Feasibility study on potential of pedestrians’ footstep based energy harvesting (case study: UiTM Pulau Pinang)

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Abstract. The rapid growth of population cause to increase demand of electricity supply. The increasing growth in population is an alternative solution to this concern, in which, human’s activity can contribute to generate electricity through energy-based released activities such as walking. Walking is an example of human activities that may do every day. When a person walks, the energy may lose to the surface in form of impact and vibration. This energy will be tapped and will convert to electrical energy. Therefore, the feasibility study on potential pedestrians’ footstep-based energy harvesting can be analyzed. UiTM Pulau Pinang has been selected as a case study because by doing in UiTM Pulau Pinang it can be seen clearly the percentage of successful of the study. Sidewalk in UiTM Pulau Pinang has the potential to be a basic medium for the study. Primary data was collected through site observation and measurement site. Meanwhile, the secondary data was by distributing questionnaire to the community in UiTM Pulau Pinang. From the questionnaire collected, the frequency of using sidewalk for each zone can be obtained. Distribution according to zones have been created to simplify the process of collecting data. After data from both methods used is obtained, the potential of footsteps-based energy harvesting can be analyzed.

1.Introduction
The world faces a phenomenon where the reduction of energy resources happens [1]. Based on data from Department of Statistics Malaysia, by 2035 Malaysia’s projection of population growth will increase about 39,575,864. Therefore, the demand for electrical sources also expected to increase. The saver usage of electrical energy must practice starting from now. With the growing number of populations, people themselves can be the best source to generate electricity through generated energy from human’s footsteps. By using human’s footsteps, it can save cost and time to generate electric sources.
Problems increased consumption in electricity tariffs rates more difficult to control. This happens because the attitude of arbitrary wastage without thinking of the consequences in the future. The rate of population increase contributes to the increasing demand of electrical products. Each type of electrical items requires different electricity rates.
For convenient movement of traffic, providing pedestrian sidewalks is important. Therefore, a pedestrian sidewalk was introduced in order to facilitate the movement of people from one destination to another safely and comfortably. The purpose of build pedestrian sidewalks is also to solve traffic congestion problems that occur from the increases in the number of vehicles on the road every day. It also can solve the problem faced by pedestrians while moving. Pedestrian sidewalks are one example of sustainable transportation systems.
A pedestrian sidewalk is a path network that is very important in a campus. This is because it connects between locations to another location within the campus. The main users are students who utilizes walking as the most effective method of mobility. A good design of pedestrian sidewalks can contribute to the increases of safety for the students. By having a good and safer pedestrian sidewalk, it can improve the safety of users and also promote good health. Therefore, to ensure sustainable development in the campus one step solution has been chosen which is by encouraging the campus community to reduce use motor vehicles when dealing in campus area which is by use cycling and walking facilities as the main medium. By using cycling and walking it is found that it is also a kind of sustainable transportation. The use of non-motorized vehicles can reduce emissions into the air thus reducing air pollution. The use of non-motorized vehicles will also free up UiTM Pulau Pinang from any pollution emissions due to severe smoke emissions from vehicles used in the campus. The concept of greening the campus is one way to preserve the sustainable development in the campus by reducing the use of motor vehicles. To ensure this concept is achieved, cultivate the practice of walking mode should be adopted so that the rate of pollution in the campus can be reduced.

2. Literature Review

2.1. Source of Electrical Generation

There are two different types of resources for generating electrical energy that is renewable energy and non-renewable energy. There are the most popular and potential resources.

2.1.1. Non-renewable Energy

An energy is created from natural resources and the resources are unable to be regenerated in a short period. This type of energy is complex to regenerate and concentrate as minerals especially in lithosphere of earth with a number of forms. Coal is a main of non-renewable energy source. It was formed from the remains of the trees and ferns grew in swamps around 500 million year ago. Due to progressive decomposition by heat and pressure, the cellulose lost moisture H₂ and O₂ and got converted into coal.

Besides that, nuclear was also one of the non-renewable sources of energy. A small amount of radioactive substance (U235) can produce a lot of energy through the process of nuclear fission. In order to obtain nuclear energy, nuclear reactors are required. The nuclear energy can be used in production of electrical energy, as a fuel for marine vessel and space crafts and for the generation of heat in chemical processing plants [2].

Like plants that burn coal, oil and natural gas, produce electricity by boiling water into steam. This steam then turns turbines to produce electricity. The difference is that nuclear plants do not burn anything. Instead, they use uranium fuel, consisting of solid ceramic pellets, to produce electricity through a process called fission.

Hydroelectric also non-renewable energy that can be transmitted to long distance trough cables and wires. The process to generate electricity from the hydroelectric power plant is the water comes from a natural source that flows through a man-made dam. Next, the water passes through a tunnel, causing the turbines to spin. The turbines connect to a generator that turns the water energy into electricity. Lastly, the electricity passes through transformers and transmission lines to places that need the electricity.

2.1.2. Renewable Energy

Renewable energy, often referred to as clean energy, comes from natural sources or processes that are constantly replenished. The energy is recreated and regenerate from natural resources with involvement of some ecological process on a time scale. However, the energy able to convert become non-renewable if the usage is greater rate than the environment’s capacity to replenish them. The movement of air takes place due to the convection current set out in the atmosphere which is again due to heating of earth’s surface by solar radiation, rotation of earth and others. The air directions occur in both horizontally and vertically.

Since wind has a tremendous amount of energy, its energy can be converted into mechanical or electrical energy using suitable devices. Water pump is an example of converting wind energy into electrical
energy. Other than that, solar energy, a primary energy source, is non-polluting and inexhaustible. Solar energy is non-ending and its conversion to some other energy form is non-polluting, attention should be paid for the maximum utilization of solar energy. One of the methods to harness solar energy is converting solar energy directly into electrical energy in solar power stations using photo cells or photovoltaic cells or silicon solar cell.

2.2. Sustainable Energy from Footsteps
Renewable energy sources such as solar power, wind power and hydropower need a high cost of investment. So, to overcome these problems, many efforts have been taken to make the sources of energy is renewable and environmentally friendly [3]. Walking is most common activities that always do every day and can produce energy. Every time when someone steps on one of tiles, the kinetic energy from their footstep is converted into renewable electricity. This electricity can be used to power lighting, advertising displays, communications networks or it can be stored in a battery for later use. Majority of university students prefer used walking for them to go to the location. Through this method, the footsteps of sustainable energy can be implemented. By using weight energy, it can gain the electrical energy. It is a simple concept; a person just needs to walk on the floor with normal speed and can know how much energy was produced by one person. By using this concept, the energy produced is environmentally friendly. It also can be effective ways to save money because by walking, there no need any fuel or any energy sources. It just used a simple way by footsteps [4].

2.3 Benefits of Walking
Walking is an activity that is done by all human beings. Through this method, it can provide a variety of positive effects on the body and reduce the negative impact to the environment. For example, it can reduce air pollution and also can produce sustainable energy from footsteps. The university is one of the locations where most of the residents using walking as a mode to perform any activity. Therefore, the university can be used as a yardstick to see how effectively to conduct a study on the feasibility study footstep based on potential of energy harvesting for lights pedestrians.

2.4 Method of Footsteps Power Generations
Daily activities such as walking by humans can produce a lot of energy. On average, humans walked about 3,000 – 5,000 dailies. According to [5], the process of acquiring the energy surrounding a system and converting it into usable electrical energy is termed power harvesting. Using the movement of the foot, it is also possible to change from kinetic energy into electrical energy. There are two method of power generation include footstep electric converter device and footsteps electricity generation using Pavegen. The first method when placed in the area of pedestrian sidewalks, it has the potential to convert kinetic energy into electrical form. The downward movement of the plate results in rotation of the shaft of an electrical alternator fitted in the device, to produce electrical energy. The electricity generated from these devices can be used for streetlights. But efficiency of the device to function properly is limited. Table 1 showed the duration of lighting, the bulb for number of footstep and corresponding energy stored by device that was operated by person walking over to it.
Table 1. Energy Storage by Foot Steps [6]

| No of Foot Steps | Duration of Lighting a 100watt 230volt bulb (s) | Total energy (J) | Energy / Steps (J) |
|------------------|-----------------------------------------------|------------------|-------------------|
| 250              | 6                                             | 600              | 2.4               |
| 500              | 12                                            | 1200             | 2.4               |
| 750              | 18                                            | 1800             | 2.4               |
| 1000             | 25                                            | 2500             | 2.5               |

Method of footsteps electricity generation using Pavegen in the slabs change kinetic energy from the people stepping on them and instantly deliver tiny bursts of electricity to nearby appliances. Moreover, it also can store energy for up to three days in an on-board battery, according to its founder. But by using this method, it has its limitation due to cost of installation and complex designing process. It designed for use in high foot-traffic areas, the tiles convert the kinetic energy from footsteps of pedestrians into renewable electricity, which can be stored in a lithium polymer battery or used to power low-wattage, off-grid applications like street lighting, displays, speakers, alarms, signs, and advertising.

Each time someone steps on the tile, a central light illuminate, "connecting" the person to the part they play in producing the 2.1 watts of electricity per hour the tiles can generate and providing self-sufficient lighting for pedestrian crossings. By walking, the human energy will lose to the road surface such as by impact, vibration, sound and others. This happened due to energy transfer from weight of the body to the road surface. By using weight energy, it can gain the electrical energy. It is a simple concept; a person just needs to walk on the floor with normal speed and can know how much energy was produced by one person. The illustration of this process is shown in Figure 1.

![Figure 1. Schematic representation of the working mode [7]](image)

2.5 Manufacturers of Energy Harvesting Devices

Manufacturers of energy harvesting devices include Pavegen and piezoelectric technology. Pavegen System is a technology company who create a paving slab that can produce electrical power from people’s footsteps. It is a typical tile that made from recycled polymer and the top surface made from...
recycled truck tires. When a pressure from footfall imposed to the floor about 5 mm (0.2 in) the power will generate. It also can generate up 7 watts at 12 volts DC that sufficient to work on an LED street light about 30 seconds.

The changes from mechanical strain into electrical voltage are called piezoelectric effect. Human motion, low-frequency seismic vibration and acoustic noise are a few example sources of strain. From walking the mechanical energy can be harvest from piezoelectric effect that is practicable [8]. Figure 2 shows metal disk with piezoelectric disk attached, used in a buzzer.

![Figure 2. metal disk with piezoelectric disk attached, used in a buzzer](image)

2.6 Working Principle
The weight of the moving vehicles or from the weight of the people walking over the piezoelectric material is example of sources of pressure. The piezoelectric material output is not a steady one so a model named bridge circuit may be used to convert the variable voltage into linear one. An AC ripple filter is used to filter out any further fluctuations in the output. The output dc voltage is the stored in a rechargeable battery. By using the Peltier sensor at load, the heat will produce the energy.

2.7 Potential Locations for Large Scale Generation of Electric Power.
To implement the different piezoelectric generators at different places, it is not possible as long as there is a frequent application of the pressure. For example, location that has high frequency of vehicular movement takes places and the places where large group of people hang around. Roads, shopping malls, footpath, railroad tracks and highways are the most common places for these conditions. Location for large scale includes roads and highways, and railroad track. Traffic conditions on roads and highways are different throughout the day where traffic in the morning is busier than in the night and sometimes 24 hours a day. The railroad track is one of example for generation of huge energy because the huge amount of pressure is exerted by trains on the railroad tracks. The pads of piezoelectric materials are placed at juncture where wheel makes the contact with tracks and it receives maximum pressure like used in airport runways, the pads are arranged in such order that a large force is tolerated and greater amount of charge is stored.

2.8 Sidewalk
In the context of traffic, sidewalk meaning is very broad. It is closely related and has a line meeting between the environment, human activities and movements. Therefore, the sidewalk can be defined as the route / road / space / footway / special lane paved designed / made for the use of pedestrians. Sidewalks are a one of the sustainable transportation systems. By walking, it can be a viable mode choice and also produce a healthy physical activity [9].
3. Methodology

The following flowchart shows the research methodology conducted.

![Flowchart of research methodology](image)

**Figure 3.** Flow chart of research methodology

4. Result and Discussion

4.1. Data Analysis for Site Observation

Each zone has a different condition of sidewalk as shown in Figure 4. The condition of sidewalk in Zone 1 start from “Dewan Besar” UiTM Pulau Pinang until in front of “BKBA” is less safe. The sidewalk is near to drainage and the drainage does not have cover. This can be harmful to the pedestrians as they most likely will fall down into the drain due to the level of facilities in the area are unsatisfied. Furthermore, in Zone 2 start from hostel Baiduri until “Unit Kesihatan”, it can be seen that the surface of sidewalk is not suitable for users because it has hole at a certain location. It may dangerous to pedestrians while they used the sidewalk during night. Zone 3 starting from “Laman Perdana” until “Dewan Besar” also has drainage next to the sidewalk and does not have cover, similar to Zone 1. And
last but not least, at Zone 4 along “Zamrud” sports court in front of “Laman Perdana” until hostel Zamrud, so far shows a satisfied level of quality.

![Image](image1)

![Image](image2)

**Figure 4.** Zone 1, Zone 2 (left to right at top level) and Zone 3, Zone 4 (From left to right at bottom level)

4.2. *Data Analysis for Site Measurement*

The dimensions of sidewalk at each zone are measured as to evaluate the optimum potential of footsteps of pedestrian. From Table 2, it shows that Zone 3 has the longest length of sidewalk about 872.05 feet. Meanwhile, Zone 4 has the shortest length, 255.58 feet. The material of all sidewalk is using interlocking block.

| Zone | Length (feet, ft) | Width (feet, ft) |
|------|-------------------|-----------------|
| 1    | 851.05            | 5.00            |
| 2    | 483.27            | 5.00            |
| 3    | 872.05            | 5.00            |
| 4    | 255.58            | 5.00            |

**Table 2.** Dimension of Sidewalk
4.3 Data Analysis for questionnaire

The questionnaire survey was analysed by converting the frequency of pedestrian’s using the sidewalk in a day to energy harvesting. The number of respondents involved is one hundred (100) persons. Based on the questionnaire results, it shows the frequency usage of the sidewalk for each zone. As stated in Table 3, Zone 4 that located along “Zamrud” sports court in front of “Laman Perdana” until hostel (Zamrud) shows the higher frequency pedestrians use the sidewalk. This is because, the zone is the route for students to return to the hostel and also as a route for lecturers who park the car in the nearby parking area while they are working. During the peak hour, most of the student used this area of sidewalk as the route to go back to the hostel and also to the cafeteria. And it showed the high potential to change from the footstep-based energy harvesting.

Table 3. Frequency of pedestrian used sidewalk based on questionnaire from “Pedestrian’s Perception toward Quality of Sidewalk Facilities Case Study: UiTM Pulau Pinang”

| Zone | Time         | Total Number of Pedestrian |
|------|--------------|-----------------------------|
|      | 7.00am – 10.00am |                           |
| 1    | 22           | 78                          |
| 2    | 3            | 16                          |
| 3    | 7            | 38                          |
| 4    | 13           | 85                          |
|      | 10.00am – 1.00pm |                        |
| 1    | 27           | 78                          |
| 2    | 6            | 16                          |
| 3    | 15           | 38                          |
| 4    | 33           | 85                          |
|      | 1.00pm – 4.00pm |                        |
| 1    | 15           | 5                           |
| 2    | 2            | 1                           |
| 3    | 6            | 10                          |
| 4    | 14           | 5                           |
|      | 4.00pm – 7.00pm |                 |
| 1    | 9            | 5                           |
| 2    | 4            | 1                           |
| 3    | 10           | -                           |
| 4    | 20           | 5                           |
|      | 7.00pm – 10.00pm |              |
| 1    | 5            | 5                           |
| 2    | 1            | 1                           |
| 3    | -            | 3                           |
| 4    | 5            | 85                          |

4.4 Frequency of Footstep at Each Zone

Based on the research made by [6], the power can be generated by the footstep generator and can be stored in an energy storing device. The number of footsteps will influence time for the lights on. It is as follows:

\[250 \text{ steps} = 6 \text{ second (s)} \text{ of duration to lighting a 100-watt bulb}\]

Hence, for every 1 second, the numbers of footsteps required are:

\[(250 \text{ steps}) / (6 \text{ seconds}) \times 1\text{seconds} = 41.66 \text{ steps} \approx 42 \text{ steps}\]

Therefore, every 1 second, 42 steps are required. According to the frequency of pedestrian in Zone 1, 2, 3 & 4, the minimum duration of lighting for each zone can be evaluated based on 1 second = 42 steps.

However, by assuming:

Every 2 feet of interlocking block sidewalk = 1 steps
(1 steps)/(2 feet ) = 0.5 steps/ feet as factor
Table 4. Number of Footsteps Calculated

| Zone | Total frequency of Pedestrian used Sidewalk | Length of Sidewalk (feet, ft) | Total Number of Footsteps (Steps) |
|------|--------------------------------------------|--------------------------------|----------------------------------|
| 1    | 78                                         | 851.05                        | 33191                           |
| 2    | 16                                         | 483.27                        | 3866                            |
| 3    | 38                                         | 872.05                        | 16569                           |
| 4    | 85                                         | 255.58                        | 10862                           |

Table 5. Duration of Lighting a 100-Watt Bulb Based on Number of Footsteps

| Zone | Number of Steps (steps) | Duration of Lighting a 100-watt Bulb (seconds) |
|------|-------------------------|-----------------------------------------------|
| 1    | 33191                   | 790                                           |
| 2    | 3866                    | 92                                            |
| 3    | 16569                   | 395                                           |
| 4    | 10862                   | 259                                           |

Table 5 showed the duration of lighting a 100-watt bulb in Zone 1 is higher than in Zone 2, 3 and 4 with a total of 790 seconds readings. While a low reading is in Zone 2 is 92 seconds. The duration of lighting a 100-watt bulb may be different according to the number of footsteps.

The duration of lighting a 100-watt bulb is influenced by the number of footsteps obtained from the result of total frequency of pedestrians and the length of the sidewalk. The higher number of frequencies of pedestrian and the higher length of sidewalk will produce a high number of footsteps for each zone. According to [6], the number of footsteps will able to light a 100 watt bulb. To check whether the duration of bulb to light up, it takes a minimum number of footsteps that is 250 numbers of footsteps to assess the time required by the 100-watt bulb to light up in 6 seconds.

5. Conclusion
Walking is an activity that will take place in everyday routine. Whether the destinations far or near, walking is preferable as it is convenient to traffic. Thus, providing safe and standardize pedestrian sidewalks is important.

According to the frequency of pedestrians using sidewalk, it can be concluded that, Zone 1 and Zone 4 that are more been used by the community within UiTM Pulau Pinang, compared to other zones. Hence, the prediction total duration of lighting a 100-watt bulb is 790 s and 259 s respectively.

Based on the findings, it shows that there is a high potential of harvest energy from footsteps, but the quality of the sidewalks shall be improved beforehand. It is also recommended to evaluate the potential at high volume of people such as station hub, airport, shopping complex and hospitals.

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