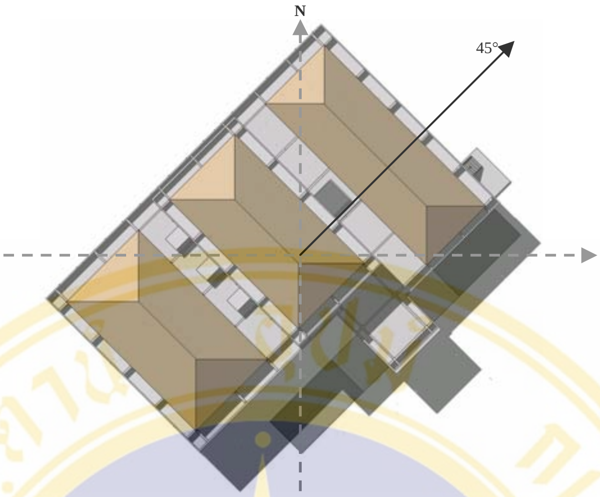
5.1 The energy analysis results from the Green Building Studio™ for the research example

5.1.1 The GBS energy analysis results of the First Prototype

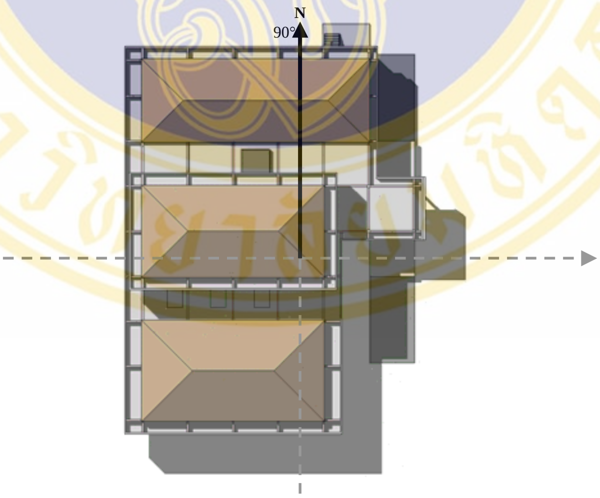


Rotation Degree of the First Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
The First Prototype (0°)	11,167	152,094	180,014	66.9	5,400,420

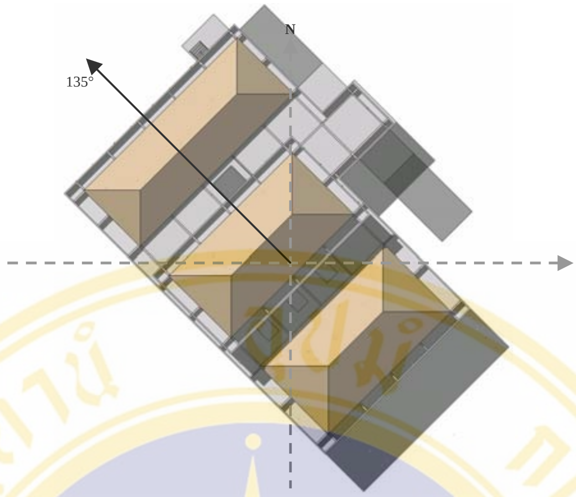
5.1.2 The GBS energy analysis results of the seven rotations of the First Prototype



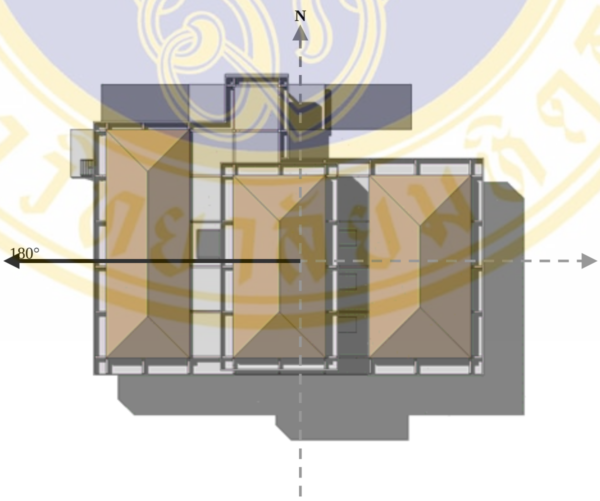
Rotation Degree of the First Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
45° rotated The First Prototype	10,944	149,056	176,419	65.1	5,292,569



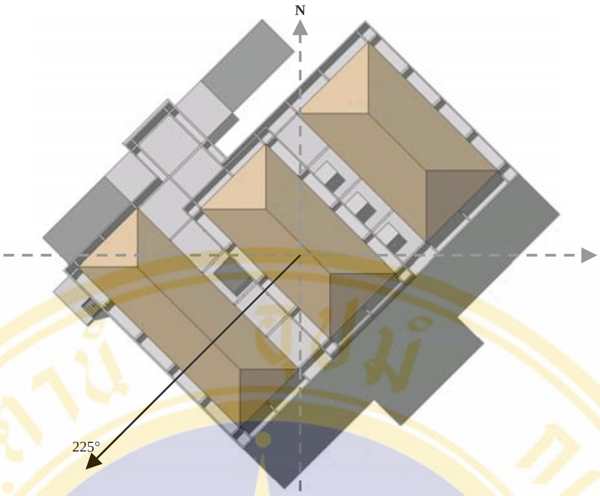
Rotation Degree of the First Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
90° rotated The First Prototype	10,827	147,463	174,534	63.9	5,236,020



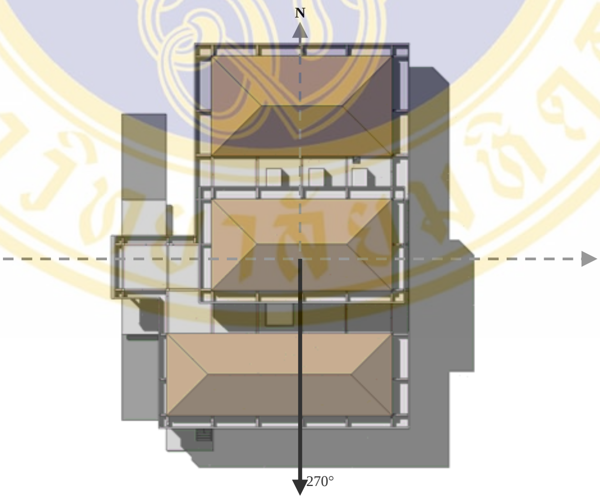
Rotation Degree of the First Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
135° rotated The First Prototype	11,445	155,883	184,500	67.0	5,534,997



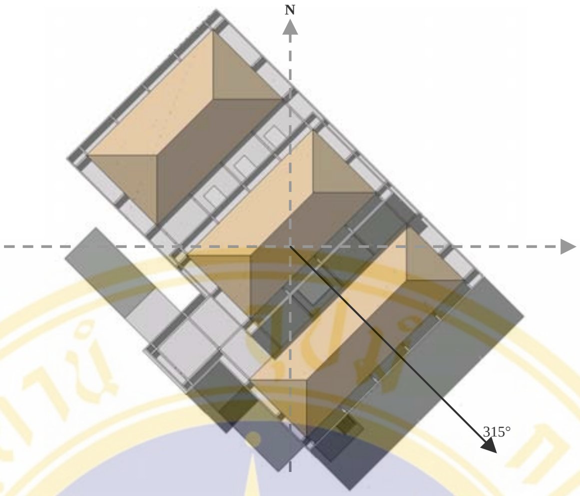
Rotation Degree of the First Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
180° rotated The First Prototype	11,537	157,138	186,009	67.1	5,580,267



Rotation Degree of the First Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
225° rotated The First Prototype	11,114	151,386	179,159	65.7	5,374,775



Rotation Degree of the First Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
270° rotated The First Prototype	10,932	148,896	176,229	65.2	5,286,864



Rotation Degree of the First Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
315° rotated The First Prototype	11,141	151,739	179,595	66.7	5,387,865

5.1.3 **Comparison of GBS results:** 0°, 45°, 90°, 135°, 180° , 225° , 270° and 315° of the First Prototype energy analysis calculations

Table 5.1 Comparison of GBS results

Rotation Degree of the First Prototype	**Annual Energy Cost ($)**	**Lifecycle Cost ($)**	**Annual Electric Energy (kWh)**	**Annual Peak Electric Demand (kW)**	**Lifecycle Electric Energy (kWh)**
The First Prototype (***The Benchmark***)	11,167 (+3.14%)	152,094 (+3.14%)	180,014 (+3.14%)	66.9 (+4.69%)	5,400,420 (+3.14%)
45°	10,944 (+1.08%)	149,056 (+1.08%)	176,419 (+1.08%)	65.1 (+1.88%)	5,292,569 (+1.08%)
90° (***The Minimum***) The Second Prototype	10,827	147,463	174,534	63.9	5,236,020

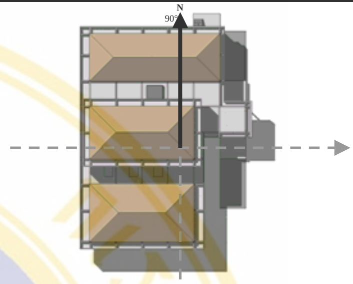
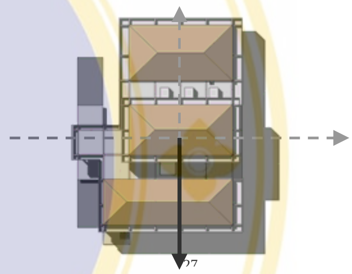
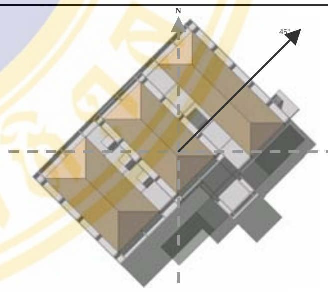
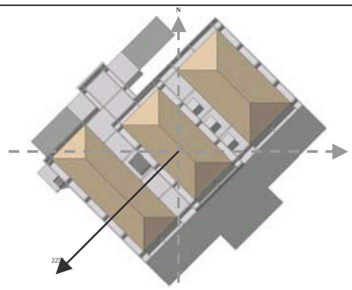
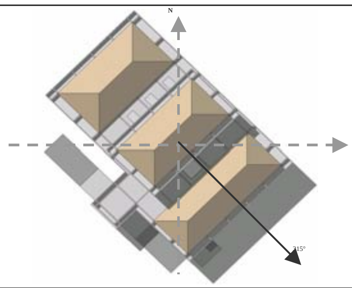
Rotation Degree of the First Prototype	**Annual Energy Cost ($)**	**Lifecycle Cost ($)**	**Annual Electric Energy (kWh)**	**Annual Peak Electric Demand (kW)**	**Lifecycle Electric Energy (kWh)**
135°	11,445 (+5.71%)	155,883 (+5.71%)	184,500 (+5.71%)	67.0 (+4.85%)	5,534,997 (+5.71%)
180° (*The Maximum*)	11,537 (+6.56%)	157,138 (+6.56%)	186,009 (+6.57%)	67.1 (+5.00%)	5,580,267 (+6.57%)
225°	11,114 (+2.65%)	151,386 (+2.66%)	179,159 (+2.65%)	65.7 (+2.82%)	5,374,775 (+2.65%)
270°	10,932 (+0.97%)	148,896 (+0.97%)	176,229 (+0.97%)	65.2 (+2.03%)	5,286,864 (+0.97%)
315°	11,141 (+2.90%)	151,739 (+2.90%)	179,595 (+2.90%)	66.7 (+4.38%)	5,387,865 (+2.90%)

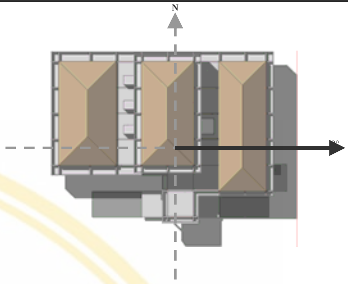
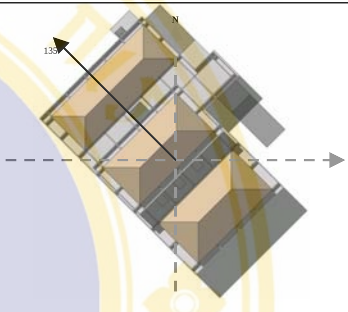
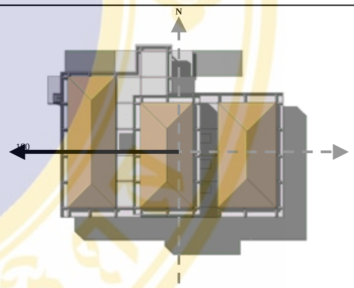
5.1.4 Discussion on the building energy measurement of the First Prototype, the rotations First Prototype and the Second Prototype

As seen above, Table 5.1 shows the Green Building Studion^{TM} results of the First Prototype, the rotations First Prototype and the Second Prototype. The results reflect that **even the same building has been placed in different ways of orientation cause extensively different of building energy usage**. The distinction can be seen clearly between the results of 180° rotated First Prototype (The Maximum) and 90° rotated First Prototype (The Minimum). When 6.56% plus in most of the results is interpreted into money: hospital energy expense, it would be imperceptible.

The meaningfulness of building orientation is not just caused differentiation between the maximum and the minimum. But **any different angle of building orientation reasons the variation of building energy usage of a building inevitably**. Table 5.2 shows the effects of the position and orientation of the research example on its energy consumption consecutively:

Table 5.2 Comparison of GBS results of the First Prototype and the rotations energy analysis calculations from the minimum to the maximum respectively

Rotation Degree of the First Prototype	**Annual Energy Cost ($)**	**Layouts**
1) 90° the minimum: **The Second Prototype**	10,827	
2) 270°	10,932 (+0.97%)	
3) 45°	10,944 (+1.08%)	
4) 225°	11,114 (+2.65%)	
5) 315°	11,141 (+2.90%)	

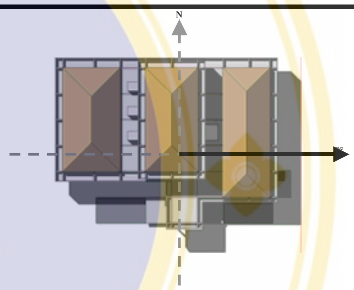
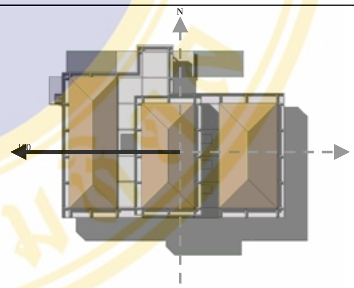
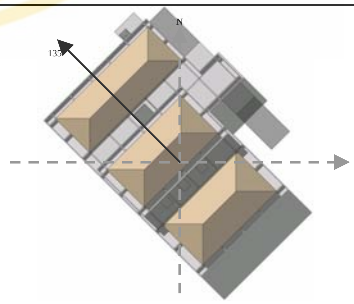
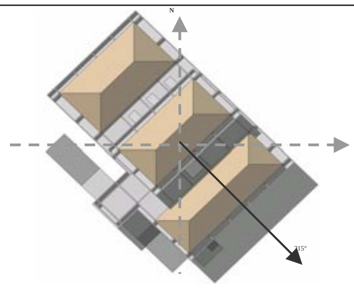
Rotation Degree of the First Prototype	Annual Energy Cost ($)	Layouts
6) 0°	11,167 (+3.14%)	
7) 135°	11,445 (+5.71%)	
8) 180° the maximum	11,537 (+6.56%)	

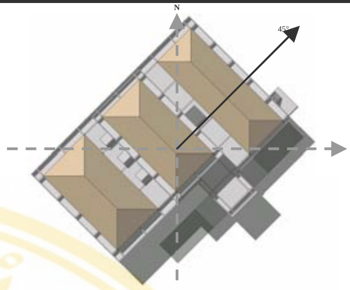
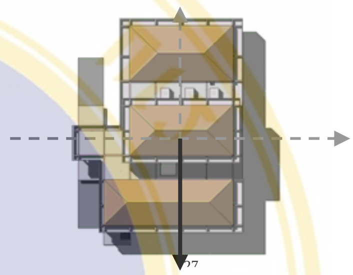
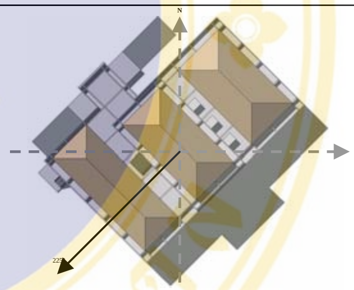
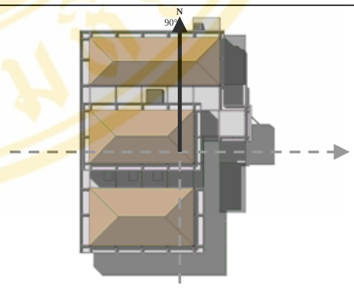
The site that the research example has been positioned is Tampa, Florida, U.S.A. (Lat. 27° 57' Long. 82° 27'). In this city, a factor that affects on building energy consumption and inhabitant's comfort is **passive solar heating of south-facing windows**. As mentioned in Chapter II it is necessary to be careful for south-facing windows using in any humid overheated region such as Florida. **The south face of building in Florida is sun-tempering and it is needed to be controlled**.

As has been shown in Table 5.2, the minimum-energy-use building (The Second Prototype) is the minimum south facing building position. Examining by building geometry of the research example, **The Second Prototype faces the south by opaque and narrow side of building** it blocks the passage of radiant energy and exceeding sunlight.

Thailand is in a humid overheated region which needs sun shading and ventilation as well. And it can be drawing an analogy between sun-tempering in Florida: south face of building and **sun-tempering in Thailand: west face of building**. Table 5.3 is a metaphorical illustration of the research example as if it was in Thailand according the sun-tempering direction: west face of building.

Table 5.3 A Metaphorical illustration of building energy analysis of the research example as if it was sited in Thailand, from the minimum to the maximum respectively

Rotation Degree of the First Prototype	Layouts
1) 0° the minimum: *Opaque and narrowest side of building facing west*	
2) 180°	
3) 135°	
4) 315°	

Rotation Degree of the First Prototype	Layouts
5) 45°	
6) 270°	
7) 225°	
8) 90° the maximum *Transparent and widest side of building facing west*	

As if the research example was sited in Thailand, **the minimum is positioned by the most opaque and narrowest side faces west: sun-tempering direction**. In contrarily the maximum faced the west by transparent and widest side of building. It can bring researcher goes to conclusions for an appropriate orientation of buildings that suggesting design strategies especially the sun tempering and the solar-gain restriction by sunshading in the next chapter.

5.1.5 The GBS energy analysis results of **the Third Prototype** (*the building components changed Second Prototype*)

Table 5.4 The GBS energy analysis results of the Third Prototype

the Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
The 3rd Prototype	10,764	146,608	173,522	63.6	5,205,651

5.1.6 Discussion on the GBS energy analysis results of the Third Prototype

The changing of building envelope components including roofs, floors and walls is not caused dramatically different between the energy performance measurement of the Second Prototype and the Third Prototype. Reduction of overall energy costs in the Third Prototype is just 0.58 percent from the Second Prototype as seen in the Table 5.4.

Table 5.5 Comparison of GBS results:
The *Second* Prototype and the *Third* Prototype energy analysis calculations

the Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
The 2nd Prototype	10,827	147,463	174,534	63.9	5,236,020
The 3rd Prototype	10,764 (-0.58%)	146,608 (-0.58%)	173,522 (-0.58%)	63.6 (-0.47%)	5,205,651 (-0.58%)

5.1.7 The GBS energy analysis results of **the Forth Prototype** (*the shading devices added Second Prototype*)

Table 5.6 The GBS energy analysis results of the Forth Prototype

the Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
The 4th Prototype	9,781	133,248	157,753	58.9	4,731,268

5.1.8 Discussion on the GBS energy analysis results of **the Forth Prototype**

It is an obvious mass of difference between the results of the Second Prototype and the Forth Prototype, almost ten percent of the distinction. Examining the numbers, the different of annual energy cost between the Second Prototype (*the minimum*) and the 180° rotated First Prototype (*the maximum*) is **710$** comparing with the **1,046$** of the difference between the Second Prototype (the minimum) and the Forth Prototype. Besides, the distinction among the maximum and the Forth Prototype is **1,756$** annually.

Table 5.7 Comparison of GBS results:
The *Second* Prototype and the *Forth* Prototype energy analysis calculations

the Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
The 2nd Prototype	10,827	147,463	174,534	63.9	5,236,020
The 4th Prototype	9,781 (-9.66%)	133,248 (-9.64%)	157,753 (-9.61%)	58.9 (-7.82%)	4,731,268 (-9.64%)

Table 5.8 Comparison of all distinguished GBS results of the research example, arranging from the maximum energy usage to the minimum respectively.

Remarks: *The percents that have been shown are compared to the 180° rotated First Prototype: The Maximum*

the Prototype	Annual Energy Cost ($)	Lifecycle Cost ($)	Annual Electric Energy (kWh)	Annual Peak Electric Demand (kW)	Lifecycle Electric Energy (kWh)
The 180° rotated First Prototype: **The Maximum**	11,537	157,138	186,009	67.1	5,580,267
The First Prototype	11,167 (-3.21%)	152,094 (-3.21%)	180,014 (-3.21%)	66.9 (-0.30%)	5,400,420 (-3.21%)
The 90° rotated First Prototype: The Minimum: **The Second Prototype**	10,827 (-6.15%)	147,463 (-6.15%)	174,534 (-6.15%)	63.9 (-4.77%)	5,236,020 (-6.15%)
The 3rd Prototype	10,764 (-6.70%)	146,608 (-6.70%)	173,522 (-6.70%)	63.6 (-5.22%)	5,205,651 (-6.70%)
The 4th Prototype	9,781 (-15.22%)	133,248 (-15.22%)	157,753 (-15.22%)	58.9 (-12.22%)	4,731,268 (-15.22%)

CHAPTER VI
CONCLUSION AND RECOMENDATION

6.1 Conclusion

The study focuses on development a building information model from a health facility building template design for energy performance measurement. This study has two main processes: (1) develop a health facility building information model, and (2) measure the energy performance of that building information model.

The elements of this research such as; tools including hardware, software and research procedures have been accustomed to architects and other building designer professionals which researcher aims this study to be widely used in the real world.

The research example is OPD building, DCD number 3130/2526 is one of the most built health facility building design in the country's history. It has affected many kinds and number of people for years in numerous good and bad. Trying to find answers for simple questions such concerning the orientation and using a right choice of walls and windows on the sun-tempering side of building may infer recommendations to CDC architects who will intend to use this OPD building design in any hospital facility in the future. Besides, it may bring recommendations for new health facility building template designs which will influence many people in many places for many years.

6.2 Recommendations

6.2.1 Green Building Studio™ is a web service building energy simulation system which enables architects to quickly calculate the operational energy implications of early design decision and as a companion through out building design process. It has many useful features, easy to use, and users need no special training in energy analysis. On the contrary, it has properties that are disaccustomed for users outside the U.S.A as following:

6.2.1.1 Simulation runs need initially enter an U.S.A. Zip code that links the weather data (TMY2, WYEC) and energy cost of the place automatically, these are cannot be customized.

6.2.1.2 Building geometry computation of a building can be miscalculated, a building at an orientation might has floor area unequal to the same building at the other orientations. GBS users need to study and practice the system operation clearly to fix this problem.

6.2.1.3 Some of the results can be very detailed. GBS users cannot customize the inquiry means they are unable to eliminate redundant results that may useless and too complicated to understand.

6.2.1.4 GBS uses the DOE-2 simulation engine to calculate energy performance. DOE-2 is the most popular public-domain whole building energy analysis tool currently in use but it is far more complicated and needs more special training in energy analysis but it is approved by worldwide users for its accuracy. It would be more beneficial if architects and designers go to DOE-2 instead of GBS.

Although the limitations of the system for users outside the U.S.A., GBS is an almost ideal building energy analysis tool for architects because of its efficiency and ease of use. Thai architects in particular, need a custom-built of a Thailand GBS building energy simulation system with Thailand weather data and other essential Thailand individual data, functions and special purposes.

A research and development of the mentioned system will be useful, convenient and gains advantages in environment-conscious building design for Thai architects greatly.

6.2.2 Sun-Tempering side of building needs to be careful controlled. Architects and building designers should avoid orienting wide sides with transparent void without sunshading to face the sun-tempering direction straightly.

6.2.3 Sunshading has been elementarily proved to be an important tool and design technique in humid overheated region. As mentioned in Chapter V, the numbers show the reduction of energy costs are massive and manifest. External shading devices can eliminate the solar direct (beam) radiation, which is normally largest and also serve to reduce the solar diffuse radiation.

As the sun's movement is unchangeable, solar orientation of the building is very important. A study of solar control with keen attention especially a study and development of a system that helps Thai architects to understand the sun's movement and containing advices of shading devices design is very important and valued.

6.2.4 Building Information Modeling (BIM) system is a very useful tool. The power of parametric modeling is superseding coordinate-based geometric modeling CAD (Computer-Aided Design) system. BIM had assisted the researcher in this study greatly. The system has so many advantageous features, though BIM users have to overcome its core barriers; building objects inadequacy. Preciseness and competence of development of building information objects including all aspects of properties (professional, scientific, and artistic) are principally required.

6.2.5 For the sake of sustainable study on environment-conscious building design, researchers should not grasp tightly on a tool or a technique. It would be more beneficial if researchers intend to the core of every tools; the interoperability: data exchange and sharing of building and construction life cycle information. These are many significant and interesting subjects that are still deficient of this knowledge for Thais such as the IFC model, ifcXML and gbXML that need to be probed and widely promoted to be national standards in the future.

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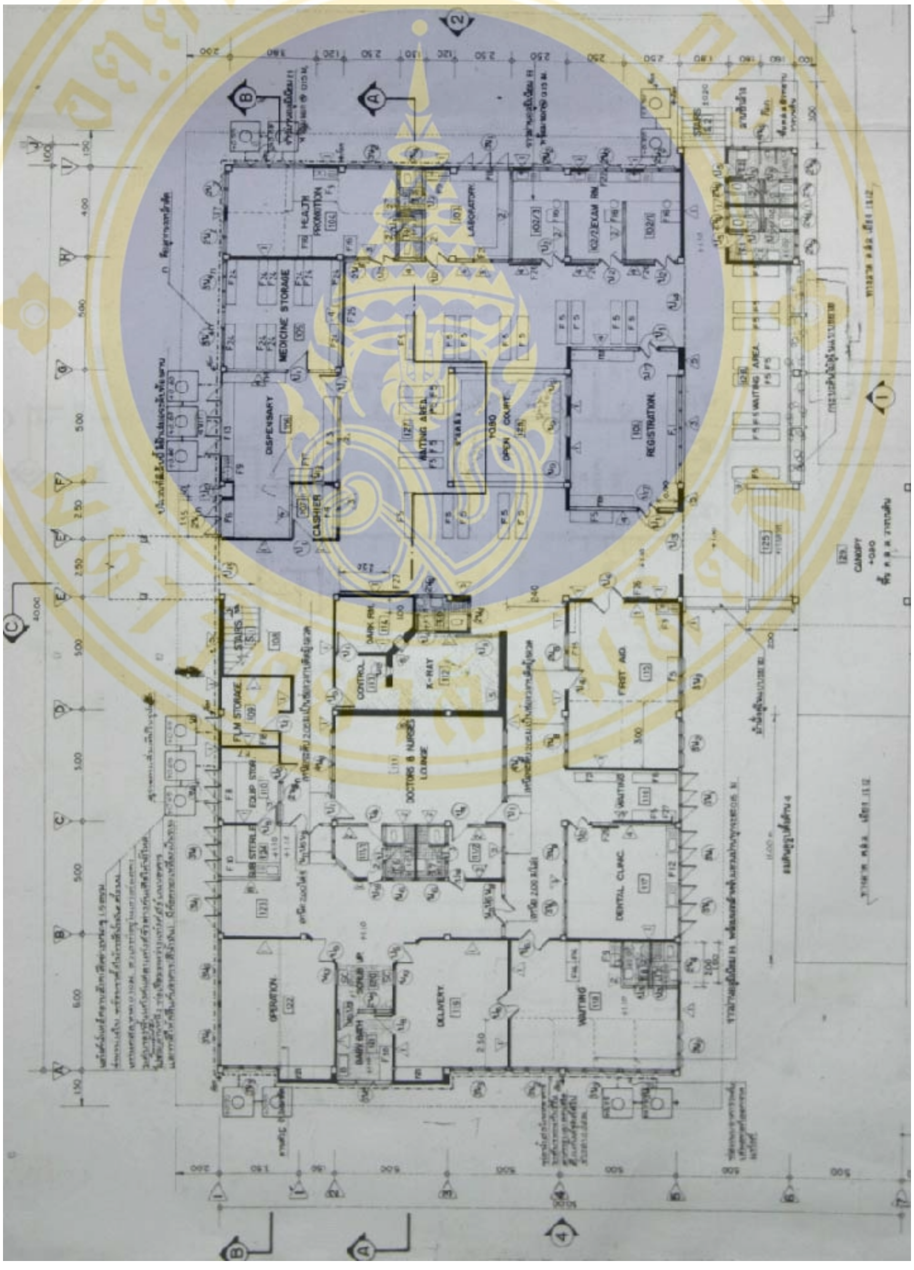
APPENDIX

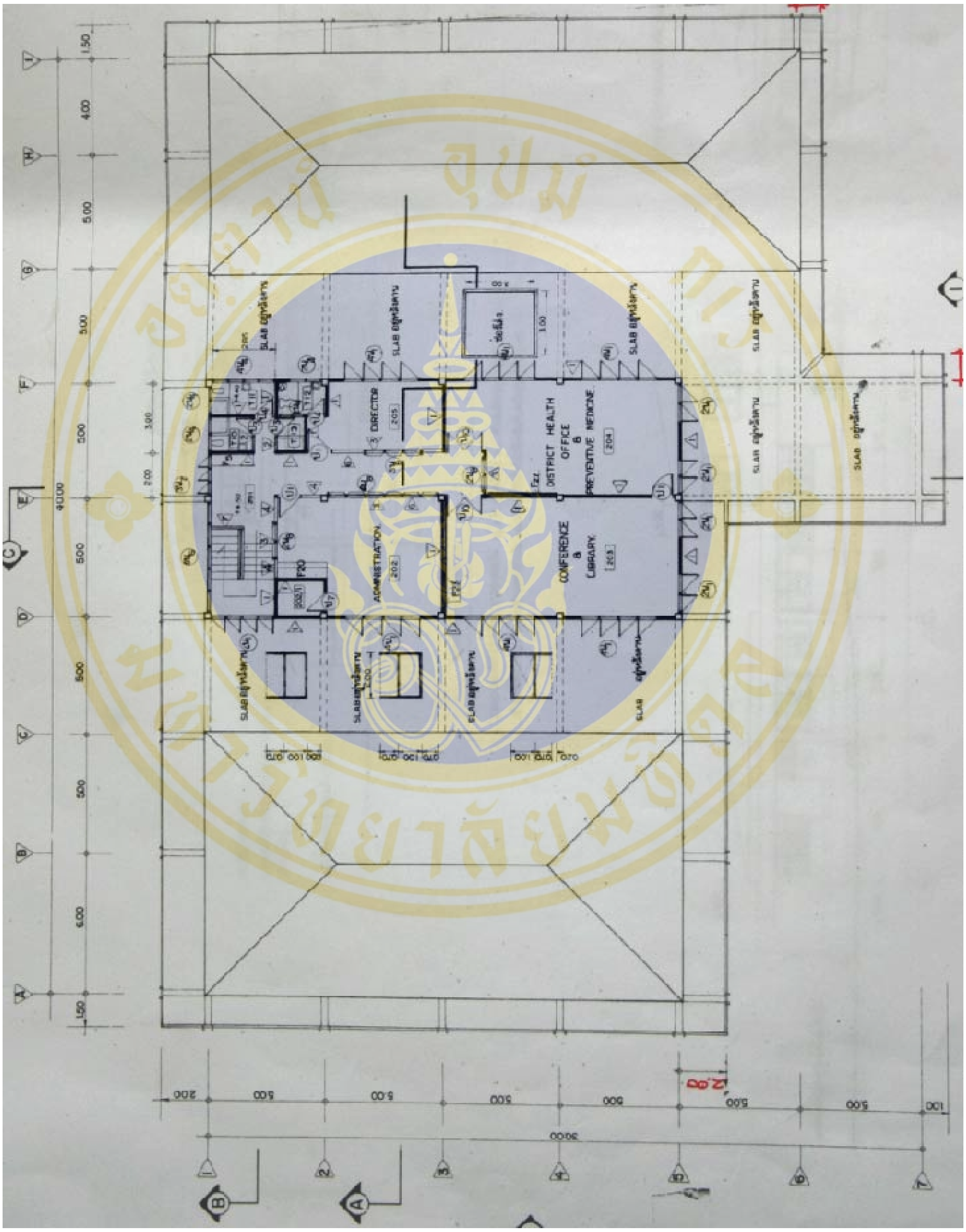
APPENDIX A

DRAWINGS AND SPECIFICATIONS OF OPD BUILDING

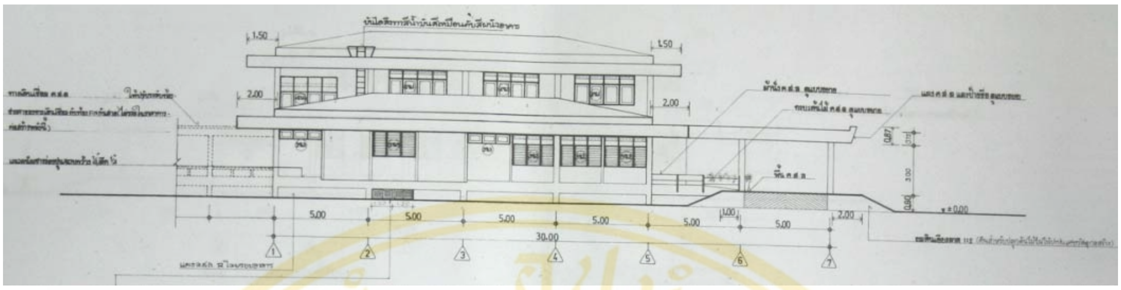
DCD NUMBER 3130/2526



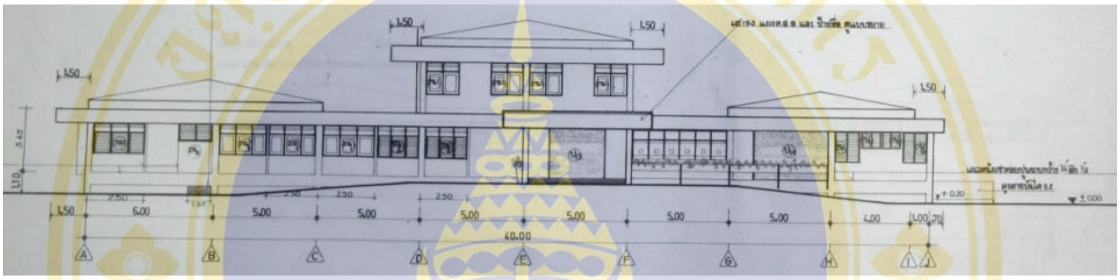
First Floor Plan



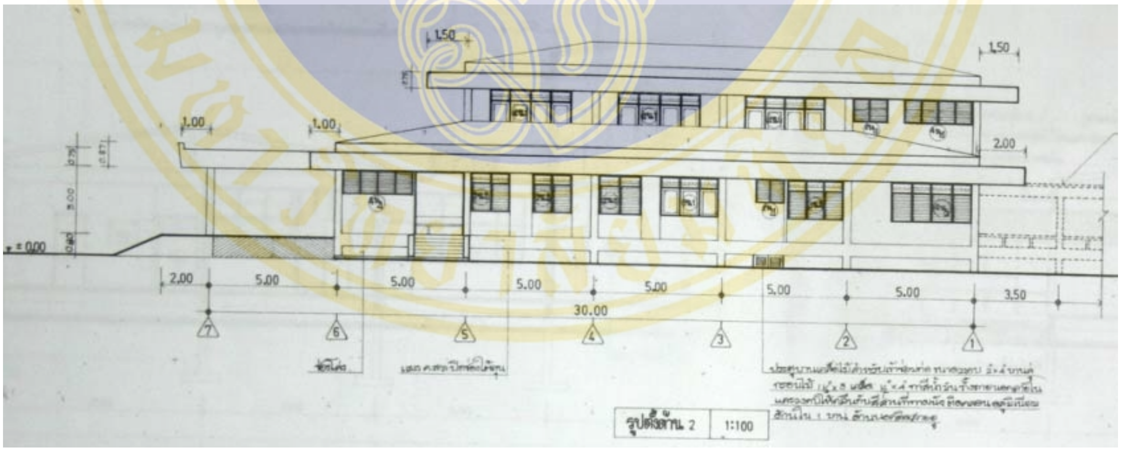
Second Floor Plan



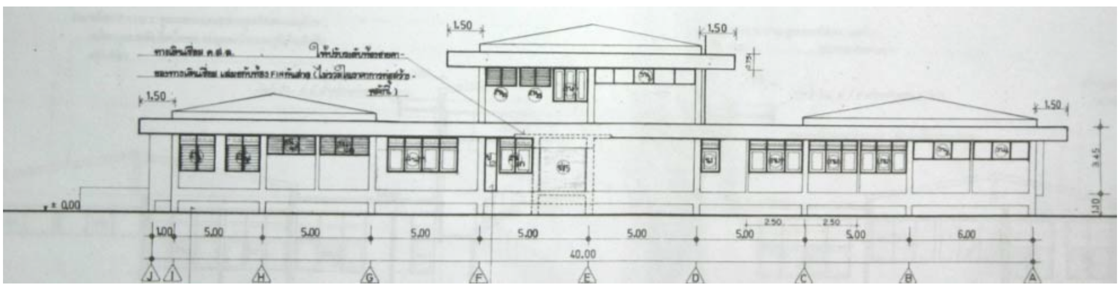
West Elevation



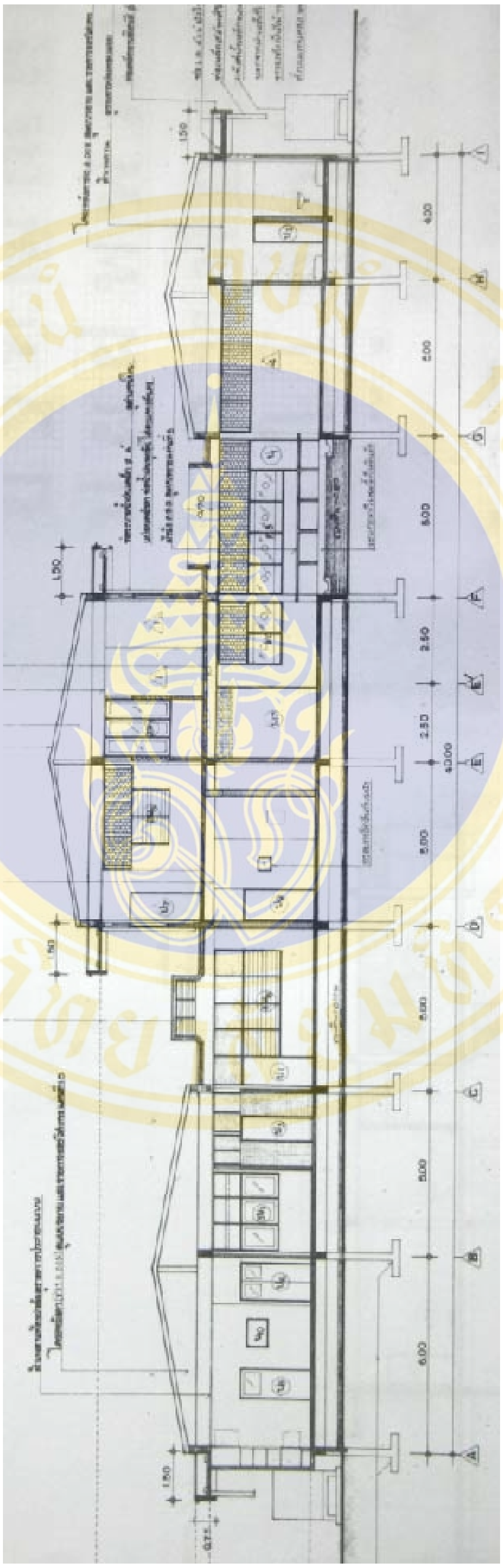
South Elevation



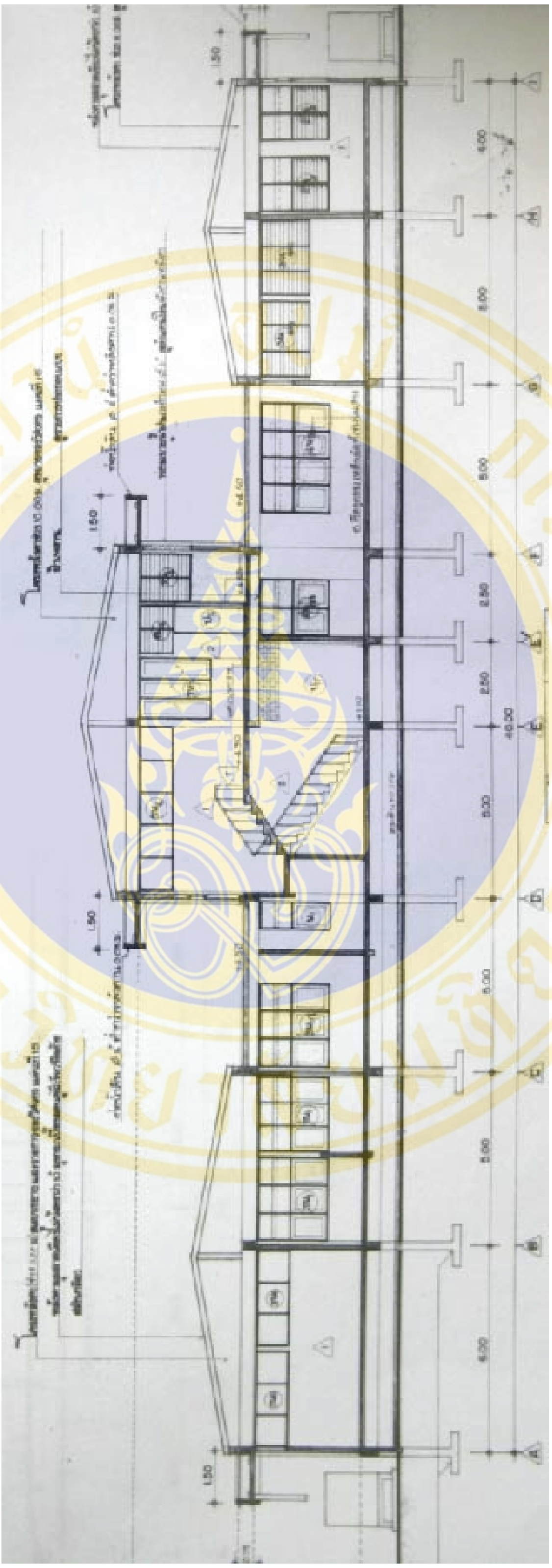
East Elevation



North Elevation



Widthwise Section of OPD Building Number 3130/2526



Longwise Section of OPD Building Number 3130/2526

APPENDIX B

THE BUILDING COMPONENT AND MATERIALS TRANSLATION INTO REVIT FAMILIES STRUCTURE

There are ten types of building material and component specifications of the OPD building number 3130/2526

1. Column Specifications

เสา 1 เสา ค.ส.ล. หน้าตัดสี่เหลี่ยมจัตุรัส 25 x 25 ซม.

- Kind of family template → Standalone Templates
- Family → M_Rectangular Column
- Type name → **250 x 250mm**
- Column structure

Column	**Material**	**Depth** (m.)	**Width** (m.)	**Colors**
1	Default	0.25	0.25	White

- Base Level→ Ground Level
- Top Level → Level ½

2. Beam Specifications

คาน 1 คาน ค.ส.ล. หน้าตัดสี่เหลี่ยม กว้าง 20 ลึก 60 ซม.

- Kind of family template → Floor-based
- Family → M_Concrete-Rectangular Beam
- Type name → **200 x 600mm**
- Structural usage → Automatic
- Beam structure

Beam	**Material**	**Width** (m.)	**Depth** (m.)	**Colors**

1	Concrete – Cast-in-Place Concrete	0.20	0.60	RGB 192-192-192 (Concrete, Non-Uniform, Gray)

- Reference Level → Level 1/2
- Elevation → 0.00 m

คาน 2 คาน ค.ส.ล. หน้าตัดสี่เหลี่ยม กว้าง 20 ลึก 55 ซม.

- Kind of family template → Floor-based
- Family → M_Concrete-Rectangular Beam
- Type name → **200 x 550mm**
- Structural usage → Automatic
- Beam structure

Beam	**Material**	**Width** (m.)	**Depth** (m.)	**Colors**
2	Concrete – Cast-in-Place Concrete	0.20	0.55	RGB 192-192-192 (Concrete, Non-Uniform, Gray)

- Reference Level → Level 1/2
- Elevation → 0.00m

คาน 3 คาน ค.ส.ล. หน้าตัดสี่เหลี่ยม กว้าง 20 ลึก 50 ซม.

- Kind of family template → Floor-based
- Family → M_Concrete-Rectangular Beam
- Type name → **200 x 500mm**
- Structural usage → Automatic
- Beam structure

Beam	**Material**	**Width** (m.)	**Depth** (m.)	**Colors**
3	Concrete – Cast-in-Place Concrete	0.20	0.50	RGB 192-192-192 (Concrete, Non-Uniform, Gray)

- Reference Level → Level 1/2
- Elevation → 0.00m

3. Door Specifications

(ป 1) ประตูไม้อัดยางสำเร็จรูป

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_1 - 900 x 2000mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
1	0.90	2.00	1.00	2.05	0.04	Plywood Door RGB 168-113-064 (Oak, White, Natural, No Gloss)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

(ป 2) ประตูไม้อัดยาง บุฟอร์ไมกา 2 ด้าน บานคู่สวิงเปิด 2 ทาง

- Kind of family template → Wall-based
- Family → M_Double-Swing
- Type name → **D_2 - Double Swing – 2(500) x 2000mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
2	0.50	1.90	1.00	2.05	0.04	Formica RGB 0-50-128 (Solid Colors, Whites, Cool, Matte)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 3 ประตูไม้อัดยาง บุฟอร์ไมกา 2 ด้าน ลอยจากพื้น

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_3 - 700 x 1900mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
3	0.70	1.90	0.80	2.05	0.04	Formica RGB 0-50-128 (Solid Colors, Whites, Cool, Matte)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 4 ประตูไม้อัดยางสำเร็จรูป บุฟอร์ไมกา 2 ด้าน

- Kind of family template → Wall-based

- Family → M_Single-Flush
- Type name → **D_4 - 700 x 2000mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
4	0.70	2.00	0.80	2.05	0.04	Formica RGB 0-50-128 (Solid Colors, Whites, Cool, Matte)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 5 ประตูไม้อัดยางสำเร็จรูป บุฟอร์ไมกา 2 ด้าน

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_5 - 900 x 2000mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
5	0.90	2.00	1.00	2.05	0.04	Formica RGB 0-50-128 (Solid Colors, Whites, Cool, Matte)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 6 ประตูบานคู่เปิด 2 ทาง บานไม้อัดสำเร็จรูป บุแผ่นสเตนเลส หนา 0.09 ม.ม. กันชนกว้าง 0.60 ม. เหนือระดับพื้น 0.60 ม. ตลอดความกว้างของบานทั้งสองด้าน

- Kind of family template → Wall-based
- Family → M_Double-Flush
- Type name → **D_6 - Double Flush – 2(600) x 2000mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
6	0.90	2.00	1.00	2.05	0.04	Formica RGB 0-50-128 (Solid Colors, Whites, Cool, Matte) Metal Bumper RGB 247-247-247 (Stainless Steel, Polished, Plain) Glass (Blue, Glass, Clear, Smooth)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 7 ประตูบานเหล็ก วงกบเหล็ก กว้าง 1.00 ม. สูง 2.00 ม.

- Kind of family template → Wall-based
- Family → M_Single-Flush

- Type name → **D_7 - 1000 x 2000mm - Mesh**
- Door structure

Door Number	**Door Leaf Width** (m)	**Door Leaf Height** (m)	**Door Width** (m)	**Door Height** (m)	**Door Panel Thickness** (m)	**Door Panel Materials**	**Door Frame Materials**
7	1.00	2.00	1.00	2.00	0.025	Metal RGB 247-247-247 (Steel, Satin, Plain)	Metal RGB 247-247-247 (Steel, Satin, Plain)

ป 8 ประตูไม้อัดยางสำเร็จรูป ลูกฟักกระจกใส

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_8 - 700 x 2000mm**
- Door structure

Door Number	**Door Leaf Width** (m)	**Door Leaf Height** (m)	**Door Width** (m)	**Door Height** (m)	**Door Panel Thickness** (m)	**Door Panel Materials**	**Door Frame Materials**
8	0.70	2.00	0.80	2.05	0.04	Plywood Door RGB 168-113-064 (Oak, White, Natural, No Gloss) Glass (Blue, Glass, Clear, Smooth)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 9 ประตูโครงไม้ ด้านหนึ่งบุแผ่นตะกั่วหนา 1 มม. ปิดทับด้วยไม้อัดยาง อีกด้านบุไม้อัดยาง

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_9 - 700 x 2000mm**
- Door structure

Door Number	**Door Leaf Width (m)**	**Door Leaf Height (m)**	**Door Width (m)**	**Door Height (m)**	**Door Panel Thickness (m)**	**Door Panel Materials**	**Door Frame Materials**
9	0.70	2.00	0.80	2.05	0.04	Plywood Door RGB 168-113-064 (Oak, White, Natural, No Gloss) Lead Plate (Stainless Steel, Polished, Plain)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 10 ประตูบานคู่เปิดทางเดียว บานไม้อัดยางสำเร็จรูป ลูกฟักกระจกฝ้า

- Kind of family template → Wall-based
- Family → M_Double-Flush
- Type name → **D_10 - Double Flush – 2(900) x 2000mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
10	0.90	2.00	1.00	2.05	0.04	Plywood Door RGB 168-113-064 (Oak, White, Natural, No Gloss) Opaque Glass RGB 247-247-247 (Glass, Clear, Frosted)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 11 ประตูบานเลื่อน โครงไม้ด้านหนึ่งบุแผ่นตะกั่วหนา 1 มม. ปิดทับด้วยไม้อัดยาง อีกด้านบุไม้อัดยาง

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_11 – 1600 x 2000mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
11	1.60	2.00	1.70	2.05	0.04	Plywood Door RGB 168-113-064 (Oak, White, Natural, No Gloss) Lead Plate	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

						(Stainless Steel, Polished, Plain)	

ป 12 ประตูไม้สักเข้าลิ้นเซาะร่องตัว V ทาสีน้ำมันให้กลืนกับผนังทั้งบานและวงกบ

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_12 – 1600 x 2000mm**
- Door structure

Door Number	**Door Leaf Width (m)**	**Door Leaf Height (m)**	**Door Width (m)**	**Door Height (m)**	**Door Panel Thickness (m)**	**Door Panel Materials**	**Door Frame Materials**
12	0.60	2.70	0.70	2.80	0.04	Teak Door RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 13 ประตูเหล็กม้วน เหนือระดับ 1.50 ม. เป็นลายโปร่ง ชนิดใช้มือดึง

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_13 – 2750 x 2700mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
13	2.75	2.70	2.85	2.80	0.01	Metal RGB 247-247-247 (Steel, Satin, Plain)	Metal RGB 247-247-247 (Steel, Satin, Plain)

ป 14 ประตูเหล็กม้วน เหนือระดับ 1.50 ม. เป็นลายโปร่ง ชนิดใช้มือดึง

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_14 – 3750 x 2700mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
14	3.75	2.70	3.85	2.80	0.01	Metal RGB 247-247-247 (Steel, Satin, Plain)	Metal RGB 247-247-247 (Steel, Satin, Plain)

ป 15 ประตูเหล็กม้วน ทึบทั้งบาน ชนิดใช้มือดึง

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_15 – 2250 x 2700mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
15	2.25	2.70	2.35	2.80	0.01	Metal RGB 247-247-247 (Steel, Satin, Plain)	Metal RGB 247-247-247 (Steel, Satin, Plain)

ป 16 ประตูไม้อัดยางสำเร็จรูป บุฟอร์ไมกา 2 ด้าน ลอยจากพื้น 10 ซม.

บานสวิงเปิด 2 ทาง

- Kind of family template → Wall-based
- Family → M_Single-Flush
- Type name → **D_16 – 700 x 1900mm**
- Door structure

Door Number	Door Leaf Width (m)	Door Leaf Height (m)	Door Width (m)	Door Height (m)	Door Panel Thickness (m)	Door Panel Materials	Door Frame Materials
16	0.70	1900	0.80	2.80	0.04	Formica RGB 0-50-128 (Solid Colors, Whites, Cool, Matte)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

ป 17 ประตูไม้อัดยางสำเร็จรูป บุฟอร์ไมกา 2 ด้าน ลอยจากพื้น 80 ซม.

บานสวิงเปิด 2 ทาง

- Kind of family template → Wall-based
- Family → M_Double-Flush
- Type name → **D_17 – 2(450) x 900mm**
- Door structure

Door Number	**Door Leaf Width (m)**	**Door Leaf Height (m)**	**Door Width (m)**	**Door Height (m)**	**Door Panel Thickness (m)**	**Door Panel Materials**	**Door Frame Materials**
17	0.45	900	1.00	2.80	0.04	Formica RGB 0-50-128 (Solid Colors, Whites, Cool, Matte)	Door Frame RGB 120-073-019 (Teak, Stained, Dark, No Gloss)

4. Window Specifications

(น 1) หน้าต่างบานเปิดลูกฟักกระจกใส

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_1**
- Window structure

Window Number	**Window Width (m)**	**Window Height (m)**	**Sill Height (m)**	**Window Frame Materials**	**Window Sash Materials**	**Window Glass Materials**	**Window Mullion Materials**
1	0.80	1.94	0.86	**Window Frame** RGB 120-	**Window Sash** RGB 168-	**Glass** Blue (Glass,	-

				073-019 (Teak, Stained, Dark, No Gloss)	113-064 (Oak, White, Natural, No Gloss)	Clear, Smooth) **Opaque Glass** RGB 247-247-247 (Glass, Clear, Frosted)	

น 2 หน้าต่างบานเกล็ดปรับมุมกระจกฝ้า

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_2**
- Window structure

Window Number	**Window Width (m)**	**Window Height (m)**	**Sill Height (m)**	**Window Frame Materials**	**Window Sash Materials**	**Window Glass Materials**	**Window Mullion Materials**
2	0.80	1.94	0.86	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	-	**Slated Glass** Blue (Glass, Clear, Smooth) **Opaque Glass** RGB 247-247-247 (Glass,	-

						Clear, Frosted)	

(น 3) หน้าต่างบานกระทุ้ง ลูกฟักกระจกฝ้า สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_3**
- Window structure

Window Number	**Window Width (m)**	**Window Height (m)**	**Sill Height (m)**	**Window Frame Materials**	**Window Sash Materials**	**Window Glass Materials**	**Window Mullion Materials**
3	2.30	0.80	2.00	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	**Window Sash** RGB 168-113-064 (Oak, White, Natural, No Gloss)	**Opaque Glass** RGB 247-247-247 (Glass, Clear, Frosted)	-

(น 4) หน้าต่างบานเกล็ดกระจกฝ้าติดตาย สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_4**
- Window structure

Window Number	Window Width (m)	Window Height (m)	Sill Height (m)	Window Frame Materials	Window Sash Materials	Window Glass Materials	Window Mullion Materials
4	0.80	1.30	1.50	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	-	**Opaque Glass** RGB 247-247-247 (Glass, Clear, Frosted)	-

(น 5) หน้าต่างบานเกล็ดกระจกฝ้าปรับมุม สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_5**
- Window structure

Window Number	Window Width (m)	Window Height (m)	Sill Height (m)	Window Frame Materials	Window Sash Materials	Window Glass Materials	Window Mullion Materials
5	0.80	1.65	1.15	**Window Frame** RGB 120-073-019 (Teak,	**Window Sash** RGB 168-113-064 (Oak, White,	-	-

				Stained, Dark, No Gloss)	Natural, No Gloss)		

น 6 หน้าต่างกระจกฝ้าติดตาย สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_6**
- Window structure

Window Number	**Window Width (m)**	**Window Height (m)**	**Sill Height (m)**	**Window Frame Materials**	**Window Sash Materials**	**Window Glass Materials**	**Window Mullion Materials**
6	1.00	0.80	2.00	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	-	**Opaque Glass** RGB 247-247-247 (Glass, Clear, Frosted)	-

น 7 หน้าต่างบานเปิดลูกฟักกระจก สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_7**
- Window structure

Window Number	Window Width (m)	Window Height (m)	Sill Height (m)	Window Frame Materials	Window Sash Materials	Window Glass Materials	Window Mullion Materials
7	1.85	1.94	0.86	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	**Window Sash** RGB 168-113-064 (Oak, White, Natural, No Gloss)	**Glass** Blue (Glass, Clear, Smooth)	-

น 8 หน้าต่างบานเกล็ดปรับมุมภายในอาคาร

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_8**
- Window structure

Window Number	Window Width (m)	Window Height (m)	Sill Height (m)	Window Frame Materials	Window Sash Materials	Window Glass Materials	Window Mullion Materials
8	0.80	1.14	0.86	**Window Frame** RGB 120-073-019 (Teak,	-	**Opaque Glass** RGB 247-247-247 (Glass,	-

				Stained, Dark, No Gloss)		Clear, Frosted) **Metal Mesh** RGB 247-247-247 (Metals, Aluminum, Polish, Screen, Medium)	

น 9 หน้าต่างบานเกล็ดกระจกฝ้าปรับมุม สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_9**
- Window structure

Window Number	**Window Width (m)**	**Window Height (m)**	**Sill Height (m)**	**Window Frame Materials**	**Window Sash Materials**	**Window Glass Materials**	**Window Mullion Materials**
9	0.80	1.95	0.85	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	-	**Opaque Glass** RGB 247-247-247 (Glass, Clear, Frosted)	-

น 10 หน้าต่างกระจกใสติดตาย

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_10**
- Window structure

Window Number	**Window Width (m)**	**Window Height (m)**	**Sill Height (m)**	**Window Frame Materials**	**Window Sash Materials**	**Window Glass Materials**	**Window Mullion Materials**
10	0.80	0.60	1.20	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	-	**Glass** Blue (Glass, Clear, Smooth)	-

น 11 หน้าต่างเกล็ดไม้ติดตาย

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name→ **W_11**
- Window structure

Window Number	Window Width (m)	Window Height (m)	Sill Height (m)	Window Frame Materials	Window Sash Materials	Window Glass Materials	Window Mullion Materials
11	0.50	2.05	0.00	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	**Window Slate** RGB 168-113-064 (Oak, White, Natural, No Gloss)	-	-

น 12 ช่องมองกระจกตะกั่วกันรังสี

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_12**
- Window structure

Window Number	Window Width (m)	Window Height (m)	Sill Height (m)	Window Frame Materials	Window Sash Materials	Window Glass Materials	Window Mullion Materials
12	0.40	0.40	1.35	**Window Frame** RGB 120-073-019 (Teak,	-	**Glass** Blue (Glass, Clear, Smooth)	-

				Stained, Dark, No Gloss)			

(น 13) ช่องวงกบติดเหล็กดัดเต็มช่อง

- Kind of family template → Wall-based
- Family → M_Fixed
- Type name → **W_13**
- Window structure

Window Number	**Window Width** (m)	**Window Height** (m)	**Sill Height** (m)	**Window Frame Materials**	**Window Sash Materials**	**Window Glass Materials**	**Window Mullion Materials**
13	2.50	0.75	2.05	**Window Frame** RGB 120-073-019 (Teak, Stained, Dark, No Gloss)	-	-	**Iron Mullion** RGB 247-247-247 (Metals, Steel, Satin, Plain)

5. Wall Specifications

(1) ผนังก่ออิฐครึ่งแผ่น สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Generic - 100mm**
- Wall structure

Exterior Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Membrane Layer	Paint	0.00	White
2	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
3	Structure (Masonry)	Brick	0.08	RGB 170-100-105
4	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
5	Membrane Layer	Paint	0.00	White

Interior Side

- Wall base constraint → Level 1/2
- Wall top constraint → Ceiling Height (offset from Level 1/2)

△2 ผนังก่ออิฐครึ่งแผ่น สูง 2.00 ม.

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Generic - 100mm - H 2.00m**
- Wall structure

Exterior Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Membrane Layer	Paint	0.00	White
2	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
3	Structure (Masonry)	Brick	0.08	RGB 170-100-105
4	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
5	Membrane Layer	Paint	0.00	White

Interior Side

- Wall base constraint → Level 1/2
- Wall top constraint → Unconnected Height = 2.00 m

3 ผนังหรือหน้าต่างสูงถึงระดับ 2.00 ม. เหนือขึ้นไปเป็นเหล็กดัด

ตลอดช่วงเสาถึงเสา

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Generic - 100mm - H 2.00m**
- Wall structure

Exterior Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Membrane Layer	Paint	0.00	White
2	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
3	Structure (Masonry)	Brick	0.08	RGB 170-100-105
4	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
5	Membrane Layer	Paint	0.00	White

Interior Side

- Wall base constraint → Level 1/2
- Wall top constraint → Unconnected Height = 2.00 m

4 ผนังก่ออิฐครึ่งแผ่น สูง 2.00 ม. เหนือขึ้นไปเป็นเหล็กดัดตลอด

ช่วงเสาถึงเสา

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Generic - 100mm - H 2.00m**

- Wall structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Membrane Layer	Paint	0.00	White
2	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
3	Structure (Masonry)	Brick	0.08	RGB 170-100-105
4	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
5	Membrane Layer	Paint	0.00	White
Interior Side				

- Wall base constraint → Level 1/2
- Wall top constraint → Unconnected Height = 2.00 m

△5 ผนังก่ออิฐเต็มแผ่น สูงจรดเพดาน

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Generic - 200mm**
- Wall structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Membrane Layer	Paint	0.00	White
2	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
3	Structure (Masonry)	Brick	0.18	RGB 170-100-105
4	Structure (Stucco)	Concrete	0.01	RGB 192-192-192
5	Membrane Layer	Paint	0.00	White

Interior Side

- Wall base constraint → Level 1/2
- Wall top constraint → Ceiling Height (offset from Level 1/2)

6 ผนังไม้อัดยาง 6 ม.ม. สองชั้น เคร่าไม้ 1½" x 3" @ 0.60 ม. สูง 2.00 ม.

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Wood Plywood - 100mm - H 2.00m**
- Wall structure

Exterior Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Structure (Plywood)	Plywood	0.012	RGB 184-187-068 (Plywood, Default)
2	Structure (Wood Stud)	Wood Stud	0.076	RGB 126-077-020 (Teak, Natural, No Gross)
3	Structure (Plywood)	Plywood	0.012	RGB 184-187-068 (Plywood, Default)

Interior Side

- Wall base constraint → Level 1/2
- Wall top constraint → Unconnected Height = 2.00 m

7 ผนังไม้แดงหรือไม้สัก ½" x 4" บังใบโชว์สองด้าน เซาะร่องตัว V ทุกระยะ 2" เคร่าไม้ 1½" x 3" ทับหลังไม้ชนิดเดียวกันขนาด 2" x 5" สูง 0.85 ม.

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Wood Teak - 100mm - H 0.85m**
- Wall structure

Exterior Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Structure (Wood - Teak)	Wood - Teak	0.012	RGB 126-077-020 (Teak, Natural, No Gloss)
2	Structure (Wood Stud)	Wood Stud	0.076	RGB 126-077-020 (Teak, Natural, No Gross)
3	Structure (Wood - Teak)	Wood - Teak	0.012	RGB 126-077-020 (Teak, Natural, No Gloss)

Interior Side

- Wall base constraint → Level 1/2
- Wall top constraint → Unconnected Height = 0.85m

8 ผนัง ค.ส.ล. สูง 1.25 ม.

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Reinforced Concrete - 100mm**

- Wall structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Finish (Ceramic Tile)	Ceramic Tile 10 x 10 cm	0.005	RGB 218-218-218 (Ceramic Tile, White, Medium Gloss)
2	Structure	Concrete – Cast In Situ	0.090	RGB 192-192-192 (Concrete, Non-Uniform, Gray)
3	Finish (Ceramic Tile)	Ceramic Tile 10 x 10 cm	0.005	RGB 218-218-218 (Ceramic Tile, White, Medium Gloss)
Interior Side				

- Wall base constraint → Level 1/2
- Wall top constraint → Unconnected Height = 1.25m

9 ผนังก่ออิฐเต็มหน้าเสา สูงถึงระดับเหนือพื้น ด้านที่สูงกว่า 0.50 ม.

ผิวด้านข้างเป็นกรวดล้างด้านบนเป็นหินขัด

- Kind of family template → Wall-based
- Family → Basic Wall
- Type name → **Tan Stucco - 100mm**
- Wall structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Finish	Tan Stucco	0.02	RGB 196-158-130 (Stucco, Tan, Textured)
2	Structure (Masonry)	Brick	0.08	RGB 170-100-

				105
Interior Side				

- Wall base constraint → Level 1
- Wall top constraint → Unconnected Height = 0.50 m

6. Floor Specifications

1 พื้นหินขัดสีขาว ขนาดเกล็ด 2, 3 อย่างละครึ่ง ฝังเส้นทองเหลือง

- Kind of family template → Floor-based
- Family → Floor
- Type name → **Generic - 100mm**
- Floor structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Structure	Concrete – Cast In Situ	0.10	RGB 192-192-192 (Concrete, Non-Uniform, Gray)
Interior Side				

- Wall base constraint → Level 1/2
- Height Offset From Level → 0.00

2 พื้นค.ส.ล.วางบนดิน

- Kind of family template → Floor-based
- Family → Floor
- Type name → **In Situ - 200mm**
- Floor structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Finish	Concrete –	0.05	RGB 192-192-192

		Sand/Cement Screed		(Concrete, Non-Uniform, Gray)
2	Membrane Layer	Vapour/Barriers - Damp-proofing	0.00	RGB 127-127-127 (Default)
3	Structure	Concrete – Cast In Situ	0.15	RGB 192-192-192 (Concrete, Non-Uniform, Gray)

Interior Side

- Wall base constraint → Ground Level
- Height Offset From Level → 0.00

3 พื้นค.ส.ล.ผิวหยาบ

- Kind of family template → Floor-based
- Family → Floor
- Type name → **In Situ - 150mm**
- Floor structure

Exterior Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Finish	Concrete – Sand/Cement Screed	0.05	RGB 192-192-192 (Concrete, Non-Uniform, Gray)
2	Membrane Layer	Vapour/Barriers - Damp-proofing	0.00	RGB 127-127-127 (Default)
3	Structure	Concrete – Cast In Situ	0.10	RGB 192-192-192 (Concrete,

				Non-Uniform, Gray)
Interior Side				

- Wall base constraint → Level 1/2
- Height Offset From Level → 0.00

4 พื้นค.ส.ล. ปูกระเบื้องเซรามิคผิวด้าน 4" x 4"

- Kind of family template → Floor-based
- Family → Floor
- Type name → **Ceramic - 100mm**
- Floor structure

Exterior Side				
Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Finish	Ceramic Tile 10 x 10 cm	0.005	RGB 218-218-218 (Ceramic Tile, White, Low Gloss)
2	Finish	Concrete – Sand/Cement Screed	0.005	RGB 192-192-192 (Concrete, Non-Uniform, Gray)
2	Membrane Layer	Vapour/Barriers - Damp-proofing	0.00	RGB 127-127-127 (Default)
3	Structure	Concrete – Cast In Situ	0.09	RGB 192-192-192 (Concrete, Non-Uniform, Gray)
Interior Side				

- Wall base constraint → Level 1/2
- Height Offset From Level → 0.00

5 พื้นค.ส.ล. ปูกระเบื้องยางสีขาวอมเทา หนา 2 มม.

- Kind of family template → Floor-based
- Family → Floor
- Type name → **Laminated Tile - 100mm**
- Floor structure

Exterior Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Finish	Ceramic Tile 10 x 10 cm	0.002	RGB 218-218-218 (Ceramic Tile, White, Low Gloss)
2	Finish	Concrete – Sand/Cement Screed	0.008	RGB 192-192-192 (Concrete, Non-Uniform, Gray)
2	Membrane Layer	Vapour/Barriers - Damp-proofing	0.00	RGB 127-127-127 (Default)
3	Structure	Concrete – Cast In Situ	0.09	RGB 192-192-192 (Concrete, Non-Uniform, Gray)

Interior Side

- Wall base constraint → Level 1/2
- Height Offset From Level → 0.00

7. Ceiling Specifications

ฝ 1 ฝ้าเพดานกระเบื้องแผ่นเรียบ 4 มม. ไม่เว้นร่อง เคร่าไม้ 1½" x 3"

@ 0.60 x 0.60 ม.

- Kind of family template → Ceiling-based
- Family → Compound ceiling
- Type name → **Plain – 4 mm**
- Ceiling structure

Upper Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Structure	Wood Stud Layer	0.040	RGB 127-127-127
2	Structure	Finishes – Interior - Plasterboard	0.004	RGB 249-249-249

Lower Side

- Level → Level 1/2
- Height offset from level → Unconnected Height = 2.80 m

ฝ 2 ฝ้าเพดานกระเบื้องแผ่นเรียบ 6 มม. เคร่าทีบาร์ เป็นเหล็กอบสีขาว

หรืออลูมิเนียม @ 0.60 x 0.60 ม.

- Kind of family template → Ceiling-based
- Family → Compound ceiling
- Type name → **600 x 600mm grid**
- Ceiling structure

Upper Side

Layer	**Function**	**Materials**	**Thickness** (m.)	**Colors**
1	Structure	Metal Stud Layer	0.040	RGB 127-127-127
2	Structure	Finishes – Interior	0.006	RGB 249-249-

		- Plasterboard		249
Lower Side				

- Level → Level 1/2
- Height offset from level → Unconnected Height = 2.80 m

8. Roof Specifications

หลังคา 1 หลังคากระเบื้องลอนคู่ โครงหลังคาเหล็ก

- Kind of family template → Roof-based
- Family → Basic roof
- Type name → **Roof - 200mm**
- Ceiling structure

Upper Side

Layer	Function	Materials	Thickness (m.)	Colors
1	Finish	Roofing Slate	0.005	RGB 127-127-127
2	Thermal/Air Layer	Air Barrier	0.045	White
2	Structure	Steel Bar Joist Layer	0.150	RGB 249-249-249

Lower Side

- Base level → Level 2
- Base offset from level → 0.20 m
- Slope angle → 15°

9. Stair Specifications

S1 บันไดหลัก เชื่อมระหว่างชั้นที่ 1 และชั้นที่ 2

- Kind of family template → Floor-based
- Family → Stairs
- Type name → **190mm max riser - Concrete**
- Stairs width → 1.40 m

- Number of risers → 18
- **Treads** properties
  - Treads material → Concrete – Cast In Situ
    RGB 192-192-192
    Concrete, Non-Uniform, Gray
  - Minimum tread depth = 0.25 m
  - Tread thickness = 0.05 m
- **Risers** properties
  - Riser material → Concrete – Cast In Situ
    RGB 192-192-192
    Concrete, Non-Uniform, Gray
  - Maximum riser height= 0.19 m
  - Riser thickness = 0.05 m
  - Riser type = Straight
- **Stringers** properties
  - Stringer material → Concrete – Cast In Situ
    RGB 192-192-192
    Concrete, Non-Uniform, Gray
  - Stringer height = 0.40 m
  - Stringer thickness = 0.05 m
- Base level → Level 1
- Top level → Level 2

S 2 บันไดด้านข้าง เชื่อมระหว่างลานซักล้างและบริเวณพักคอยผู้ป่วยนอก

- Kind of family template → Floor-based
- Family → Stairs
- Type name → **190mm max riser - Concrete**
- Stairs width → 1.00 m
- Number of risers → 7

- **Treads** properties
  - Treads material → Concrete – Cast In Situ
    RGB 192-192-192
    Concrete, Non-Uniform, Gray
  - Minimum tread depth = 0.25 m
  - Tread thickness = 0.05 m
- **Risers** properties
  - Riser material → Concrete – Cast In Situ
    RGB 192-192-192
    Concrete, Non-Uniform, Gray
  - Maximum riser height= 0.19 m
  - Riser thickness = 0.05 m
  - Riser type = Straight
- **Stringers** properties
  - Stringer material → Concrete – Cast In Situ
    RGB 192-192-192
    Concrete, Non-Uniform, Gray
  - Stringer height = 0.40 m
  - Stringer thickness = 0.05 m
- Base level → Ground Level
- Base offset→ 0.20 m
- Top level → Level 1

10. Railing Specifications

ราวบันได ของบันได S 1

- Kind of family template → Floor-based
- Family → Railing
- Type name → **1100mm**
- Railing height → 1.10 m
- Rail structure → Default
- Baluster placement → Default

BIOGRAPHY

NAME	Mr. Nuttasit Somboonwit
DATE OF BIRTH	14th June 1974
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	Khonkaen University, 1991-1996: Bachelor of Architecture (Architecture)
	Mahidol University, 2001-2006: Master of Science (Information Management on Environments and Resources)
POSITION & OFFICE	1997-Present, Design and Construction Division (DCD), Ministry of Public Health, Nontaburi, Thailand
	Position: Architect
	Email: donkrub@yahoo.com