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Energy Efficiency Factors for Existing Toll Plazas

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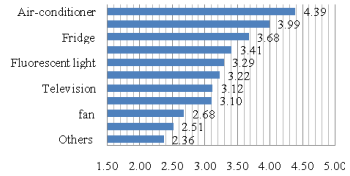
Graphical abstract



Abstract

Energy efficiency is one of the most important issues for green buildings and their sustainability. This is not only due to the environmental impacts, but also because it incurs significantly high energy cost. The aim of this study is to identify the potential actions required for toll plaza that lead to energy reduction. The data were obtained through set of questionnaire and interviewing targeted respondents, including the employees at toll plaza, and architects and engineers who are directly involved in the design of highway projects. The data was analyzed using descriptive statistical analysis method. The findings of this study are the critical elements that influence the energy usage and factors that lead to energy wastage. Finally, potential actions were recommended to reduce energy consumption in toll plazas.

Keywords: Energy efficiency; toll plaza; energy consumption

1.0 INTRODUCTION

United Nations Environment Programme report, states that 30–40% of the world's energy is used in buildings [1]. Thus, all green building and energy efficient design can contribute to reduction in energy used to operate the building. In the same time, huge energy and cost can be saved meanwhile carbon emissions will be reduced [2].

Several studies have been carried out on green material in highway and building construction, in order to improve the environmental performance e.g. noise level, improvement of construction materials [3-11], adding inhibitors to the concrete for the new buildings[12-14], etc. However, only a few reports are available on non-physical aspects of green highways, including management.

Green highways are defined as having a sustainability performance metric for highways that can receive an award points for achieving sustainable practices [15]. Fundamentally, Green highway is a metric to provide safe, energy-efficient roads and minimizing the negative impact on the environment that helps to measure the roadway sustainable attributes.

Energy Efficiency (EE) is the most important issue in green buildings, because of its environmental impacts and due to its significantly higher future energy costs [5, 6]. Using EE products to construct highway facilities such as toll plazas will reduce the energy that required operating and maintaining a toll plaza. This in turn would respond to reduction in the carbon footprint.

Toll plaza is a building where tollhouse and tollbooth are located along highways. It consumes high amount of energy due to the nature of its operation. Toll plazas are always on operation for the whole day (24 hours). Therefore, the design and operation of energy efficient toll plazas contribute to a successful green highway. Based on the above statement, energy efficient toll plazas may become essential in designing green highways.

The aim of this study is to identify the critical elements that influence the energy usage, factors that lead to energy wastage and potential action that respond to energy reduction at toll plaza based on the frequency analysis. The methodology consisted of Primary data collection; literature review was done covering areas of Energy Efficiency. While for secondary data collection, two main methods were used; questionnaire interviews and focus group discussion. All the data from questionnaire survey was key-in using the Statistical Package for the Social Sciences (SPSS) software.

2.0 GREEN BUILDING

The green building is to design, construct and use keeping in mind to increase the environmental performance of the site and the building together [16]. The Office of Federal Environment Executive in United states of America defined green building as "the practice of (1) increasing the efficiency of the buildings and (2) reducing building impacts on human health and the environment" [17].

The advantages of the green and sustainable building are technological, economical and ecological, by enhancing productivity and using the most efficient amount of energy. For example using any renewable or recycled resources [18] like daylight, active solar and photovoltaic technique. The key approaches according to low energy building design are as follow:

i. Organizing the building orientation.
ii. Reducing cooling loads.
iii. Using natural light.
iv. Use more efficient cooling equipment and,
v. Using computerized building control system

■3.0 ENERGY EFFICIENCY (EE)

Definitions, Concepts, and the importance of EE has been discussed by Patterson [19]. Energy efficiency is the most important issue in green buildings, because of its environmental impacts and due to its significantly higher future energy costs[20, 21].

A study conducted by e-Energy in Singapore [22]. EE were calculated with operating hour and occupancy rate. Another study conducted by department of Energy in United states [23] measured EE in the USA commercial buildings. There are some indicators that were established, such as lighting intensity, and space heating intensity.

The most energy consumption activities in the building are the cooling and the heating then comes the electrical usage, for lighting and appliances [24]. To reduce the energy use, several techniques are necessary, such as increased energy efficiency, and energy reduction [25, 26].

3.1 Factors Affecting Energy Usage in the Building

According to Chan (2009), the factors affecting energy use in buildings can be categorised into two groupings [14].

• END USE:
- Lighting
- Air Conditioning and Space Heating
- Power and Process

• FACTORS:
- Climate
- Environmental Standards
- Occupancy and Management
- Mechanical and Electrical Equipment
- Building Design and Construction

■4.0 POTENTIAL RETROFITTING

Building Retrofit is the most appropriate way to improve EE of existing buildings including toll plaza. There are many actions can be taken to implement retrofitting in building e.g. enhancement of the landscape, reduction of appliances, energy saving appliances and energy management. Guillermo, (2011) came out with actions to improve EE in commercial buildings as follow [27]:

- Accurate measurement.
- Doing a proper schedule.
- Doing an individual responsible for energy use in building.
- Pro-active actions to increase EE.
- Modify facilities to be easier management.
- Connect the users and the building manager.

■5.0 CURRENT ENERGY USAGE AT TOLL PLAZA AND CARBON EMISSION

The energy consumption data and monthly electrical cost for every toll plaza were provided by PLUS Expressway. The carbon dioxide emission is acquired from the calculation as a value for scaling emissions. The standard rate of emissions per unit is kWh. Every kWh from the energy consumption at the toll plaza is multiplied by 6.8956×10^{-4} metric tons CO_2 / kWh [18].

Table 1 Energy consumption and the carbon dioxide emission at toll plaza for month of January and February 2012 (source: PLUS Expressway authority)

Toll plaza Name	Energy consumption (KWH)		Dioxide emission metric ton	
	January	February	January	February
Skudai	39613	36533	27.31	25.19
Kempas	25870	27080	17.8	18.67
Tg Kupang	23739	23244	16.37	16
Lima Kedai	23459.5	21914	16.18	15.11

Increase in energy consumption has relation with the increase of carbon dioxide emission. According to Table 1, the carbon emission at Skudai toll plaza was about 27 metric tons in January 2012 and 25 metric ton February 2012. While the carbon emission at Lima Kedai plaza on the other hand is 16 metric tons in January 2012 and 15 metric tons in February 2012. It clearly proves that increase in the size of a building will directly increase the carbon dioxide emission.

■6.0 METHODOLOGY USED IN IDENTIFYING ENERGY EFFICIENCY FACTORS

Based on the literature, varies elements has been classified as EE factors for toll plaza. then the questionnaire is designed in order to obtain information related to the objectives of the study.

A questionnaire was prepared and distributed among (Kempas, Skudai, Senai Utara, Lima Kedai, Perling, Tanjung Kupang, Kulai, and Sedenak) toll plaza that has been selected for this study. 300 respondents were targeted and 239 respondents responded whereby these feedbacks representing 79.6% of the total number. The collected data has been analyzed using Statistical Package for Social Sciences (SPSS).

The questionnaire was divided into two phases. The first phase was conducted on 24-30 April 2012. The targeted group were the employees at toll plaza that are being coordinated by the PLUS Expressway officer. Whilst, the second phase of the survey was conducted on 1-16 May via email, the target group was the professionals such as architects and engineers whom may involved directly in highway projects. the main purpose of analyze is to know the causes that lead to energy wastage and indentify the potential steps to reduce energy consumption at the toll plaza. The survey used Likert's scale of five ordinal measures to know the causes leading to energy wastage, and to indentify the steps to reduce energy consumption at the toll plaza. The second survey focused on the professionals group such as engineers and architect that are involved directly or indirect in toll plaza management. The participant perspective on the actions and steps to retrofit the existed toll plaza is being considered.

7.0 RESULTS AND DISCUSSION

7.1 The Critical Elements that Influence the Energy Usage in Toll Plaza

From the results shown in Figure 1, the findings revealed the top three critical elements that influence the energy usage in toll plaza.

The first critical element that influences the energy usage in toll plaza is Air-conditioner. The reason behind that is the toll plaza operates for 24 hours so the amount of energy consumption is very high especially for Air-conditioner, which is running for 24 hours. The literature review also confirmed that the most critical element that influences the energy usage in building is Air-conditioner.

The second top critical element that influences the energy usage in toll plaza is the Computer. Most of the respondents (72.4%) agreed that Computer is a critical element that influences the energy usage in a toll plaza.

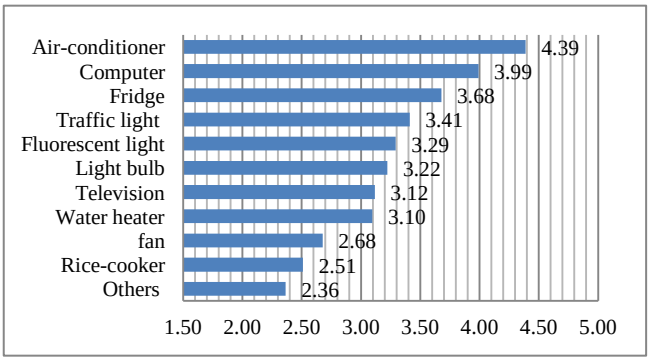


Figure 1 Critical elements that influence the energy usage in toll plaza

The third top critical element that influence the energy usage in toll plaza was Fridge with average index of 3.68. Most of the respondents (60.7%) agreed that fridge is a critical element influencing the energy usage in toll plaza.

While the two low critical elements that influence the energy usage in toll plaza are Rice-cooker and other equipment (other equipment such as toll fare indicator). Figure 3 also indicates that the respondents believe that other equipment does not influence the energy usage in toll plaza.

7.2 Determination of the Factors LeadingTowards Energy Wastage in Toll Plaza

According to the literature review, the factors affecting energy usage are crucial for any building in order to attain efficiency level of the building. The factors leading towards energy wastage in toll plaza are presented in two parts which are, Toll houses and Toll booths.

7.2.1 Factors Leading Towards Energy Wastage in Toll House

Figure 2 shows the factors that lead to energy wastage in a toll house. 14 different factors were identified. The air conditioner is the highest factor which has the highest average index of 4. While the fan operating without any user had lowest average index of 2.8.

The respondents believed that the top factor that leads to energy wastage in tollhouse is the air conditioner that operates for 24 hours with the average index of 4.01, Most of the respondents (68.6%) agreed with that statement.

The second factor that leads to energy wastage in tollhouse was, the air conditioner which served only few users. With average index of 3.57, the respondents (54%) agreed with the statement and they thought it is a significant factor that leads to energy wastage in a tollhouse.

The third factor that influence energy wastage in tollhouse is the lighting system that operates for 24 hours, with an average index of 3.53. The respondents (50.6%) agreed with the statement and they thought it is a significant factor that leads to energy wastage in a tollhouse.

The fourth factor that influenced energy wastage in tollhouse is, “the project was not design to meet minimum levels of energy efficiency”. With an average index of 3.50, The respondents (43.5%) agreed with the statement and they think that the design of the building does not consider energy efficiency.

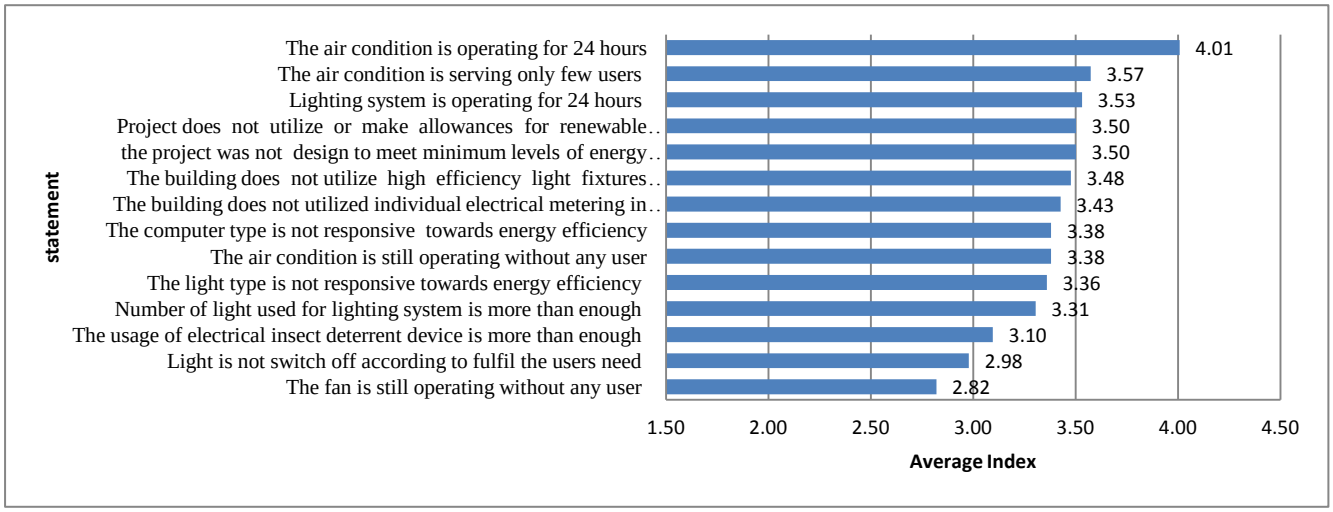


Figure 2 Factors toward energy wastage in toll house

7.2.2 Factors Leading Towards Energy Wastage in Toll Booth

Figure 3 shows the respondents' opinions about the factors that leads to energy wastage in toll booth. 12 factors were identified; the highest factor, which has the highest average index of 3.81 was the air conditioner operating for 24 hours. This was slightly above the acceptable index, however, it indicates a potential future for any new tollbooth system.

On the other hand, "the Lights were not switched off to fulfill the users need", had the lowest average index of 2.95. This is probably due to the security aspect. Respondent believed that the top factor that affect energy wastage in toll booth is "the air conditioner is operating for 24 hours". With an average index of 3.81, Most of the respondents (60.6%) agreed and strongly agreed with that statement. This is also in line with the literature review.

The second factor that had an effect on energy wastage in toll booth is "the project was not designed to meet minimum levels of energy efficiency". With average index of 3.63, The respondents (56.1%) agreed and strongly agreed with that statement and they thought it is a significant factor that leads to energy wastage in toll houses. From an interview with the users, they believed that in order to achieve energy efficiency in toll plaza we have to use the electronic toll system.

The third factor that had an effect on energy wastage in tollbooth was "The air condition is serving only few users". with an average index of 3.57. The respondents (59%) agreed and strongly agreed with the statement and they think it is a significant factor that effect the energy wastage in toll house.

The fourth factor that affect the energy wastage in toll booth is "The building does not utilized individual electrical metering in multifamily units to reduce electricity consumption" with an average index of 3.54. The respondents (41.9%) agreed and strongly agreed with the statement and they think it is a significant factor that affect the energy wastage in toll house.

7.3 Potential Action to Reduce Energy Consumption in Toll Plaza

All the data are presented in two parts for tollhouses and tollbooths in order to determine the potential action to reduce energy consumption.

7.3.1 Potential Action to Reduce Energy Consumption in Toll House

In this section, the significant actions to reduce energy consumption in an existing Tollhouse were identified. Figure 4 shows the results obtained from the questionnaire survey.

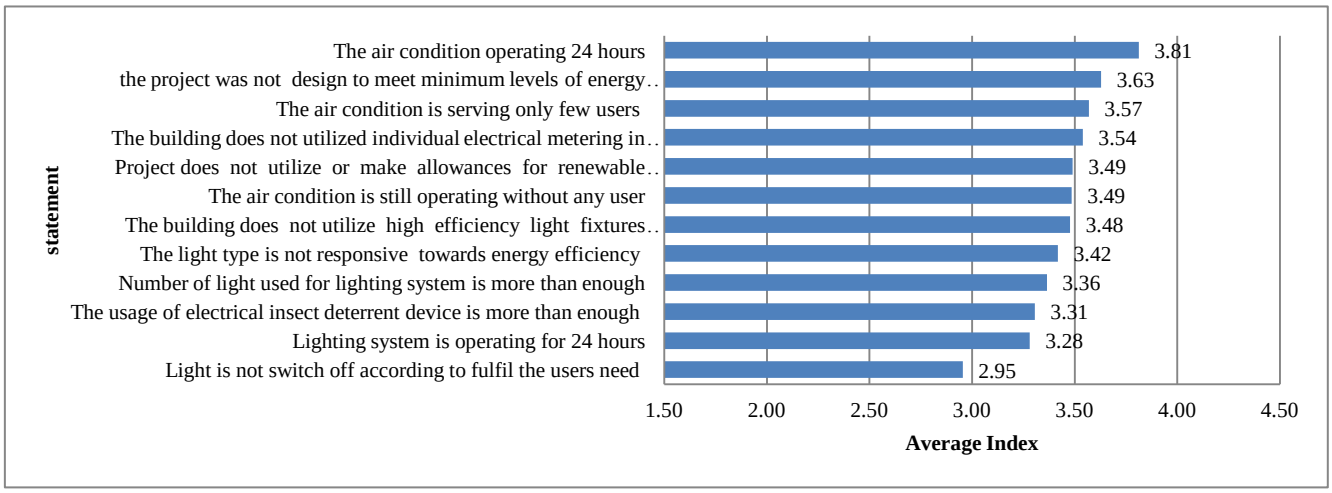


Figure 3 The factors toward energy wastage in toll booth

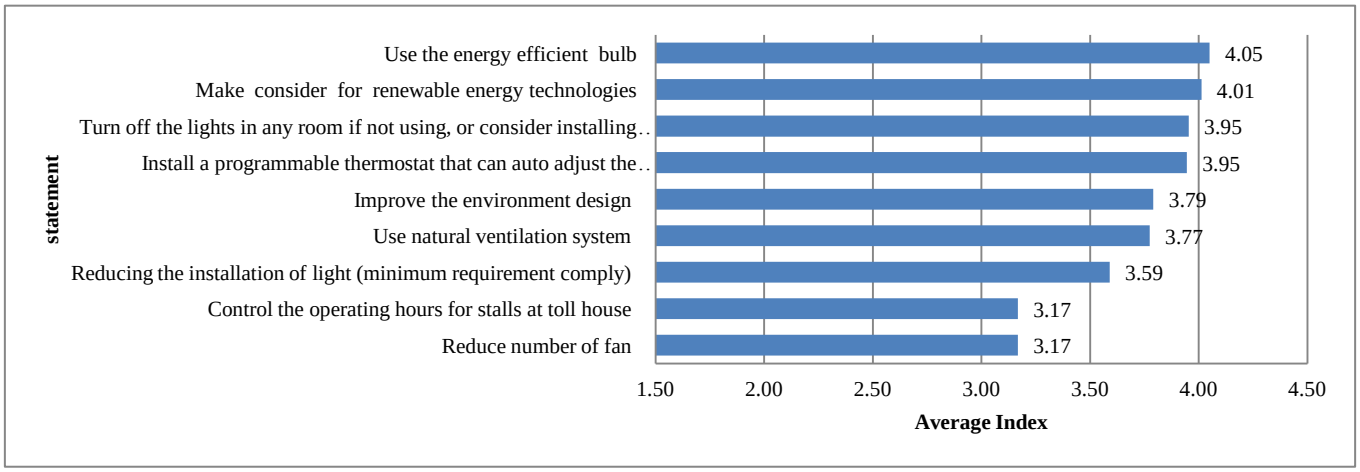


Figure 4 Potential action to reduce energy consumption in toll hous

Figure 4 indicates the potential and significant steps to reduce energy consumption in a toll house. The first significant step which, has the highest of average index of 4.05 was "to use the energy efficient lighting". The respondents (74.5%) agreed and strongly agreed with the statement.

The second step which has the average index of 4.01 to reduce energy consumption in toll house was "considering renewable energy technologies" with respondents (73.6%) agreed and strongly agreed with the statement. Renewable energy has almost no negative impact on the environment. Green Building Index for Non-Residential Existing Building (NREB) in the item of Innovation, there are uses of renewable energy technologies and Promotion of innovative and environmental initiatives.

The third step to reduce energy consumption in tollhouse was "turned off the lights in any room if not in use, consider installing timers photo cells, or occupancy sensors". Therefore, with an average index of 3.57. The respondents (72%) agreed and strongly agreed with the statement.

7.3.2 Potential Action to Reduce Energy Consumption in Toll Booth

In this section, the significant action required to reduce energy consumption in an existing toll booth were identified. Figure 5 shows the results obtained from the questionnaire survey.

Figure 5, indicates the potential and significant steps to reduce energy consumption in a toll booth. The first significant step which has the highest of average index of 4 was "consider renewable energy technologies".

The second step with average index of 3.9 was "use the energy efficient bulb". The respondents (70.7%) agreed and strongly agreed with the statement.

The third step to reduce energy consumption in tollhouse was "improve the building design". The average index of 3.96 and respondents 67.8% agreed and strongly agreed with the statement.

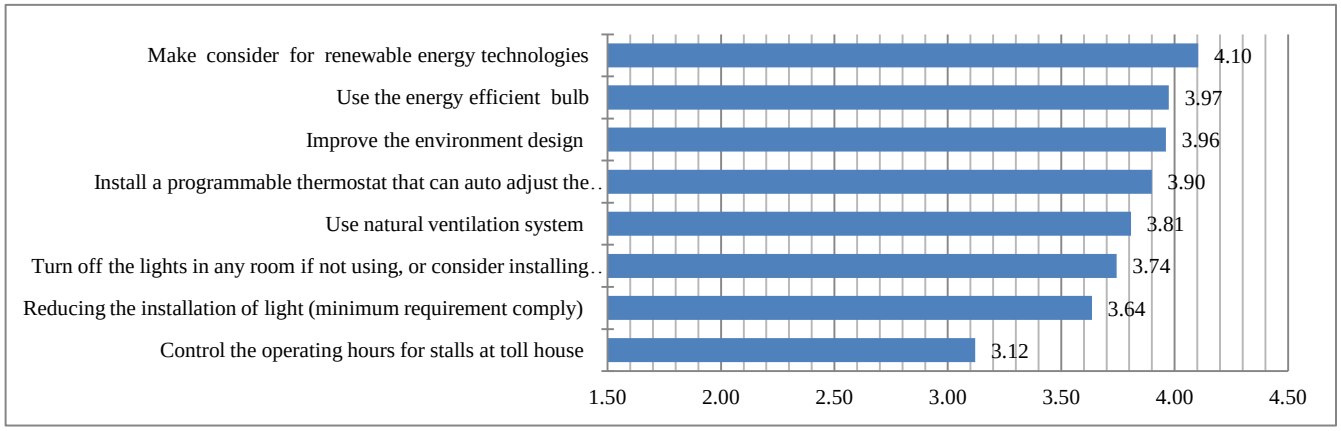


Figure 5 Potential action to reduce energy consumption in toll booth

8.0 CONCLUSION

From the study, the critical elements that influenced energy usage in existing toll plaza were identified through the highest average index. Air-conditioner had the highest agreement level with a percentage of 86.2, which confirmed that it is the single most significant critical element that influences energy usage in a toll plaza.

It was found that the average index values of some of the factors toward energy wastage in toll plaza exceed 3.5, which means that it is significant and consider it as an acceptable results for this study. The air conditioner operating for 24 hours continuously, has the highest agreement level for strongly agree and agree with a 68.6 %, which confirm that it is the most significant with the average index of 4.

Consequently, the potential actions to reduce energy consumption for toll plaza were identified through the highest average index. The use of the energy efficient bulb and "to make consideration for renewable energy technologies" have highest agreement level of agree and strong agree, which confirm that it is the most significant potential action to reduce energy consumption for toll plaza.

This study will support the existing toll plaza to be more efficient in order to reduce energy consumption as well as the carbon dioxide emission in the atmosphere.

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