Article


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Abstract: In Malaysia, the Stormwater Management Manual for Malaysia (Manual Saliran Mesra Alam or MSMA) was introduced to manage stormwater and solve water-related problems. However, massive development caused the conventional stormwater system to be unable to cater to the excessive runoff and led to flooding, also affecting residential areas. This shows that there is an urgent requirement for a sustainable stormwater management practice (SSMP) in residential areas. This study is conducted to evaluate stormwater practitioners’ opinions on the proposed SSMPs, including green roofs, rain gardens/bioretention systems, and porous pavements, based on Strength, Weakness, Opportunity, and Threat (SWOT) factors through surveys and correlation analysis. The questionnaire was distributed to 14 branches of the Department of Irrigation and Drainage (DID), 14 branches of the City Council, and 28 selected private engineering companies. In total, 118 respondents were targeted to obtain their perspectives on the SWOT factors for each selected SSMP according to the Likert scale. The survey showed that the respondents agreed with most of the SWOT factors on the selected SSMPs. The results of the distributed questionnaire were used as the data for the correlation analysis. The analysis indicated that green roofs, rain gardens/bioretention systems, and porous pavements have a strong positive relationship, with a p-value of less than 0.05 for the Strength and Opportunity factors, and a weak positive relationship, with a p-value of more than 0.05 for the Weakness and Threat factors. This shows that the proposed SSMPs are suitable to implement in residential areas. Observations were conducted to obtain the residents’ opinions on the performance of stormwater management in their residential areas and to evaluate the suitability of the proposed SSMPs to be implemented in the observed areas. Based on the observations, it can be concluded that only rain gardens/bioretention systems and porous pavements are suitable when compared to green roofs. An interview session was conducted with practitioners in stormwater management to gain their opinions on the studies and the proposed SSMPs. The interviewees agreed with the issues and that the SSMPs should be implemented in landed residential areas.

Keywords: stormwater management system; residential areas; sustainability; water quantity control; water quality control

1. Introduction

Massive development since the Industrial Revolution (IR) has progressed rapidly in many countries [1,2]. Even though the IR showed an impressive achievement in terms of economy and poverty alleviation, it also contributed some negative outcomes, especially to the environment. As cities developed, roads, buildings, housing developments, parking
lots, and other concrete structures replaced the natural landscapes or pervious surfaces with impervious surfaces, which eventually altered the overall hydrology of the areas [3]. In addition, other than affecting commercial and industrial areas, residential areas have also suffered the same consequences of flash floods in terms of casualties and property loss [4,5]. As development grows, together with the increase in impervious surfaces, the demand for effective stormwater management systems also increases [6,7]. Stormwater management is the control and use of stormwater runoff that includes the planning and maintaining of the performance of the stormwater system [8]. Limited space for water storage has caused the elevation in the surface runoff and rates as the runoff flows directly to nearby water bodies [9]. Therefore, many countries have promoted sustainable building design and construction to mitigate environmental problems, particularly in water-related issues.

The operations of sustainable stormwater management systems are divided into two categories: stormwater quantity control and stormwater quality control [10]. Water quantity control is conducted to mitigate flooding by facilitating the runoff flow, while the main purpose of water quality control is to reduce pollution by treating and removing pollutants [10]. Conventional stormwater management in Malaysia has been practiced by transporting runoff through the drainage system as quickly as possible to prevent floods [11–13]. However, to date, Malaysia is facing the consequences of increasing impervious areas that lead to major water-related issues, such as flash floods, water shortages, and water pollution, although the average rainfall per year is 3500 mm [12,14]. Thus, there is an urgent requirement for an efficient, sustainable stormwater management system in residential areas. To achieve this insight, new technologies or innovations need to be introduced in the design of sustainable stormwater management facilities [12,14].

Many studies have shown that sustainable stormwater practices, such as green roofs, rain gardens, bioretention systems, and pervious pavements, are appropriate to implement in residential areas [15]. In residential areas, especially high-rise buildings, roof areas can be used to implement stormwater management systems to overcome water-related problems, as roof areas can account for about 50% of the total area [15]. Due to the scarcity of land areas, the green roof, a vegetated SSMP, has become one of the alternatives to change impermeable areas into permeable areas, especially for high-rise residential buildings located in highly dense urban areas [5,7,15]. The ground areas need more attention and care, as these areas are occupied by many kinds of complicated infrastructure. The ground catchment area allows runoff storage and infiltration into the ground through the soil to take place naturally [15]. A bioretention system can be defined as a landscape consisting of several layers of filter media: an overflow weir, various vegetation, and an optional underdrain. Rain gardens and bioretention systems have almost similar concepts in their operations, but they differ in terms of design requirements, where rain gardens do not require the several layers of filter media required by bioretention systems [16,17].

Despite the design requirements, both practices are able to collect and receive large quantities of runoff and store them temporally before being evaporated through the vegetation. The presence of soil and vegetation also helps in treating pollutants and sediments for water quality measures. In addition, porous pavements are nonvegetated SSMPs that allow the infiltration of runoff into the ground to reduce the flow and improve the water quality in an area [18]. Though there is an absence of vegetation, porous pavement contains voids in its structure that allow water to infiltrate into the ground, of which concrete pavement is incapable [18]. However, more studies on the performance of porous pavements in terms of water quality parameters should be performed, as this practice does not have the vegetation that is much needed for treating pollutants and sediments. Table 1 shows the summaries of the previous studies performed to evaluate the performance of the SSMPs in terms of water quantity and water quality controls.
Table 1. Previous studies on the performance of the SSMPs.

<table>
<thead>
<tr>
<th>Practices</th>
<th>References</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Water Quantity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water Quality</td>
</tr>
<tr>
<td>Green Roof</td>
<td>[19]</td>
<td>Peak discharge reduced up to 26%</td>
</tr>
<tr>
<td></td>
<td>[20]</td>
<td>• Peak flow was 0.41 for 110 mm/h precipitation and 0.19 for 150 mm/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Peak flow reduction showed efficiency between 59% and 81%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Peak flow reduction increased with the intensity of the rain</td>
</tr>
<tr>
<td></td>
<td>[21]</td>
<td>• Reduced the average peak flows to 89%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Caused a delay in the initiation of the runoff</td>
</tr>
<tr>
<td></td>
<td>[22]</td>
<td>• Creeping ox-eyes reduced peak flow as high as 41%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Morning glory reduced peak flow by 15%</td>
</tr>
<tr>
<td></td>
<td>[23]</td>
<td>• Overall runoff rate was 13.78%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Average rainfall intensity of 28.18 mm/h</td>
</tr>
<tr>
<td></td>
<td>[24]</td>
<td>• Runoff volume reduced by almost 15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Peak flow reduced by almost 30%</td>
</tr>
<tr>
<td></td>
<td>[25]</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>[26]</td>
<td>Outflow peaks were delayed by 52% for at least 13 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water volume and peak flow reduced by 58.6–67.9% and 72.0–86.4%,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>respectively</td>
</tr>
<tr>
<td>Porous Pavement</td>
<td>[18]</td>
<td>Reduced runoff by up to 65%</td>
</tr>
<tr>
<td></td>
<td>[28]</td>
<td>No generation of surface runoff under rainfall intensities of five minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>duration</td>
</tr>
<tr>
<td></td>
<td>[29]</td>
<td></td>
</tr>
</tbody>
</table>

Generally, in terms of water quantity controls, the SSMPs are able to decrease the flow rate, peak flow, and total volume by retaining a large amount of runoff. In terms of water quality controls, the SSMPs are able to treat pollutants and sediments to improve the quality of the water according to the Water Quality Index (WQI). Thus, this indicates that the SSMPs should be implemented in residential areas to mitigate any water-related issues, i.e., flooding and water pollution.

In the context of stormwater management, a Strength, Weakness, Opportunity, and Threat (SWOT) analysis can be used to provide solutions for sustainable development,
The analysis was performed on selected SSMPs, including green roofs, rain gardens or bioretention systems, and porous pavements, to encourage their implementation for the existing and future development of residential areas in the Kinta and Perak Tengah districts, Perak. The sustainable practices were selected based on their suitability for implementation in residential areas, as reviewed by a previous study [15]. The SWOT analysis from previous studies was used as the reference for this study to identify the SWOT factors that will be used for survey purposes. According to a previous study, the Strength and Opportunity factors are the helpful elements to achieving organizational objectives, while the Weakness and Threat factors are the harmful elements that hinder the achievement of project objectives [30]. Previous studies showed that the Strength factors show the positive performance of the SSMPs in terms of water quantity and water quality control, while the Weakness factors are more focused on the lack of knowledge and experts, as well as cost estimation, regardless of the technical performance of the SSMPs [13,31]. Additionally, the findings also show that more benefits in various aspects can be achieved in the future with the implementation of sustainable stormwater practices, which are concluded as Opportunity factors. The Threat factors also show that most of the risks come from the perception of the community itself and their acceptance, not from the risks caused by the performance of the practices [13,31]. Table 2 shows the lists of the SWOT factors on the SSMPs generally that were discovered by some previous studies.

Considering the above discussion, it is evident that Malaysia faces heavy rains and that there is a need to raise awareness about the remedies to control the damage linked with such heavy rains [12,14]. It shows that the implementation of the SSMPs becomes an urgent requirement in residential areas due to the frequent flooding that affects the areas. However, there are some barriers that have caused difficulties in promoting this effort. The literature supports the fact that, although some SSMPs have been implemented in industrial and commercial areas, residential areas seem to receive less attention in this effort [13,31–34]. Studies show that the unfamiliarity with the operation of SSMPs in residential areas has caused this sector to implement fewer SSMPs [13,31]. Moreover, there are some difficulties in providing suitable locations for SSMPs in existing or future residential areas, especially for high-rise buildings [13,31,31].

Due to the limited space around the buildings, especially in compacted areas such as Penang, Kuala Lumpur, and Selangor, it is hard to choose the most suitable practices to implement for managing stormwater [32]. A lack of knowledge about sustainable stormwater management among practitioners and stakeholders, as well as the lack of programs and initiatives related to sustainable stormwater management in Malaysia provided by the government and private agencies, has made the implementation of these SSMPs seem impossible [13,31,32]. In addition, the lack of technical capabilities, the lack of immediate benefits for investing in green stormwater management systems, and scarce financing are some of the issues that should be considered as well [13,31,34]. Hence, various solutions should be explored to overcome these barriers, considering the vulnerability of residential buildings in Malaysia to the risks associated with storms and natural disasters. In this study, the implementation of SSMPs is specific towards landed residential areas in the Kinta and Perak Tengah districts.

Due to the urgent demand to implement SSMPs caused by arising water-related issues, especially flooding, this study aims to evaluate the agreement on implementing the mentioned SSMPs for landed residential areas, specifically in the Kinta and Perak Tengah districts, Perak, Malaysia. This study also aims to promote the wide implementation of SSMPs in existing and future developed residential areas, as this sustainable approach is less adopted in this sector as compared to others. The SWOT analysis is conducted in this study to identify the benefits and barriers of implementing SSMPs in the present, as well as the opportunities and threats that can be gained in the future if this effort is successfully adopted in the residential areas. The surveys, including a pilot study, a questionnaire distribution, observations, and interview sessions, were conducted to obtain.
the stakeholders’ and residents’ opinions on the performance of the selected SSMPs and the measures to overcome the barriers of this effort. The correlation analysis aimed to identify the preferable SSMP(s) to be implemented in the residential areas based on the questionnaire distribution data. The observations were conducted at the selected residential areas in Kinta and Perak Tengah districts to evaluate the existing stormwater management in the observed areas and to consider the suitability of implementing the preferable SSMP(s) based on the analysis. Overall, this study will help to raise awareness, especially among the stakeholders, regarding the applications of sustainable stormwater practices in managing stormwater, and will help in understanding the barriers to its implementation, which can be countered in the future.

Table 2. Previous studies on the SWOT analysis on SSPMs generally.

<table>
<thead>
<tr>
<th>Reference</th>
<th>SWOT Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength (S)</strong></td>
<td><strong>Weakness (W)</strong></td>
</tr>
<tr>
<td>[15]</td>
<td>1. Able to collect and store runoff. 2. Mitigates the adverse effects of urbanization. 1. Limited space available for LID implementation. 2. Limited information on LID technology. 3. Lack of technical power and manpower, and less financial power. 1. Identifies the basic function of each LID practice. 2. Considers the suitable LID practices.</td>
</tr>
<tr>
<td>[32]</td>
<td>1. Minimizes the amount of pollution. 2. Reduces stormwater runoff peaks and volumes. 1. Adverse impacts on downstream properties. 2. Damages stormwater systems due to greater runoff volumes.</td>
</tr>
<tr>
<td>[33]</td>
<td>1. Flood protection, and minimizes pollution. 2. Groundwater recharged. 3. Rainwater harvesting. 1. Lack of informal institutions. 2. Lack of trust between different sectors. 3. Lack of experienced teams for the implementation.</td>
</tr>
<tr>
<td>[34]</td>
<td>1. Slows down and minimizes runoff. 2. Minimizes erosion and recharges groundwater resources. 1. Financial issue-design, construction, operation, and maintenance. 2. Reluctance to accept new approaches for sustainability.</td>
</tr>
</tbody>
</table>

2. Research Methodology

This study has been designed following three main phases. For the first phase, the barriers towards the implementation of sustainable stormwater management systems have been identified via the literature. The second phase consists of a preliminary investigation with the help of a pilot survey, questionnaire distribution, observations, and interviews for the evaluation of the selected SSMPs based on the SWOT factors and the perceptions towards this study. The third phase is the collection of feedback via a questionnaire survey and statistical analyses.
2.1. Identification of Barriers towards Implementing Sustainable Stormwater Management Systems

The implementation of a sustainable stormwater management system has become an urgent requirement in residential areas due to the frequent flooding that affects the areas. For the identification of barriers towards implementing sustainable stormwater management systems, literature was collected from the Scopus database. The relevant studies were refined by using keywords covering (barriers OR challenges OR implement*) AND (stormwater management system OR green roof OR rain garden OR bioretention system OR pervious pavement). The most relevant studies were selected and reviewed for factors or barriers towards the effective implementation of sustainable stormwater management systems [13,31–34].

2.2. Preliminary Investigation: Pilot Study

A pilot study is a modest test instigated with the objective of collecting samples from a target pool, and helps the researcher to have a clear vision of the research topics, questions, methods, and techniques [35–37]. In this study, a pilot study was conducted with three engineers from private engineering consultation companies. It was performed to obtain their opinions regarding the SWOT factors for this study, which acted as preliminary results before proceeding with the questionnaire distributions.

2.3. Survey: Questionnaire Distributions

In this study, the method of gathering data by surveying was conducted through questionnaire distributions. An online survey was conducted, and the questionnaire was prepared in a Google form. The link to the survey form was distributed for the respondents to participate. The questionnaire was designed as a checklist that was divided into sections including Strength (S), Weakness (W), Opportunity (O), and Threat (T), or (SWOT) categories, as variables. There are five (5) factors for each category. The SWOT factors listed were applied to every practice: grass swales, rain gardens or bioretention systems, and porous pavements, in which the respondents were required to provide their scores based on the Likert scale. In this scale, a score from 1 to 5, in which a score of 1 strongly disagrees (SD), a score of 2 disagrees (D), a score of 3 is neutral (N), a score of 4 agrees (A), and a score of 5 strongly agrees (SA), was applied to each SWOT factor for every selected practice. All the data gathered are considered primary data and were analyzed through correlation analysis to evaluate the relationship between the factors for each category. Table 1 shows the SWOT analysis performed by the authors as the guideline to construct the questionnaire. The SWOT factors are listed as follows:

(A) Strength (S) factors: Helpful Internal factors
- S1: Captures and stores rainfall temporarily.
- S2: Enhances infiltration and slows down the runoff flow.
- S3: Treats pollutants and improves water quality.
- S4: Increases the landscape value.
- S5: Cost-effective.

(B) Weakness (W) factors: Harmful Internal factors
- W1: Lack of knowledge.
- W2: Lack of experts and implemented projects.
- W3: Limited available space.
- W4: Limited policies and public awareness.
- W5: Financial issues.

(C) Opportunity (O) factors: Helpful External factors
- O1: Develops models that upgrade the stormwater management system.
- O2: Provides long-term solutions for stormwater management problems.
- O3: Encourages local stakeholders’ participation.
- O4: Develops new stormwater management procedures and planning routines.
- O5: Enables cost estimation.
(D) Threat (T) factors: Harmful External factors

- T1: Compatibility with the existing practices.
- T2: Reluctant to accept these practices.
- T3: Different guidance and criteria.
- T4: Difficult to obtain permits or approvals.
- T5: Lack of cooperation between the participants.

In this study, the questionnaire was distributed to the main branch of the Department of Irrigation and Drainage (DID) and the City Council from every state in Malaysia, which include 14 branches of the DID and 14 branches of the City Council, as well as to the 28 selected private contractors or consultation engineering companies. The DID and City Council are represented as government agencies. It was anticipated that three respondents would be obtained from each branch of the DID and City Council in Malaysia, while three respondents would be obtained from private contractors or consultation engineering companies. The total population obtained would be 168 people. The simplified formula to calculate a sample size is shown in Equation (1) [38]. The level of precision, an \( e \) of \( \pm 5\% \), was chosen in this study. Based on the calculation below, there are 118 respondents required for this study.

\[
n = \frac{N}{1 + N(e)^2}
\]

where:
- \( n \) = sample size;
- \( N \) = population size;
- \( e \) = level of precision.

\[
n = \frac{168}{1 + (168)(0.05)^2} = 118 \text{ respondents}
\]

2.4. Data Analysis: Correlation Analysis

Correlation analysis is the analysis conducted to evaluate the relationship between two or more variables [39]. If the value of one variable changes, the value of another variable either increases or decreases; hence, the two variables are said to be related. Correlation analysis provided the strength of the linear relationship between a pair of variables, while the relationship in the form of an equation was expressed by regression analysis [39,40]. The correlation coefficient, \( r \), measures the linear relationship between two variables. It can take on any value in the range \([-1, 1]\]. The sign of the correlation coefficient indicates the direction of the relationship, while the magnitude of the correlation (how close it is to \(-1\) or \(+1\)) indicates the strength of the relationship [40,41].

Since the Strength (S) and Opportunity (O) factors are helpful factors in achieving the objective of implementing a sustainable stormwater management system, the \( r \)-value for the positive correlation analysis on the Strength (S) and Opportunity (O) factors should be between 0.7 and 1 [42,43]. An \( r \)-value that is close to 1 indicates a strong positive correlation between the factors. Meanwhile, the Weakness (W) and Threat (T) factors are harmful factors that hinder the implementation of sustainable stormwater practices [42,43]. Therefore, the \( r \)-value for the correlation analysis on these harmful factors should be below 0.5 or close to 0. An \( r \)-value that is close to 0 shows a weak correlation between the factors. In this study, the practice(s) that has/have a strong positive correlation between the Strength (S) and Opportunity (O) factors, and a weak positive correlation between the Weakness (W) and Threat (T) factors, is/are the preferable practice(s) and should be proposed for the implementation in residential areas [44,45].

2.5. Observations

To validate the current performance of the existing stormwater management system and to observe the suitability of implementing the studied SSMPs, site visits to the selected residential areas in Ipoh (Kinta district) and Seri Iskandar (Perak Tengah district) were
conducted. Six residential areas were visited in Ipoh and three were visited in Seri Iskandar. The chosen residential areas in Ipoh were Taman Meru Perdana, Taman Meru Perdana 2, Taman Meru Suria, and Halaman Meru Permai. All the chosen residential areas can be considered new residential developments and are located in Bandar Meru Raya. Bandar Meru Raya can also be considered a newly developed area that includes residential, commercial, and industrial activities. Thus, any achievements or constraints achieved in this area can provide a good reference for future development in other locations. Seri Iskandar is also a good area to study, as there are also residential, commercial, and industrial activities. The selected areas were Taman Lakeville, Taman Seri Iskandar, and Taman Gemilang.

To acquire valid results, the observations were taken during or after rain to monitor the condition of the residential areas receiving rainwater. Some photos were taken to evaluate the capability of the existing stormwater management systems to cater to the runoff. It was also conducted to identify alternatives for sustainable practices in managing stormwater in the residential areas. Additionally, the other purpose of the observation was to interview some of the residents on their opinions and suggestions regarding the performance of the stormwater management systems implemented in their housing areas. This method helped to gain a clear understanding of the purpose of this study, as the information was obtained directly from the residents. The residents' opinions and suggestions are also important, as they are the ones who closely experience the performance of the stormwater management systems in their residential areas, even though the residents are not experts in this field.

2.6. Interview Sessions

An interview is an effective data collection method for documenting an individual's or group's perspectives, opinions, and beliefs about their personal experiences and social worlds [46]. The interview session may consist of a set of prepared questions to be asked in a particular order or unstructured questions that consist of a general list of topics for possible exploration. In this study, semistructured and prearranged interviews were performed with a few engineers from the DID. The interview sessions were conducted virtually through Microsoft Teams and Zoom, and they were interviewed individually with prepared questions. The engineers were chosen as they are the experts and have the authority as government servants to approve stormwater management projects. In addition, their personal opinions and suggestions that were not included in the questions were also accepted.

3. Results and Discussion

3.1. Preliminary Findings

To reduce the flaw rate in this study, the authors conducted a pilot study to test the feasibility of the research and data collection method. This procedure also helped the authors to identify any possible flaws before proceeding with the survey. Table 3 shows the findings obtained through a pilot study that was conducted with three civil engineers. The engineers approached are from private construction engineering companies. The pilot study was performed to obtain their general opinions on the performance of the selected sustainable stormwater practices based on the factors for each variable. Based on the results, most factors are highly supported by the engineers, as most of the factors obtained a mean of three and above. However, a few factors were agreed to have a higher weightage of importance, such as factors 6, 8, and 10, which belong to the Weakness (W) categories. This indicates that these factors should be highlighted, and the measures to overcome these issues should be developed to ensure the successful implementation of the SSMPs in residential areas.
### Table 3. Pilot study findings.

<table>
<thead>
<tr>
<th>No.</th>
<th>Variables</th>
<th>Factors</th>
<th>Score (1–5)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Respondent 1</td>
<td>Respondent 2</td>
</tr>
<tr>
<td>1</td>
<td>Strength (S)</td>
<td>Captures and stores rainfall temporally.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Strength (S)</td>
<td>Enhances infiltration and slows down runoff flow.</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Strength (S)</td>
<td>Treats pollutants and improves water quality.</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Strength (S)</td>
<td>Increases the landscape value.</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Strength (S)</td>
<td>Cost-effective.</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Weakness (W)</td>
<td>Lack of knowledge.</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Weakness (W)</td>
<td>Lack of experts and implemented projects.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Weakness (W)</td>
<td>Limited available space.</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Weakness (W)</td>
<td>Limited policies and public awareness.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Weakness (W)</td>
<td>Financial issues.</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>Opportunity (O)</td>
<td>Develops models that upgrade the stormwater management system.</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Opportunity (O)</td>
<td>Provides long-term solutions for stormwater management problems.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>Opportunity (O)</td>
<td>Encourages local stakeholders’ participations.</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>Opportunity (O)</td>
<td>Develops new stormwater management procedures and planning routines.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>15</td>
<td>Opportunity (O)</td>
<td>Enables cost estimation.</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>Threat (T)</td>
<td>Compatibility with the conventional practices.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>17</td>
<td>Threat (T)</td>
<td>Reluctant to accept these practices.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>Threat (T)</td>
<td>Different guidance and criteria</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>19</td>
<td>Threat (T)</td>
<td>Difficult to obtain the permits or approvals.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>Threat (T)</td>
<td>Lack of cooperation between participants.</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

#### 3.2. Questionnaire Respondents

At the end of the survey, 118 respondents answered the online questionnaire. Based on the findings, the target population was achieved, where 50% of the respondents were from government agencies, the main branches of the DID and the City Council from every state in Malaysia, while another 50% were from private engineering companies. Their equal participation in this study is significant, as both groups are involved in the construction of stormwater management systems, which includes planning, designing, managing, and approving processes. Table 4 shows the demographic summary and details.
Table 4. Demographic profile of the respondents.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Agency</td>
<td>50%</td>
</tr>
<tr>
<td>Private Agency</td>
<td>50%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Designation</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td>21.2%</td>
</tr>
<tr>
<td>Project Director/Manager/Assistant Manager</td>
<td>35.6%</td>
</tr>
<tr>
<td>Engineer/QAQC</td>
<td>43.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Working Experience</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 years</td>
<td>26.3%</td>
</tr>
<tr>
<td>5–10 years</td>
<td>31.4%</td>
</tr>
<tr>
<td>11–15 years</td>
<td>29.7%</td>
</tr>
<tr>
<td>&gt;15 years</td>
<td>12.7%</td>
</tr>
</tbody>
</table>

In terms of the designation, the respondents comprise parties who are involved in stormwater management. Out of 118 respondents, 43.2% are engineers/quality assurance (QA) or quality control (QC), 35.6% are the project directors, managers, or assistant managers, and 21.2% are developers. The working experience (years) of the respondents showed that respondents with a working experience between 5 and 10 years reached a higher percentage, with 31.4%, followed by 11–15 years with 29.7%; less than 5 years reached 26.3%, and more than 15 years achieved 12.7%. It is important to have respondents with many years of working experience, as it represents their involvement in the industry. However, the fresh-graduate-employee respondents are also crucial for this study, as they have a more theoretical knowledge on sustainability learnt during their undergraduate study.

3.2.1. Data for Strength (S) Factors

Table 5 shows the results for the Strength (S) factors. The data represent the number of respondents obtained for each SSMP according to the Likert scale score.

Table 5. Results of Strength (S) factors.

<table>
<thead>
<tr>
<th>Practices</th>
<th>Green Roof</th>
<th>Rain Garden/Bioretention System</th>
<th>Porous Pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scale</td>
<td>D (1)</td>
<td>N (2)</td>
</tr>
<tr>
<td>S1</td>
<td>1</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>S2</td>
<td>2</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>S3</td>
<td>0</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>S4</td>
<td>1</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>S5</td>
<td>1</td>
<td>10</td>
<td>29</td>
</tr>
</tbody>
</table>

According to the table, factors S1 and S5 obtained a score of 4, the most for all practices. Factor S1 refers to Captures and Stores Rainfall Temporally. All the selected sustainable stormwater practices can capture and store rainfall temporally before being delivered to the nearby streams [15,32,33]. It also helps to control the flow and volume of water that is being delivered. Factor S5 refers to Cost-Effective. These practices are cost-effective for long-term usage, as the runoff flow can be controlled and water-related problems, such as clogging and flooding, can be minimized. Moreover, other than porous pavement, green roofs and rain gardens/bioretention systems are vegetation-based structures that help to infiltrate water through the soil and which are able to slow down the runoff flow,
which can be referred as factor S2, Enhances Infiltration and Slows Down the Runoff Flow. The vegetation also helps to improve the soil quality, which is important for the treatment of pollutants and sediments [10], which can be referred to as factor S3, Treats Pollutants and Improves Water Quality. This indicates that vegetation-based structures help to manage stormwater in terms of water quantity and water quality control. Factor S4 refers to Increases the Landscape Value. The results show that most of the respondents agreed that these SSMPs, especially the vegetation-based practices, including the green roof and rain garden/bioretention system, are able to increase the landscape value of an area.

Even though porous pavement is not a vegetation-based practice, it is invented with special compositions or components that allow water to flow [18, 28, 29]. However, this practice is unable to treat pollutants due to the absence of vegetation, as referred to by factor S3. Factor S4, Increases the Landscape Value, shows that the respondents agreed that porous pavement could increase the landscape value of an area. The efforts of using or combining a variety of vegetation with porous pavement helps to improve the landscape value in that area [15, 18]. Overall, the results indicated a good response in the Strength (S) factors for all the selected sustainable stormwater practices.

3.2.2. Data for Weakness (W) Factors

Table 6 shows the results for the Weakness (W) factors. The data represent the number of respondents obtained for each SSMP according to the Likert scale score.

Table 6. Results of Weakness (W) factors.

<table>
<thead>
<tr>
<th>Practices</th>
<th>Green Roof</th>
<th>Rain Garden/Bioretention System</th>
<th>Porous Pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors</td>
<td>Scale SD D N A SA</td>
<td>SD D N A SA</td>
<td>SD D N A SA</td>
</tr>
<tr>
<td>W1</td>
<td>1 5 26 61</td>
<td>25 0 17 30 56 15 2 13 32 58 13</td>
<td></td>
</tr>
<tr>
<td>W2</td>
<td>2 6 23 59</td>
<td>28 2 2 28 55 31 1 12 30 58 17</td>
<td></td>
</tr>
<tr>
<td>W3</td>
<td>1 7 26 72</td>
<td>12 0 3 28 69 18 6 27 26 49 10</td>
<td></td>
</tr>
<tr>
<td>W4</td>
<td>2 2 24 62</td>
<td>28 2 0 24 65 27 2 3 24 69 20</td>
<td></td>
</tr>
<tr>
<td>W5</td>
<td>0 1 27 65</td>
<td>25 0 4 27 69 18 1 2 29 66 20</td>
<td></td>
</tr>
</tbody>
</table>

According to the table, all selected sustainable stormwater practices obtained a score of 4, the most for all factors, which include factors W1 to W5. As indicated in factor W1, which is Lack of Knowledge, all of the selected SSMPs require detailed knowledge, design standards, guidelines, or technical documentation for their operation and maintenance purposes. This factor obtained a score of 4 and indicated that most of the respondents agreed that the implementation of these selected sustainable stormwater practices requires sufficient knowledge to achieve a good performance in stormwater management [13].

Additionally, all practices obtained a score of 4, the most for factor W2, which is Lack of Experts and Implemented Projects. It showed that the respondents agreed that Malaysia is still lacking in experts and projects that implement these practices, including green roofs, rain gardens/bioretention systems, and porous pavements, in residential areas. Most of the projects that have been executed are still in the observation phase. Thus, the current performance, as well as any successful projects, should be shared and exposed to encourage the implementation of these practices. Moreover, factor W3, Limited Available Space, also obtained similar responses as factor W2, in which all practices obtained a score of 4. The respondents agreed that the authorities should monitor any unattended empty spaces in residential areas to overcome the limited space available for constructing sustainable stormwater practices. Factor W4 refers to Limited Policies and Public Awareness. This factor obtained a score of 4, the most for all practices. This shows that the respondents agreed that the authorities or experts should also put a lot of effort to expose the knowledge on stormwater management to the public so to enhance their awareness regarding this issue.
Factor W5 refers to Financial Issues and received a score of 4, the most for every practice except for porous pavement, which received a score of 3. This shows that the respondents are not sure about the cost of constructing and maintaining porous pavement. Meanwhile, the respondents agreed that the construction and maintenance costs for other green roofs and rain gardens/bioretention systems are high. Thus, the authorities should also have efficient planning and discussion for implementing a sustainable stormwater management system so that the financial aspect would not be an issue. According to the results of the survey, these factors, W1 to W5, made the implementation of sustainable stormwater practices seem impossible. Therefore, the authorities and public should consider any measures to tackle these barriers to implementing a sustainable stormwater management system.

3.2.3. Data for Opportunity (O) Factors

Table 7 shows the results for the Opportunity (O) factors. The data represent the number of respondents obtained for each SSMP according to the Likert scale score.

<table>
<thead>
<tr>
<th>Practices</th>
<th>Green Roof</th>
<th>Rain Garden/Bioretention System</th>
<th>Porous Pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scale</td>
<td>SD (1) D (2) N (3) A (4) SA (5)</td>
<td>SD (1) D (2) N (3) A (4) SA (5)</td>
</tr>
<tr>
<td>O1</td>
<td>2 1 22 48 45</td>
<td>1 1 25 46 45</td>
<td>0 3 24 47 44</td>
</tr>
<tr>
<td>O2</td>
<td>3 1 24 42 48</td>
<td>0 1 23 42 52</td>
<td>1 2 26 43 46</td>
</tr>
<tr>
<td>O3</td>
<td>2 2 22 41 51</td>
<td>0 1 22 45 50</td>
<td>0 4 24 41 49</td>
</tr>
<tr>
<td>O4</td>
<td>2 1 21 38 56</td>
<td>0 1 24 39 54</td>
<td>0 2 26 39 51</td>
</tr>
<tr>
<td>O5</td>
<td>2 1 24 39 52</td>
<td>1 1 23 40 53</td>
<td>1 3 24 40 50</td>
</tr>
</tbody>
</table>

The table shows that all practices obtained a score of 4 and 5 for all factors, from factors O1 to O5. It showed that the respondents agreed with all the factors. Factor O1 refers to Develops Models that Upgrade the Stormwater Management System. With this effort, the performance of stormwater management in terms of water quantity and water quality can be improved. Factor O2 refers to Provides Long-term Solutions for Stormwater Management Problems. It indicated that the respondents agreed that this implementation is one of the efforts to mitigate water-related issues so that these problems can also be controlled in the future [47]. Factor O3 refers to Encourages Local Stakeholders’ Participation. These efforts also provide the opportunity for the stakeholders to participate in the design and operation of a sustainable stormwater management system that may help in their career achievement [48]. Factor O4 refers to Develops New Stormwater Management Procedures and Planning Routines. It shows that the respondents agreed that the successful implementation of sustainable stormwater practices may develop a new guideline for stormwater management. In addition, as refers to factor O5, Enables Cost Estimation, the successful implementation of projects can also help to estimate the cost needed for future constructions of stormwater management systems in residential areas, as well as in other sectors. Based on the results, the respondents agreed with all the Opportunity (O) factors for all the practices. Thus, the implementation of sustainable stormwater management should be encouraged to gain its benefits for future development [49].

3.2.4. Data for Threat (T) Factors

Table 8 shows the results for the Threat (T) factors. The data represent the number of respondents obtained for each SSMP according to the Likert scale score.
Table 8. Results of Threat (T) factors.

<table>
<thead>
<tr>
<th>Practices</th>
<th>Green Roof</th>
<th>Rain Garden/Bioretention System</th>
<th>Porous Pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factors</strong></td>
<td>SD (1)</td>
<td>D (2)</td>
<td>A (3)</td>
</tr>
<tr>
<td>T1</td>
<td>2</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>39</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>26</td>
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<td></td>
<td></td>
<td>52</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>54</td>
<td>34</td>
</tr>
<tr>
<td>T2</td>
<td>2</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>48</td>
<td>37</td>
</tr>
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<tr>
<td></td>
<td></td>
<td>53</td>
<td>31</td>
</tr>
<tr>
<td>T3</td>
<td>0</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>51</td>
<td>36</td>
</tr>
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<td></td>
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<td>50</td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>53</td>
<td>29</td>
</tr>
<tr>
<td>T4</td>
<td>0</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>61</td>
<td>29</td>
</tr>
<tr>
<td>T5</td>
<td>2</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>51</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>23</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>53</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

As referred to in the table, and similar to the Opportunity (O) factors, all practices obtained a score of 4 for all factors, from factors T1 to T5. It indicated that the respondents agreed that all of the factors are harmful to the implementation of a sustainable stormwater management system. However, these factors do not arise from the practical operations of the practices, but from the perception of the people, which include the practitioners or the citizens, to accept and cooperate in these efforts. As referred to by factor T1, Compatibility with the Existing Practice, there is a possibility for the public to compare any new alternative with existing practices. This is because, as referred to by factor T2, Reluctant to Accept These Practices, it shows that the public already accepts and adapts to the existing practices [15]. Additionally, as referred to by factors T3 and T4, the differences in the guidance or criteria from different regions, and the difficulty to obtain permits or regulatory approvals, made the implementation of sustainable stormwater practices seem impossible [47]. Since these factors do not arise practically from the sustainable stormwater practice performance, the authorities should consider these efforts so that any successful project implementation may help to overcome the Threat (T) factors from affecting future developments, especially a sustainable stormwater management system. Thus, the authorities or practitioners should overcome the factor T5, the Lack of Cooperation between Participants in the Operations, to cater to factors T1 to T4, and to achieve the goals of implementing a sustainable stormwater management system.

3.3. Correlation Analysis

A correlation analysis was conducted for each selected sustainable stormwater system, the green roof, rain garden/bioretention system, and porous pavement, by using Microsoft Excel. The data were analyzed for each SWOT factor to identify which practice(s) is/are preferable to implement in residential areas. The score, based on the Likert scale for each factor of each sustainable stormwater practice, was taken as the data to be analyzed. An r-value that is close to 1 indicates a strong correlation between the factors. Thus, the r-value for a positive correlation analysis on the Strength (S) and Opportunity (O) factors should be between 0.7 and 1 [23]. The Strength (S) and Opportunity (O) variables should have a strong relationship between each factor because these factors are helpful in achieving the objective of implementing a sustainable stormwater management system [gure]. Meanwhile, the Weakness (W) and Threat (T) factors are harmful factors that hinder the implementation of sustainable stormwater practices [30]. Therefore, the r-value for the correlation analysis on these harmful factors should be below 0.5 or close to 0. An r-value that is close to 0 shows a weak correlation between the factors [42–45]. In this study, the practice(s) that has/have a strong positive correlation between the Strength (S) and Opportunity (O) factors, and a weak positive correlation between the Weakness (W) and Threat (T) factors, is/are the preferable practice(s) and should be proposed for the implementation in residential areas. Based on the results, all the selected stormwater practices are preferable to implement in residential areas, as they achieve the goal of the correlation analysis.
3.3.1. Correlation Analysis on Strength (S) Factors

Table 9 shows the correlation analysis results on the Strength (S) factors for the green roof, rain garden/bioretenion system, and porous pavement, respectively.

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>0.832</td>
<td>0.818</td>
<td>0.753</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>S3</td>
<td>0.708</td>
<td>0.719</td>
<td>0.693</td>
<td>0.748</td>
<td>0.784</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0.759</td>
<td>1.000</td>
</tr>
<tr>
<td>S4</td>
<td>0.518</td>
<td>0.500</td>
<td>0.528</td>
<td>0.613</td>
<td>0.650</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>0.613</td>
<td>0.673</td>
</tr>
<tr>
<td>S5</td>
<td>0.576</td>
<td>0.591</td>
<td>0.692</td>
<td>0.570</td>
<td>0.594</td>
</tr>
</tbody>
</table>

The Strength (S) factors refer to the positive factors that sustainable stormwater practices currently achieve. Based on the results, it shows that factors S1 to S3 have a strong correlation, with r-values of more than 0.7 between each factor for both practices. Factor S1 refers to Captures and Stores Rainfall Temporally, and factor S2 refers to Enhances Infiltration and Slows Down the Runoff Flow. These factors are related to the water quantity and water quality parameters. The strong correlation between these factors shows that the performance of the green roof, rain garden/bioretention system, and porous pavement have good performance for both the water quantity and water quality parameters.

Factors S4 and S5 obtained r-values between 0.5 and less than 0.7 between their correlations with other factors for both practices. The r-value between 0.5 and less than 0.7 shows a moderate correlation between the factors. Factor S4 refers to Increases the Landscape Value. While aiming to enhance the landscape value, the proper selection of vegetation should be considered, because the performance of sustainable stormwater practices in terms of water quantity and water quality parameters depends on the type of vegetation, especially the type of roots [10,15]. Factor S5 refers to Cost-Effective, which can be defined as producing good results without costing a lot of money. Factor S5 has a moderate correlation with the other factors because, to achieve the aims of factors S1, S2, S3, and S4, a lot of money is required, especially for maintenance [34]. However, the SSMPs can be considered cost-effective for long-term use if the water-related problems can be controlled, as the cost to repair the consequences of water-related problems is even higher [12]. Thus, by implementing the SSMPs, we can use the budget allocated for repairing the failure of water-related problems to maintain and upgrade the SSMPs for the better management of stormwater controls.

3.3.2. Correlation Analysis on Weakness (W) Factors

Table 10 shows the correlation analysis results on the Weakness (W) factors for the green roof, rain garden/bioretention system, and porous pavement, respectively.

<table>
<thead>
<tr>
<th></th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W2</td>
<td>0.415</td>
<td>0.405</td>
<td>0.499</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>W3</td>
<td>0.472</td>
<td>0.464</td>
<td>0.294</td>
<td>0.358</td>
<td>0.315</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.365</td>
<td>0.401</td>
</tr>
<tr>
<td>W4</td>
<td>0.496</td>
<td>0.353</td>
<td>0.374</td>
<td>0.464</td>
<td>0.449</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.449</td>
<td>0.401</td>
</tr>
<tr>
<td>W5</td>
<td>0.483</td>
<td>0.479</td>
<td>0.404</td>
<td>0.469</td>
<td>0.386</td>
</tr>
</tbody>
</table>

The Weakness (W) factors refer to the barriers that hinder the implementation of sustainable stormwater practices. The tables show that the r-values obtained by all selected practices are less than 0.5. An r-value of less than 0.5 shows a weak correla-
3.3.3. Correlation Analysis on Opportunity (O) Factors

Table 11 shows the correlation analysis results on the Opportunity (O) factors for the green roof, rain garden/bioretention system, and porous pavement, respectively.

Table 11. Correlation analysis results on Opportunity (O) factors.

<table>
<thead>
<tr>
<th></th>
<th>O1</th>
<th>O2</th>
<th>O3</th>
<th>O4</th>
<th>O5</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O2</td>
<td>0.876</td>
<td>0.853</td>
<td>0.875</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>O3</td>
<td>0.893</td>
<td>0.844</td>
<td>0.862</td>
<td>0.901</td>
<td>0.851</td>
</tr>
<tr>
<td>O4</td>
<td>0.873</td>
<td>0.837</td>
<td>0.847</td>
<td>0.874</td>
<td>0.912</td>
</tr>
<tr>
<td>O5</td>
<td>0.875</td>
<td>0.823</td>
<td>0.857</td>
<td>0.865</td>
<td>0.887</td>
</tr>
</tbody>
</table>

Green Roof; Rain Garden/Bioretention System; Porous Pavement.

The Opportunity (O) factors refer to the helpful factors that contribute benefits for stormwater management systems in the future if sustainable stormwater practices are implemented. The tables show that the Opportunity (O) factors for the green roof, rain garden/bioretention system, and porous pavement have a strong correlation, as the r-values obtained by each practice are more than 0.7. As described in Section 3.2.3, it indicates that these practices can contribute benefits to stormwater management systems in the future if these practices are successfully implemented. Many studies also agree with these contributions generally, but we can expect the same results in the residential sector specifically [13,15,30–34]. Thus, the implementation of green roofs, rain gardens/bioretention systems, and porous pavements should be encouraged to mitigate water-related problems. We can also experience an increment in the future environmental quality if these sustainable stormwater practices are successfully implemented.

3.3.4. Correlation Analysis on Threat (T) Factors

Table 12 shows the correlation analysis results on the Threat (T) factors for the green roof, rain garden/bioretention system, and porous pavement, respectively.

Table 12. Correlation analysis results on Threat (T) factors.

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>0.503</td>
<td>0.472</td>
<td>0.444</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>T3</td>
<td>0.501</td>
<td>0.201</td>
<td>0.246</td>
<td>0.426</td>
<td>0.375</td>
</tr>
<tr>
<td>T4</td>
<td>0.425</td>
<td>0.373</td>
<td>0.484</td>
<td>0.506</td>
<td>0.419</td>
</tr>
<tr>
<td>T5</td>
<td>0.490</td>
<td>0.462</td>
<td>0.387</td>
<td>0.376</td>
<td>0.462</td>
</tr>
</tbody>
</table>

Green Roof; Rain Garden/Bioretention System; Porous Pavement.

The Threat (T) factors refer to the harmful effects that harm the performance of sustainable stormwater practices in the future if they are implemented. The tables show...
that most of the r-values obtained by both practices are less than 0.5. It shows that these Threat (T) factors have weak correlations and would not affect the performance of the green roofs and rain gardens/bioretention systems in the future.

However, there are some factors on the green roof that show a moderate correlation between T1 and T2, T1 and T3, and T2 and T4. A moderate correlation occurs between T1 and T2 because, if the public still compares the green roof with the existing practices, there is a tendency for the public to be reluctant to accept a sustainable approach [15,34]. As for the moderate correlation between T1 and T3, the compatibility between sustainable and conventional stormwater practices may arise due to different guidance or criteria [34]. For the moderate correlation between T2 and T4, the implementation of the green roof might be hard to accept due to the difficulties in obtaining permits or approvals [32,47]. Overall, other than a few moderate correlations between Threat (T) factors for the green roof, the other Threat (T) factors showed weak correlations and are not strong enough to harm the performance of the green roof, rain garden/bioretention system, and porous pavement in the future. Thus, the implementation of these sustainable stormwater practices in residential areas should be encouraged.

3.4. Observations

Observations were conducted to evaluate the performance of existing stormwater management practices in the selected areas and to propose the preferable SSMP(s) to implement in the observed areas. Based on the observations, it can be seen that stormwater system design and management in all selected residential areas are according to the MSMA requirements. Out of the surveyed residential areas, there are three residential areas that have a retention pond as a sustainable stormwater practice. The residential areas are Taman Meru Perdana and Taman Meru Suria, which are in Ipoh and Taman Lakeville, which is in Seri Iskandar. Only Taman Gemilang, located in Seri Iskandar, has a detention pond. As a part of the observation, a few residents were approached for an interview session to gain their opinion regarding the performance of the stormwater management systems in their residential areas. However, most of the residents preferred not to disclose their identities, while another three residents agreed to share their details. Based on the interviews, the residents are satisfied with the management of stormwater in their residential areas. The drainage system can flow water efficiently to the detention pond during the rainy season. The available retention/detention pond is also sufficient to store water. Instead of flooding, the residents only experienced water ponding in certain locations within their residential area, and stated that the water ponding will be reduced slowly when the rain stops. In addition, other than the existing stormwater practices, the residents agreed that sustainable stormwater practices, such as rain gardens or bioretention systems, should be implemented, as these systems can help to improve the landscape value of their residential areas. Table 13 summarized the approximate details of each residential area that was visited.

However, in terms of sustainability and environmentally friendly concepts, it was observed that most of the residential areas are not aware of the sustainable stormwater management systems, other than the retention/detention pond. Based on the observations, the green roof is not suitable to implement because all of the observed areas are landed housing areas with angle-designed roofs. The green roof is more suitable to be implemented in high-rise residential areas or flat-design roofs [50]. As agreed by the residents, rain gardens/bioretention systems and porous pavements are the preferable practices to be proposed for the implementation of SSMPs in the selected residential areas. In addition, there are many unattended empty spaces within the areas which can be allocated to construct the SSMPs. Thus, the authorities and the residents should utilize the available spaces for sustainable stormwater management to mitigate water-related issues.
Table 13. Approximate details of the residential areas.

<table>
<thead>
<tr>
<th>Residence Criteria</th>
<th>Taman Meru Perdana</th>
<th>Taman Meru Suria</th>
<th>Taman Lakeville</th>
<th>Taman Gemilang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Ipoh</td>
<td>Ipoh</td>
<td>Seri Iskandar</td>
<td>Seri Iskandar</td>
</tr>
<tr>
<td>Total Area (sf)</td>
<td>320,500</td>
<td>220,500</td>
<td>340,000</td>
<td>210,500</td>
</tr>
<tr>
<td>Type of Housing</td>
<td>Landed</td>
<td>Landed</td>
<td>Landed</td>
<td>Landed</td>
</tr>
<tr>
<td>Total House (unit)</td>
<td>224</td>
<td>186</td>
<td>255</td>
<td>140</td>
</tr>
<tr>
<td>Total Population (4 people per house)</td>
<td>896</td>
<td>744</td>
<td>1020</td>
<td>560</td>
</tr>
<tr>
<td>Type of sustainable stormwater management</td>
<td>Retention Pond</td>
<td>Retention Pond</td>
<td>Retention Pond</td>
<td>Detention Pond</td>
</tr>
<tr>
<td>Size of the sustainable practices (m²)</td>
<td>250</td>
<td>280</td>
<td>550</td>
<td>230</td>
</tr>
<tr>
<td>Location of the sustainable practice in the residential area</td>
<td>East</td>
<td>South-East</td>
<td>South</td>
<td>South-East</td>
</tr>
</tbody>
</table>

3.5. Interview Sessions

The interview sessions were conducted separately with a few engineers from different branches of the DID to obtain their perceptions regarding the study and the proposed SSMPs. All the interviewees were familiar with the sustainable stormwater management systems and agreed that these practices are environmentally friendly, and that the implementation of rain gardens and porous pavements should be encouraged. Table 14 summarizes the results obtained from the interview sessions.

Table 14. Results of the interviews.

<table>
<thead>
<tr>
<th>Participant Criteria</th>
<th>Interviewee 1</th>
<th>Interviewee 2</th>
<th>Interviewee 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>DID Ampang</td>
<td>DID Cheras</td>
<td>DID Kuala Langat</td>
</tr>
<tr>
<td>Designation</td>
<td>Civil Engineer</td>
<td>Civil Engineer</td>
<td>Assistant Director</td>
</tr>
<tr>
<td>Working experience</td>
<td>2 Years</td>
<td>&gt;10 years</td>
<td>&gt;10 years</td>
</tr>
<tr>
<td>Knowledge on sustainable stormwater management systems</td>
<td>ü</td>
<td>ü</td>
<td>ü</td>
</tr>
<tr>
<td>Involvement in sustainable stormwater management projects</td>
<td>ü</td>
<td>ü</td>
<td>ü</td>
</tr>
<tr>
<td>Opinion on the performance of the existing stormwater system</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Reasons for flood occurrence and other water-related problems</td>
<td>• Misinterpretation of the MSMA. • Natural disaster.</td>
<td>• New development near existing areas. • Natural disaster.</td>
<td>• Miscalculation in design process. • No double check-up. • Natural disasters.</td>
</tr>
<tr>
<td>Agreement on the implementation</td>
<td>ü</td>
<td>ü</td>
<td>ü</td>
</tr>
</tbody>
</table>

Based on the findings, the Strength factors show positive technical outcomes for both quantity and quality control. It indicates that the practices could control the runoff volume and treat pollutants. The Weakness factors are more focused on the lack of knowledge and experts, as well as cost estimation, but not really on the performance of the practices. It indicates that the shortcomings of sustainable stormwater practices are not barriers to implementing these alternatives. Additionally, the findings also show that more benefits in various aspects can be achieved in the future with the implementation of sustainable stormwater practices, which concluded as Opportunity factors. The Threat factors also show that most of the risks come from the perception of the community itself and their acceptance.
4. Conclusions

The objectives of the implementation of a sustainable stormwater management system are to develop a more environmentally friendly stormwater management system and to improve the performance of water quantity and quality controls. Based on the feedback received, the respondents agreed with most of the SWOT factors on the selected sustainable stormwater practices, including the green roof, rain garden/bioretention system, and porous pavement. The correlation analysis showed that the green roof, rain garden/bioretention system, and porous pavement have a strong positive relationship for the Strength and Opportunity factors, with the r-values for most relationships being close to one (1), which are statistically significant, with a p-value of less than 0.05. The selected sustainable stormwater practices also showed a weak positive relationship for the Weakness and Threat factors, with the r-values for most relationships close to zero (0), which are not statistically significant, with a p-value of more than 0.05. However, the observations showed that green roofs are not suitable to implement in the observed residential areas as compared to rain gardens/bioretention systems and porous pavements. The interviewees also agreed with the implementation of rain gardens/bioretention systems and porous pavements in the landed residential areas. Thus, the implementation of rain gardens/bioretention systems and porous pavements in residential areas should be encouraged. The barriers and risks for implementing these practices should be catered to achieve a more sustainable and environmentally friendly stormwater management system.


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