COST-PERFORMANCE ANALYSIS OF PASSIVE DAYLIGHTING IN RESIDENTIAL DWELLINGS TO DEVELOP COST-EFFICIENT FUNCTIONS

Ronaldo Gallardo and Bertrand Teodosio
De La Salle University - Civil Engineering Department

Abstract: This dissertation mainly relates on creating cost – effective design nomographs for a tropical area, Damar Village, Metro Manila as the specific research focus. Specific objectives includes the observation of passive daylighting trends, collection and comparison of data, consideration of the location, orientation size and efficiency; estimation of first cost, operational as well as for the maintenance cost, execute cost benefit and cost performance analysis.

Methodology for the study was divided into three phases: input, process, and output phases. Input phase includes distribution and obtaining of surveys from thirty-eight (38) residential houses derived from sample size calculation. Process phase is the cost-performance analysis, which would cover the area of passive daylighting system, estimate and economics, as well as for the visual comfort for the qualitative factors.

The significance of this study is to promote sustainability, comfortability and practicality of architectural and engineering designs for prompt design encounters creating acceptable basis for actual, efficient and economical passive daylighting systems, and most importantly to promote environmental consciousness to developing countries.

Key Words: Passive Daylighting; Residential Dwellings; Cost-Performance Analysis; Nomographs; Sustainable Design.

1. INTRODUCTION

In the present era, Civil Engineers do not only focus on designing and constructing different components of structures. The operation, maintenance and disposal of buildings are taken into profound consideration due to the necessity of applying sustainable design. Life cycle analysis of structural members tends to be of highest interest for designers and contractors nowadays.

And due to the continuously arising constraint concerning climate change, sustainable design in buildings, especially in residential dwellings, became prominent to produce efficient structures that can possibly use low amount of power effecting into energy conservation. Architectural building designs maximize the effect of passive mode of sustainable architecture analogous to daylighting. However, the cost are higher in comparison with common designs since the materials and specifications for passive sustainable design systems have expensive expenditure and require decisive conditions in planning and construction.

In reference with green design, supplemental tools that are beneficial for architects and civil engineers should accompany the process of planning. These tools should include economical estimates and qualitative assessment to give importance to the limited resources and other qualitative factors of the occupants.

The problems arise on the ability of professionals and structures to be adaptive and competitive. The main emphasis of building design gives emphasis on construction phase, from mobilization until the construction completion. In some cases, the operational and maintenance practicality of designs are disregarded.

In small – scale design and construction, which are mostly residential structures, assessing and evaluating proper vertical and horizontal openings are not widely practiced by professionals due to time constraint. Besides, most architects and engineers follow outdated manuscripts that are somehow not applicable to our present state.

Moreover, the practicality and efficiency of design is questionable since most small – scale constructions are not pragmatically analyzed. The operational and maintenance costs can escalate rapidly due to lack of non – renewable resources and deterioration of the environment leading to climate change.

Due to the problems stated, gathering and analyzing current data to cope up with global demand concerning economic status, ergonomic designs, and climate change might be an essential phase to conduct.

Focusing on passive daylighting is a step to adapt on the growing demand of sustainable and cost – conscious designs. Passive daylighting is a form of sustainable architectural design that carries out placement of openings and reflective surfaces to provide sufficient and efficient indoor lighting. It is a complex science that relates the use of orientation, sun path, bioclimatology, thermal comfort, passive solar thermal dynamics and many more.

In summary, analyzing the life cycle cost - performance of daylighting in residential dwellings of Metro Manila, Philippines will induce the development of design functions that will be supplemental tool for structural, contractors and architectural designers to produce prompt and proficient daylighting designs giving particular attention to the environment, cost and visual comfort intended by the occupants.

The main objective of this study is to create a function that will give aid to architects and engineers in examining the diverse aspect in designing passive daylighting of low – rise residential dwellings with respect to the environment, cost and efficiency of its features. This study fosters in adding more information to the difference in design of tropical zones. Given that most tropical countries adapt specifications for designing different structures from developed temperate nations, this study will aid on researches for sustainability of tropical states.

On a different note, this study upholds in contributing a solution to the aggravation of energy scarcity and the continuing drastic change in temperature that will undoubtedly devastate the ecosystem.

A survey regarding the qualitative effects of passive daylighting systems, such as advantageous and comfort factor, will be given to residential owners for life cycle cost – performance analysis. In line with this, the monthly energy bill spanning at least six months will be collected for the estimation of cost effective – benefit analysis. The construction cost will be computed effectively by referencing a definite point in time, specifically the present worth of the house.

As reference for the efficiency of the passive daylighting system, the space – area investigation would be used and the orientation of windows would be gathered.
Life Cycle Cost – Benefit Analysis, Life Cycle Cost – Performance Analysis and Qualitative Scoring and Analysis will be used for the quantitative cost and qualitative performance features of the systems. Moreover, Microsoft Excel Cost – Benefit Template, and STATICTICA for estimate and performance investigation, correspondingly, will be used for processing and examining the data collected.

The investigation will be limited to the houses surveyed and analyzed by the researcher of this study and for simplification; the floor plan design of architectural plans will be neglected since this factor is very complex to deal with. Only low – rise houses would be surveyed and analyzed, ranging from one – storey (bungalow) to three – storey houses. Refer to Appendix A for the sample nomograph worksheet.

Altitude placement will be neglected since residential dwellings have almost the same elevation or standard height. Special conditions will be indicated in the specifications and disclaimer of nomographs to provide clear distinction in analysis and design of the said passive daylighting systems.

Since the main objective and scope of this study is to determine the cost and performance of the said daylighting systems with respect to lighting capability and possible qualitative effects, heat gain and loss (Heat, Ventilation and Air – Conditioning) will not be a concern in this research.

Shading and obstruction due to external surroundings will not be considered in this research. The houses considered and analyzed will have least or no obstruction at all.

For this study, the collected data are assumed to be accurate, reliable, and consistent with underlying logical and theoretical considerations. Data collected from the survey for home owners are assumed to be unprejudiced and credible for the present analysis of this thesis. The elevations of the houses were assumed to be alike with respect to the mean sea level.

The energy consumption of every family member is assumed to be equal among constituents.

With the use of “PDS Functions”, prompt design encounters with clients can be easily done. Supplemental tool for an actual, efficient, and economical passive daylighting system would be an acceptable basis in design. Even though the nomographs developed will only be supplements for the architectural planning, this will help the designer to consider the essential part of building a residential structure, focusing on the sustainability, comfortability and practicality of the structure.

Furthermore, the data and functions will serve as a great contribution for researches focused on tropical sustainability. Since most of the study adapts temperate and developed countries as standard codes, tropical and developing countries should research and investigate more on the practical and applicable designs rather than adopting rules and standards from other countries. Tropical and temperate locales have so much differences, the climate, design, shading, wind path, sunpath, fungi growth, and comfortability issues in air – conditioning and many more. These differences should be accurately considered to attain effective and efficient design depending on the context.

In summary, this study promotes green designing using passive daylighting system without compromising the essential aspects such as cost and comfortability. Hence, this step to develop “PDS Nomographs” will be a vast mindset revolution for people to conserve energy since most of the populations contribute to the degradation of our environment. Furthermore, this might be the key to ignite competence and environmental consciousness to developing countries like the Philippines that could, in some way, contribute in achieving progression of its nation.

2. METHODOLOGY

Collecting data from residential dwellings through surveys and estimates for qualitative and quantitative factors of this study is the core to determine if a certain daylighting system is performing effectively. For the quantitative parameters, this study will collect data including the life cycle, space, area, material, and cost. The qualitative parameters can be assessed through a survey with subject related to lighting comfort, thermal comfort, and productivity. After gathering the data, functions will be extracted using statistical analysis to develop supplemental tools in designing passive daylighting systems The figure (Figure 1) below graphically explains the theories of this study to develop cost – effective design functions.

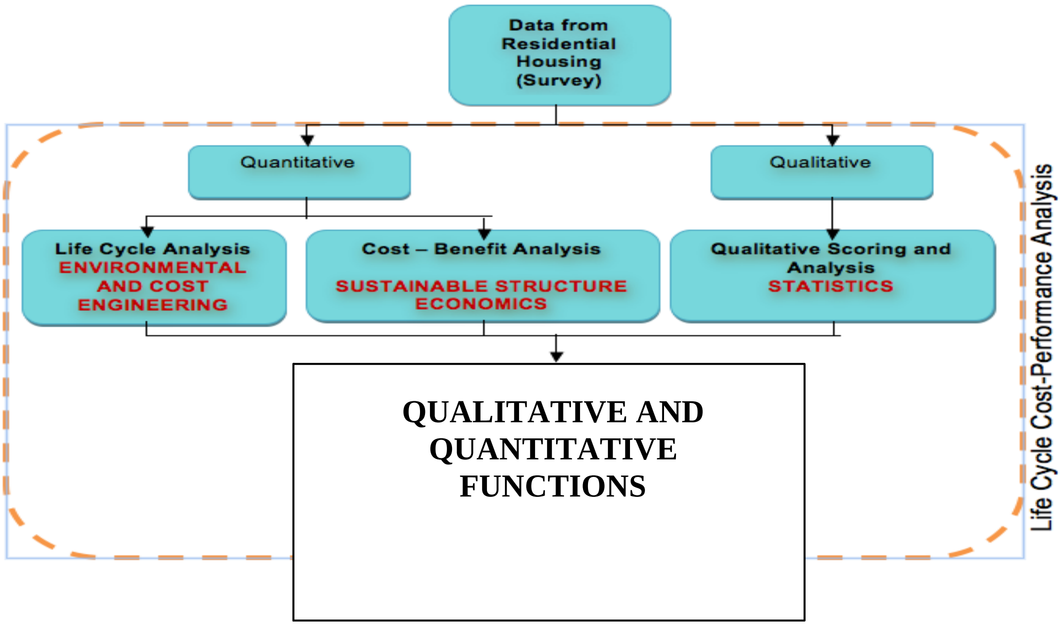


Figure 1. Theoretical Framework of the Study

Sustainable design advocates the use of present natural resources without abusing the environment and compromising the quality of living of the future generations. Thus, Sustainable Engineering and Architecture of the University of Michigan proposed three significant principles in designing a green structure. These three principles defined by the author (Kim, 2006) consist of the Economy of Resources, the Life – Cycle Design (LCD), and the Humane Design of the structure.

The Economy of Resources is concerned with the usability of material or natural resources through reusing, recycling and disposal. On the other hand, Life Cycle Design relates the process of assessing the building procedure and its possible impacts to its surroundings. The Humane Design gives priority to the interaction between the structure and the environment and between the structure and the occupants. Hence, these principles would have the possibility to provide global awareness to the aggravation of the planet. (Figure 2).

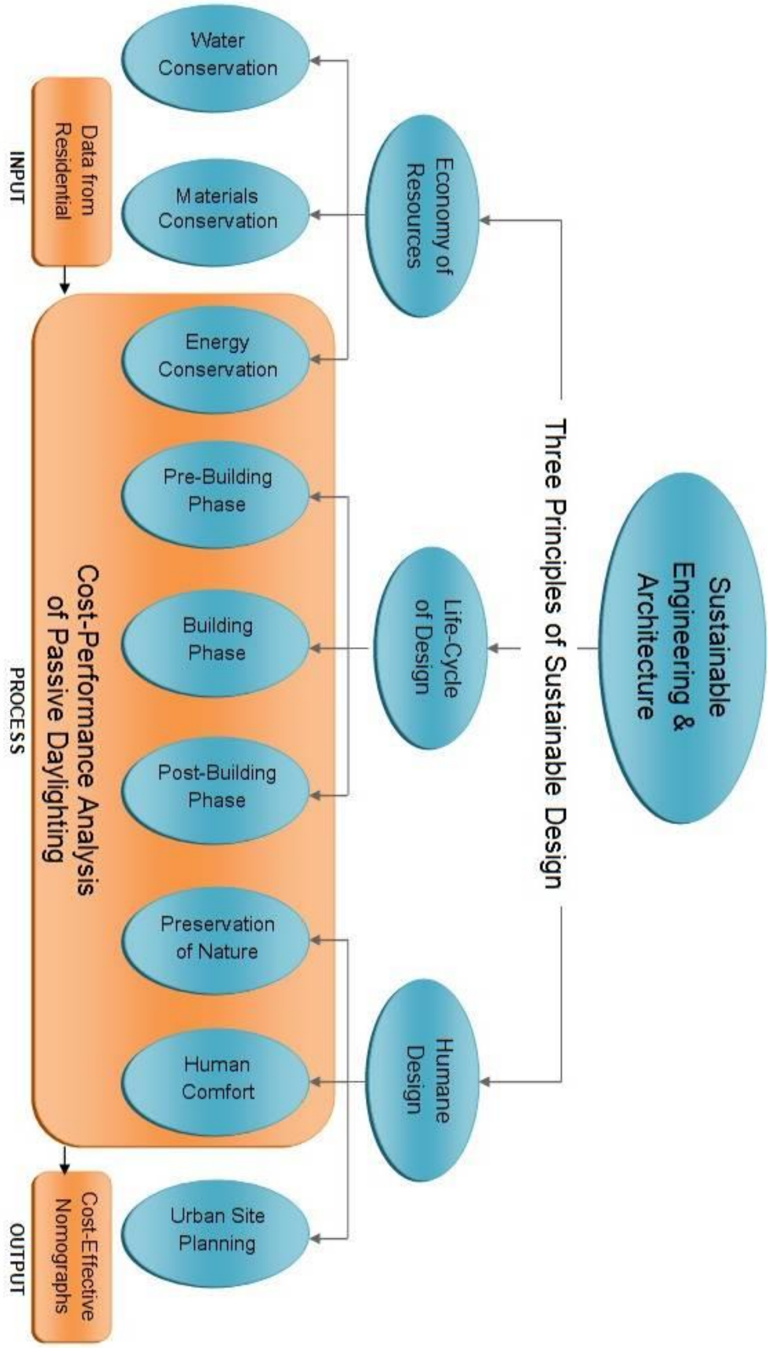
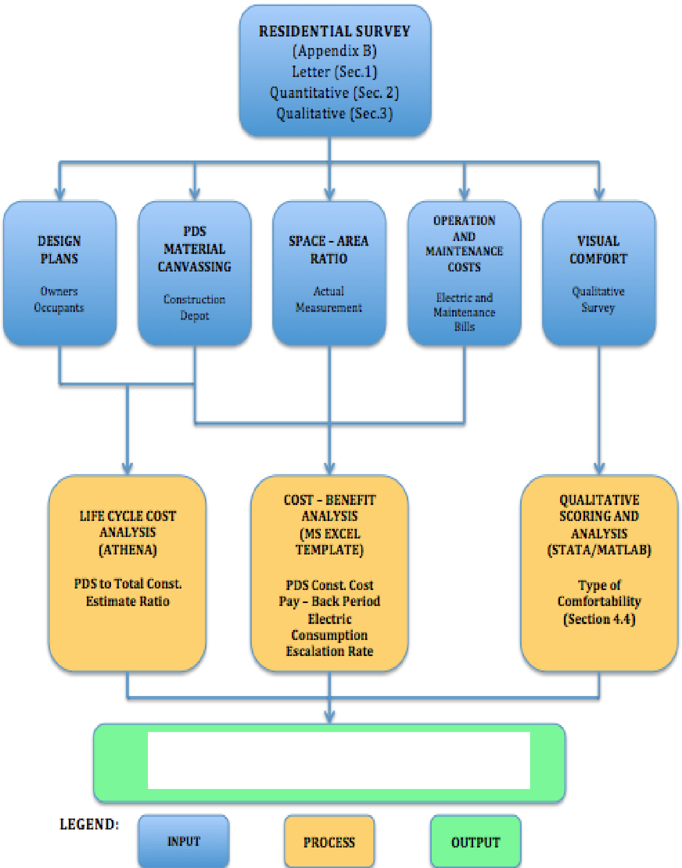


Figure 2. Conceptual Framework of the Study

The research is divided into three phases: input, process, and output. For the input phase, the data collection will require both quantitative and quantitative components of the passive daylighting system for low – rise residential dwellings. The environmental life cycle, space and area, and electric consumption cost will be collected and stratified from residential houses for quantitative analysis while the qualitative factor will include the survey that will assess the lighting and productivity parameters.



FUNCTIONS FOR CONDUCIVE AND COST-EFFICIENT PASSIVE DAYLIGHTING SYSTEM

Figure 3. Research Methodology

For the process phase, the life cycle cost – performance analysis is divided into three components: life cycle analysis for environmental consideration; cost – benefit analysis for economical consideration and qualitative scoring and analysis for qualitative factors.

The following section will discuss the application of life cycle analysis, cost – benefit analysis, Likert – Five Scale Survey, and qualitative scoring and analysis for the methodology of this dissertation. The figure for the Methodology of this Study (Figure 3) will explain further the process of this dissertation.

3. RESULTS AND DISCUSSION

According to the analysis used in this research, a function was deduced to get an efficient passive daylighting area (sq. meters) with independent variables including the total floor area of the house (in sq. meters), total usage of electrical lighting (in hours per day), and desired average lighting bill per month (in Pesos). Equation 1 is the end result of the data collected for the quantitative factor stated above. Table 1 is the summary of significance tests of the cluster of data collected.

PDS = 0.089059406**A** + 0.266969745**B** + 0.000787932**C**

Equation 1

Where, A = Total Floor Area
(m^2) B = Usage (hr/day)
C = Lighting Bill (Pesos)

Table 1. Quantitative Factors Significance Tests (Cost-Benefit Analysis)

Regression Statistics	
Multiple R	0.968793087
R Square	0.938560045
Adjusted R Square	0.844986719
Standard Error	17.5704658
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	56592.51157	18864.17052	61.10421	3.80899E-07
Residual	12	3704.655223	308.7212686		
Total	15	60297.16679			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
A, Total Floor Area (m^2)	0.089059406	0.018241303	4.882294159	0.000377	0.049315022	0.128804	0.049315	0.128804
B, Usage (hr/day)	0.266969745	0.175639486	1.519987051	0.154416	-0.115715821	0.649655	-0.11572	0.649655
C, Lighting Bill (Pesos)	0.000787932	0.003945092	0.199724535	0.84504	-0.007807685	0.009384	-0.00781	0.009384

Below is Equation 2, a combination of the qualitative and quantitative effect of Passive Daylighting System for a residential dwelling. Table 2 is the summary of the significance tests made for the sets of data, for both qualitative and quantitative.

PDS = 0.086632868**A** + 0.161084851**B** + 0.001701715**C** + 1.246743836**D** - 2.286080922**E**

Equation

2 Where, A = Total Floor Area (m^2)
B = Usage (hr/day)
C = Lighting Bill (Pesos)
D = Comfort (Rank 4 to 20, 20 being the highest comfortability)
E = Constraint (Rank 3 to 15, 15 being the lowest comfortability)

Table 2. Quantitative and Qualitative Factors Significance Tests (Cost-Performance Analysis)

Regression Statistics	
Multiple R	0.971925579
R Square	0.944639331
Adjusted R Square	0.822495063
Standard Error	18.27044468
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	56959.08	11391.82	34.12673	1.37E-05
Residual	10	3338.091	333.8091		
Total	15	60297.17			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Total Floor Area (in m^2)	0.086632868	0.033903	2.555325	0.028602	0.011093	0.162173	0.011093	0.162173
Usage (in hours/day)	0.161084851	0.280054	0.575193	0.577873	-0.46291	0.785083	-0.46291	0.785083
Average Light Bill/month	0.001701715	0.004665	0.364764	0.722884	-0.00869	0.012097	-0.00869	0.012097
Comfort	1.246743836	1.490817	0.836282	0.422529	-2.075	4.56849	-2.075	4.56849
Constraint	-2.286080922	2.229713	-1.02528	0.329393	-7.25419	2.68203	-7.25419	2.68203

4. CONCLUSIONS

The equations (Equation 1 and Equation 2) will be a supplement for designers to design passive daylighting systems in a residential dwelling or house. This will serve only as a guide. It is evident that the increase in total floor area, usage, lighting bill, and comfort yearning will lead to a higher area of Passive Daylighting. If the owner can compromise the comfort (too much light, glare, and unbalanced lighting) to lessen the total area of PDS, the constraint rank (from 3 to 15) maybe increased to lessen the cost of PDS.

In summary, there is no ideal PDS Area, lighting is subjective and the authors recommend verification of this complex system including orientation.

5. ACKNOWLEDGEMENT

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