DEVELOPMENT OF AFFORDABLE AND USER FRIENDLY COST MODELLING TOOL FOR MALAYSIA CONSTRUCTION PROJECT

BY

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ABSTRACT

The focus of this research is to develop cost modelling tool which can help the designer to estimate affordable green home. This is in line with the aspiration of this country to become a developed and sustainable community. Therefore, this research aims to develop cost modelling tool for the construction project which is affordable and user-friendly. In order to achieve the aim and the objectives of this research, the theoretical framework was developed as a basis for establishing the cost modelling framework. It was started by identifying the green criteria which can be possibly implementing during planning, design and construction. Then it followed by determining the most appropriate cost model which can help the designers to predict the green home project at the design stages. The process continued with the development of the cost modelling tool by utilising Microsoft Excel (MS Excel) software to make it interactive and handy. This tool is expected to compliment with the shortfall of BIM (Revit software as for example) as it still lacking a real-time base cost modelling tool which can merge between green design and cost. Functional Testing was conducted once the cost model completed then it was calibrated to adapt with the environment of its use. User Acceptance Test (UAT) has been conducted to ensure that the tool is easy to use and operate. The result from UAT shows that the tool is user-friendly, handiness and economical to evaluate construction project especially green home. It also allows the designers to estimate and conduct comparative cost studies on the economics of the project during the design stage without going through the conventional process.

خلاصة البحث

يركز هذا البحث على تطوير أداة نمذجة التكلفة التي يمكن أن تساعد المصمم على تقدير المنزل الأخضر الميسور التكلفة. وهذا يتماشى مع طموح هذا البلد ليصبح مجتمعًا متطورًا ومستدامًا. لذلك، يهدف هذا البحث إلى تطوير أداة نمذجة التكلفة لمشروع البناء الذي يكون بأسعار معقولة وسهلة الاستخدام. من أجل تحقيق أهداف هذا البحث، لقد تم تطوير الإطار النظري كأساس لوضع إطار نمذجة التكلفة. وقد بدأ بتحديد المعايير الخضراء التي يمكن تنفيذها أثناء التخطيط والتصميم والبناء. ثم يلي ذلك تحديد نموذج التكلفة الأنسب الذي يمكن أن يساعد المصممين على التنبؤ بمشروع المنزل الأخضر في مراحل التصميم. واستمرت العملية مع تطوير أداة نمذجة التكلفة من خلال استخدام برنامج (MS Excel) لجعلها تفاعلية وسهلة الاستخدام. من المتوقع أن تكمل هذه الأداة النقص في برنامج BIM (برنامج Revit على سبيل المثال) لأنه لا يزال يفتقر إلى أداة نمذجة التكلفة الأساسية في الوقت الفعلي والتي يمكن دمجها بين التصميم الأخضر والتكلفة. تم إجراء الاختبار الوظيفي بمجرد الانتهاء من نموذج التكلفة، ثم تمت معايرته للتكيف مع بيئة استخدامه. وتم إجراء اختبار قبول المستخدم (UAT) لضمان سهولة استخدام الأداة وتشغيلها. تظهر نتيجة UAT أن الأداة سهلة الاستخدام وسهلة الإدارة واقتصادية لتقييم مشروع البناء وخاصةً المنزل الأخضر. كما يسمح للمصممين بتقدير وإجراء دراسات التكلفة المقارنة على اقتصاديات المشروع خلال مرحلة التصميم دون الدخول في العملية التقليدية.

APPROVAL PAGE

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Nurul Akmam Naamandadin

Signature ..... Date .....

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LIST OF ABBREVIATIONS

3D	3–Dimension
4D	4–Dimension
5D	5–Dimension
ABS	Acrylonitrile Butylene Styrene
Al_2O_3	Aluminium Oxide / Alumina
ASME	American Society of Mechanical Engineers
BAS	Building Automation Systems
BECS	Building Energy Consumption Simulation
BIM	Building Information Modelling
BREEAM	Building Research Establishment Environmental Assessment Method
CAD	Computer Aid Design
CaO	Calcium Oxide / Lime
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
$CaSO_4 \cdot 2H_2O$	Crystalline Calcium Sulfate Dihydrate
CETDEM	Centre for Environment, Technology and Development, Malaysia
CFLs	Compact Fluorescent Lamps
CIDB	Construction Industrial Development Board
CO_2	Carbon Dioxide
DU	Distribution Uniformity
ECA	Elemental Cost Analysis
EDC	Ethylene Dichloride
EE	Energy Efficient
EPA	Environmental Protection Agency
Fe_2O_3	Ferric Oxide / Ferromagnetic
FEMP	Federal Energy Management Program
FSC	Forest Stewardship Council
FSC	Forest Stewardship Council
GBCA	Green Building Council of Australia
GBI	Green Building Index
GFA	Gross Floor Area
GMS	Green Marks
gpf	gallons per flush
gpm	gallon per minute
HVAC	Heat, Ventilation and Air Conditional
IEQ	Indoor Environmental Quality
IS	Information System
IWK	Indah Water Konsortium Sdn Bhd
JBA	Jabatan Bekalan Air
JPS	Jabatan Perparitan dan Saliran
LEED	Leadership in Energy and Environmental Design
M&E	Mechanical and Electrical

MANV	Mechanically Assisted Naturally Ventilated
MEF	Modified Energy Factor
MIEEIP	Malaysia Industrial Energy Efficiency Improvement Project
MS	Malaysian Standard
MS Excel	Microsoft Excel
MS2680:2017	Malaysian Standards Code of Practice for Energy Efficiency and Use of Renewable Energy for Residential Building
MTCS	Malaysian Timber Certification Scheme
NV	Natural Ventilation
PFCs	Perfluorinated Compounds
PFOA	Perfluorooctanoic Acid
PVC	Polyvinyl Chloride
QS	Quantity Surveyor
RH	Relative Humidity
RIBA	Royal Institution of British Architects
RICS	Royal Institution of Chartered Surveyor
RISM	Royal Intuition of Surveyor Malaysia
RM	Ringgit Malaysia
SiO_2	Silicon Dioxide / Silica
SIRIM	Standard and Industrial Research Institute of Malaysia
SMM2	Standard Method of Measurement 2
SYABAS	Syarikat Bekalan Air Selangor Sdn. Bhd.
TM	Telekom Malaysia
TNB	Tenaga National Berhad
U.S. EPA	United States Environmental Protection Agency
UAT	User Acceptance Testing
UBBL	Uniform Building by Law
UK	United Kingdom
US	United State
USA	United State of America
VCM	Vinyl Chloride Monomer
VOC/VOCs	Volatile Organic Chemicals
WBLFF	Works Below Lowest Floor Finish
WELS	Water Efficiency Labelling Scheme
WF	Water Factor
WWR	Window to Wall Ratio

LIST OF SYMBOLS

%	percent
d	optimum depth of a point measured on the working plan
ft^2	feet square
h	the vertical height of the window
l	the length of the window
L	liter
m	meter
m/s	meter per second
m^2	meter square
mm	milimeter
no	number
^{o}	degree
^oC	degree Celcius
pCi/L	Picocuries per litre
W/m/K	Watt per meter per Kelvin
x	the distance of a point measured on the working plan from room axis

LIST OF GREEN ASSESSMENTS CODE

Code	***Green Assessments***
Management / Project Management	
MAN 1	*Home User Guide*
MAN 2	*Considerate Constructors*
MAN 3	*Construction Site Impacts*
MAN 4	*Security*
MAN-1	*Green Star Accredited Professional*
MAN-2	*Commissioning Clauses*
MAN-3	*Building Tuning*
MAN-4	*Independent Commissioning Agent*
MAN-5	*Building Users' Guide*
MAN-6	*Environmental Management*
MAN-7	*Waste Management*
MAN-16	*Metering*
LH 3-3	*Environmental Management Practice*
LH 3-4	*Stormwater Management*
SM 5	*Construction System and Site Management*
SM 6	*Stormwater Management*
SM 7	*Redevelopment of Existing Sites and Brownfield Redevelopment*
SM 8	*Avoiding Environmentally Sensitive Areas*
SM 9	*Building User Manual*
Energy	
EA 1	*ENERGY STAR Labelled Home*
EA 2	*Insulation*
EA 4	*Windows Maximum*
EA 5	*Heating and Cooling Distribution System*
EA 6	*Space Heating and Cooling Equipment*
EA 7	*Water Heating*
EA 10	*Renewable Energy System*
ENE 1	*Dwelling Emission Rate*
ENE 2	*Building Fabric*
ENE 3	*Drying Space*
ENE 4	*Eco Labelled Goods*
ENE 5	*Internal Lighting*
ENE 6	*External Lighting*
LR_H1.1.1	*Energy Saving through Building Innovation: Control of Thermal Load of Building*
LR_H1.1.2	*Energy Saving through Building Innovation: Natural Energy Use*

$LR_H1.2.1.1$	*Energy Saving through Equipment Performance: Air-Conditioning Systems – Heating system*
$LR_H1.2.1.2$	*Energy Saving through Equipment Performance: Air-Conditioning Systems – Cooling System*
$LR_H1.2.2.1$	*Energy Saving through Equipment Performance: Hot-water equipment – Hot-water Supply Equipment*
$LR_H1.2.2.2$	*Energy Saving through Equipment Performance: Hot-water equipment –Heat Insulation of Bathtub*
$LR_H1.2.3$	*Energy Saving through Equipment Performance: Lighting Fixtures, Home Electric Appliances, and Kitchen Equipment*
$LR_H1.2.4$	*Energy Saving through Equipment Performance: Ventilation System*
$LR_H1.2.5.1$	*Energy Saving through Equipment Performance: Highly Energy-Efficient Equipment – Home Cogeneration System*
$LR_H1.2.5.2$	*Energy Saving through Equipment Performance: Highly Energy-Efficient Equipment – Solar Power Generation System*
ENE-CON	*Conditional Requirement (Land Use & Ecology)*
ENE-1	*Greenhouse Gas Emissions*
ENE-7	*Unoccupied Areas*
ENE-11	*Energy Efficient Appliances*
ENE-12	*Peak Electricity Demand Reduction*
LH 1-1	*Optimised Building Orientation*
LH 1-2	*Window to Wall Ratio (WWR)*
LH 1-3	*Shading Device Design*
LH 1-4	*Maximum Permissible Wall U-Value*
LH 1-5	*Maximum Permissible Shading Coefficient (SC) Value of Glass*
LH 1-6	*Cross Ventilation for Habitable Rooms*
LH 1-7	*Open Space with Greenery Provision*
LH 1-8	*Covered Parking Space*
LH 1-9	*Daylighting Provision*
LH 1-10	*Cool / Green Ro*
LH 1-11	*Cool Hardscaped Areas*
LH 1-12	*Sustainable Landscape Design*
EE 1	*Minimum Energy Performance*
EE 2	*Renewable Energy*
EE 3	*Advanced EE Performance Based on OTTV & RTTV*
EE 4	*Home Office & Connectivity*
EE 5	*Sustainable Maintenance*

<u>Transportation</u>

TRA 1	*Public Transport*
TRA 2	*Cycle Storage*
TRA 3	*Local Amenities*
TRA 4	*Home Office*
TRA-1	*Provision of Car Parking*
TRA-2	*Fuel Efficient Transport*

TRA-3	*Cyclist Facilities*
TRA-4	*Commuting Mass Transport*
TRA-5	*Trip Reduction - Mixed Use*

Water

WE 1.1	*Rainwater Harvesting System*
WE 1.2	*Graywater Reuse System*
WE 1.3	*Use of Municipal Recycled Water System*
WE 2.1	*High-Efficiency Irrigation System*
WE 2.2	*Third-Party Inspection*
WE 2.3	*Reduce Overall Irrigation Demand*
WE 3.1	*High-Efficiency Fixtures*
WE 3.2	*Very High-Efficiency Fixtures and Fittings*
WAT 1	*Internal Potable Water Use*
WAT 2	*External Potable Water Use*
LR_H1.3.1	*Conserving Energy and Water: Water Conservation – Water Saving Systems*
LR_H1.3.2	*Conserving Energy and Water: Water Conservation – Rainwater Use*
WAT-1	*Occupant Amenity Water*
WAT-3	*Landscape Irrigation*
WAT-4	*Heat Rejection Water*
WAT-5	*Fire System Water*
WAT-7	*Water Efficient Appliances*
WAT-8	*Swimming Pool/Spa Water Efficiency*
LH 2-1	*Water Efficient Fittings*
LH 2-2	*Water Efficient Landscaping*
WE 1	*Rainwater Harvesting*
WE 2	*Water Recycling*
WE 3	*Water Efficient Landscaping*
WE 4	*Water Efficient Fittings*

Materials & Resources / Ensuring A Long Service Life

MR 1.1	*Framing Order Waste Factor Limit*
MR 1.2	*Detailed Framing Documents*
MR 1.3	*Detailed Cut List and Lumber Order*
MR 1.4	*Framing Efficiencies*
MR 1.5	*Off-Site Fabrication*
MR 2.1	*FSC Certified Tropical Wood*
MR 2.2	*Environmentally Preferable Products*
MR 3.1	*Construction Waste Management Planning*
MR 3.2	*Construction Waste Reduction*
MAT 1	*Environmental Impact of Materials*
MAT 2	*Responsible sourcing of Materials: Basic Building Elements*
MAT 3	*Responsible sourcing of Materials: Finishing Elements*
MAT 4	*Recycling Facilities*