UFMonev application design for managing urban forest data and information

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Abstract. Fallen tree incidents in urban areas are frequently reported and often result in loss of property and even death. Therefore, tree health monitoring in urban forests needs to be carried out regularly. The tree health monitoring and evaluation (monev) requires a large amount of time, money, and labor, while the availability is very limited. This condition leads to the lack of tree health monitoring in the urban forest. Up to now, monev activities and reports are still conducted traditionally by using pen and paper. This method has many shortcomings such as ineffectiveness and inefficiency during monev and less engagement of the results. To solve this problem, the method must be modified in a new approach that is relevant to today's era of Industry 4.0, namely the Internet of Things. This study aims to overcome the shortcomings by designing a Management Information System (MIS) named UFMonev. UFMonev was developed by prototyping method using kodular. Analysis in the information system was carried out by assessing the physical condition of the tree. UFMonev was built in the form of an application that is operated via a smartphone. This application can only be accessed by the party responsible for managing trees in urban areas.

1. Introduction
One of the essential components of the urban landscape is trees [1]. Trees can improve urban environmental conditions such as reducing environmental temperatures, reducing air pollution, managing rainwater runoff, and others [2]. It is very important to ensure that the trees are healthy and not to pose a threat of falling trees or tree branches breaking [3]. The risk of falling trees is very difficult to predict. This incident can result in traffic jams, road closures, property damage, and even fatalities. [4]. For example, falling trees often occur in the city of Bandung. The Bandung City Housing and Settlement Areas and Landscaping Service said that within a period of 1 year there had been more than 10 fallen tree incidents that claimed lives [5].

These trees are damaged as a result of air pollution, especially from motor vehicle and industrial gas emissions, poisoning from hazardous and toxic materials of industry. Not only because of gas poisoning, but natural conditions such as storms, strong winds, rain, lightning, and physical impact by cars and building materials are also other factors causing damage. Improper tree maintenance practices such as improper pruning, inadequate planting procedures, transplant shocks due to changing urban dynamics due to construction paving or ditch opening can also result in fallen trees. Biological factors also influence, such as damage by pests, diseases, and plant parasites [6].
Economically and technically, cutting down trees as a solution to the incidence of fallen trees is not a preference, because cutting trees will only reduce the benefits of ecosystem services provided by trees and weaken the stability of the remaining trees. In this case, the management of monitoring and maintaining trees in urban areas plays a role in keeping the condition of the trees healthy and long-lived, as well as providing optimal benefits. Monitoring as doing tree assessment will make less risk of tree fall accidents while conserving their ecosystem services[3]. Lack of detailed information about tree conditions and reasons for tree stability disturbances causes generalizations of tree conditions that tend to be subjective. Usually, tree assessment is only done occasionally for investment purposes or land tenure applications. This assessment is biased because current conditions are not based on ongoing changes in the tree and its surroundings [7].

Tree monitoring and evaluation (monev) activities require a large amount of time, cost, and labor, but their availability is currently very limited. The procedure for implementing and presenting the results is also still done conventionally, namely manually recorded using a pen in the register book or the reports. This method has many weaknesses, including (1) Monitoring and data processing activities take a long time, (2) Presentation of data and information on trees health monitoring and evaluation result cannot be accessed quickly, (3) Data and information cannot be updated quickly, (4) Display of presentation of data and information is not attractive, more difficult to calculate and understand. To overcome this problem, this old method must be modified with a new approach that is relevant to the current Industry 4.0 era, namely the Internet of Things (IoT). It had already been built by [8] in Greece. They built an information system web-based named URBAN for recording tree databases in a city to help the policymaker make decisions on the existence of urban forest. URBAN focuses on informing microclimate in an area to overcome climate change. There’s a similar concept between URBAN and this study, an information system for tree databases. But this study aims to transform the conventional way of data management within monitoring and evaluation activity to prevent fallen trees by designing a Management Information System (MIS) called UFMonev.

2. Research method

2.1. System development method
Management Information System (MIS) is a system within the organization that is used to present information to support operations, management, and decision-making [9]. MIS can also be referred to as an information management technique in an organization [10]. In general, a complex system is arranged in a systematic and integrated manner by following development methods that can guide its developers to achieve a standardized information system. Several methods have been developed to build information systems, such as the method prototyping, System Development Life Cycle (SDLC), and spiral [11]. We use prototyping as a method to develop our information system. Prototyping is a simple information system development method that allows users to have a basic overview of the application program and conduct initial testing to facilitate communication between developers and users [12]. The prototype MIS built in this study uses a kodular. Kodular is an android app inventor based on visual block programming (drag and drop) which can be accessed through the website. The design tool of this information system uses the Unified Modeling Language (UML).

2.2. Data analysis method
Analysis was carried out by assessing the physical condition of the tree based on the modified [13] method. The scoring system applied is by giving a score (0-5) on damage by pests, diseases and parasites, and mechanical damage. Damage to the technique will be described descriptively based on observations in the field.

2.2.1. Damage by pests, diseases, and parasites. The assessment of the level of damage is divided into 2 parts, namely: part of the root base above ground and main stem (table 1) and branches and leaves (table 2).
Table 1. Categories of tree damage by pests, diseases, and parasites at the root base above ground and main stem.

| No. | Damage                                      | Score |
|-----|---------------------------------------------|-------|
| 1   | No damage by pests, diseases and parasites  | 0     |
| 2   | Pest/disease                                | 1     |
| 3   | Parasitic                                   | 2     |
| 4   | Dry stem/decay/open wound                   | 3     |
| 5   | Rotten stem                                 | 4     |
| 6   | Tree hollow                                 | 5     |

Table 2. Categories of tree damage by pests, diseases, and parasites on branches and leaves.

| No. | Damage                                      | Score |
|-----|---------------------------------------------|-------|
| 1   | No damage by pests, diseases and parasites  | 0     |
| 2   | Pest/disease                                | 1     |
| 3   | Parasitic                                   | 2     |
| 4   | Chlorosis/necrosis                          | 3     |
| 5   | Withered shoots                             | 4     |
| 6   | Weathered tree branch                       | 5     |

The level of tree damage by pests, diseases, and parasites at the root base above ground and the main stem is calculated using the formula below (equation 1).

\[ T_{ab} = \frac{(n_i \times 100)}{\sum n_i} \]  

Where:
- \( T_{ab} \): The level of tree damage by pests, diseases, and parasites at the root base above ground and main stem
- \( n_i \): Tree damage score
- \( \sum n_i \): Total score of tree damage by pests, diseases, and parasites at the root base above ground and main stem

The level of tree damage by pests, diseases, and parasites on branches and leaves is calculated using the formula below (equation 2).

\[ T_{cd} = \frac{(n_i \times 100)}{\sum n_i} \]  

Where:
- \( T_{cd} \): The level of tree damage by pests, diseases, and parasites on branches and leaves
- \( n_i \): Tree damage score
\[ \sum n_i : \text{Total score of tree damage by pests, diseases, and parasites on branches and leaves} \]

After getting the value of tree damage by pests, diseases, and parasites at the root base and main stem (Tab) and on branches and leaves (Tcd), then the total damage to trees by pests, diseases, and parasites (Thpt) is calculated using the formula below (equation 3).

\[ T_{\text{htpt}} = \left( \frac{\text{Tab} + \text{Tcd}}{2} \right) \] (3)

2.2.2. Mechanical damage. Mechanical damage is caused by direct contact with physical objects such as scratches, friction, impact, cuts, and so on. Categories of mechanical damage levels are presented in table 3.

| No. | Damage                                    | Score |
|-----|-------------------------------------------|-------|
| 1   | No mechanical damage                       | 0     |
| 2   | Scribbles                                 | 1     |
| 3   | Advertisements/nails                       | 2     |
| 4   | Scratches                                 | 3     |
| 5   | Tree organs (roots, trunks, branches) are broken | 4     |
| 6   | Struck by lightning                        | 5     |

The level of tree mechanical damage is calculated using the formula below (equation 4).

\[ T_m = \frac{\text{ni} \times 100}{\sum n_i} \] (4)

Where:
- \( T_m \) : The level of tree mechanical damage
- \( n_i \) : Tree damage score
- \( \sum n_i \) : Total score of tree mechanical damage

After getting the value of tree mechanical damage, total tree damage is calculated using the formula below (equation 5).

\[ T = \frac{(T_{\text{htpt}} + T_m)}{2} \] (5)

Where:
- \( T \) : Total tree damage

Using the modified Gray and Daneke (1978) method, the tree's physical condition was categorized into:

- Very good: Total tree damage score 0\% \( \leq T < 15\% \). The condition of the tree is healthy and vigorous so that no maintenance action is needed.
- Good: Total tree damage score 15\% \( \leq T < 30\% \). The condition of the tree is quite good so it still needs maintenance.
- Bad: Total tree damage score 30\% \( \leq T < 50\% \). The condition of the tree is not healthy so it requires intensive care.
- Very bad: Total tree damage rate \( T \geq 50\% \). The condition of the tree is threatened with death or has died.

3. Results and discussion

3.1. Application design

The design of this information system uses an object-oriented model, namely UML, which consists of:
3.1.1. Use case diagrams. Use case diagrams are used to describe interactions that can be carried out by users to information systems (figure 1). In this diagram, there are actors (users) and use cases where the actor represents the user who interacts and runs the system, while the use case represents all operations performed by the actor.

![Use case diagram of the information system.](image)

**Figure 1.** Use case diagram of the information system.

3.1.2. Activity diagram. Activity diagrams are used to describe various activity flows from the beginning of the system starting to the end of the system process. Activity diagrams in this information system are divided into account login activity diagram (figure 2), tree inventory activity diagram (figure 3), and analysis results in activity diagram (figure 4).
Figure 2. Account login activity diagram.
Figure 3. Inventory activity diagram.
3.2 Application display
The system is built in the form of an application that is operated via a smartphone. This application can only be accessed by the party responsible for managing trees in urban areas, it is not accessible to the public. This application is named UFMoney with the appearance of the application as follows:

3.2.1. Login page display. The login page is used to identify the logged-in manager account to ensure the security of the application. On this page, the user is asked to enter the username and password for the account that has been registered (figure 5).
3.2.2. **Inventory menu display.** The inventory menu is a page that assists users to fill in information about the tree. It's based on inventory results in the field. The inventory menu consists of 2 other menus, namely:

- **Tree register menu**
  Tree register is managed to record trees that have not been registered in the database (figure 6). Users are required to enter the physical size of the tree, the physical condition of the tree, photos of the damage, and location. The system processes the data based on the analysis method to assess tree physical condition. Processed data would be formed in a QR code installed in every tree. So, the QR Code contains tree information.

- **Edit data menu**
  Edit data is used to update the tree data that has been registered in the database. In this menu, the user is assisted to scan the QR code installed in each tree that contains tree information based on the last entered data. QR code contains information about ID number, tree species, DBH, height, tree condition and maintenance suggestions (figure 7). If there is a change then the user is asked to fill out the page update tree data.

![Figure 6. Tree register menu display.](image)

![Figure 7. Edit data menu display.](image)
3.2.3. Analysis results menu display. The analysis results menu is a page that functions displaying the results of the processing database tree in the form of maps, descriptions, or graphs. The analysis results menu consists of 2 other menus, namely:

- Tree map menu
  Tree map is a page that displays tree data that has been processed and marked with symbols based on 4 different colors, namely black for trees with very bad status, red for trees with bad status, yellow for trees with a good status, and green for trees with very bad status (figure 8). The dialog box below the map contains a description of the tree which includes the location, tree type, tree status, and recommended maintenance.

- Tree data menu
  Tree data is a page that displays all databases that have been processed. This page displays a pie chart based on the status of the tree's physical condition. Users can search specific trees by typing keywords in the first line of the dialog box (figure 9).

4. Conclusion and suggestion
UFMonev can overcome the problems that exist in tree monitoring and evaluation activities in urban areas regarding tree databases, processing, presenting, and accessing data. The advantages of UFMonev are (1) UFMonev presents data in the form of text, graphics, maps, and photos, (2) UFMonev is easy to operate by a smartphone, (3) Data updates are managed with a QR Code so that it is easier and faster, (4) Data calculation can be done quickly. Besides that, there are some disadvantages, particularly (1) UFMonev has to be connected to the internet, (2) Analysis method to assess tree physical condition has to be validated according to the living area of the tree, (3) UFMonev can not be accessed by the public.

At the end of the research, there are some suggestions for further research namely: (1) This research can be used as a reference for the further researcher who wants to conduct a similar strategy as in this
research. It would be better to apply some different locations using UFMonet, (2) It needs to be developed with a customary database so it doesn’t need to be connected to the internet, (3) It needs to be completed by a platform for the public to access the information of the trees and input tree health condition that they found.

5. References

[1] Crosby M K, McConnell T E, Holdereith J J, Kjartansson B, Traustason B, Jónsson D H, Snorrason A and Oddsdotti E S 2021 Urban street tree characteristics and benefits in the city centre Reykjavik Iceland Trees For People 4 100066

[2] Croeser T, Ordóñez C, Threlfall C, Kendal D, Ree R, Callow D and Livesley S J 2020 Patterns of treeremoval and canopy change on public and private land in the City of Melbourne Sustain. Cities Soc. 56 102096

[3] Coelho-Duarte A P, Daniluk-Mosquera G, Gravina V and Vallesjos-Bar Ó 2021 Tree risk assessment: component analysis of six visual methods applied in an urban park, Montevideo, Uruguay Urban For. Urban Green 59 127005

[4] Lazim R M and Misni A 2016 Public perceptions towards tree risk management in Subang Jayamunicipality Malaysia Procedia - Social and Behavioral Sciences 222 881-889

[5] Abdurrahman N 2017 Antisipasi pohon tumbang di kota bandung, ini yang dilakukan upt penghijauan dan pemeliharaan pohon [Anticipate fallen trees in the city of Bandung, this is what is done by reforestation and tree maintenance] [Internet] Jabar Tribun [cited 17 April 2021] Available from: https://jabar.tribunnews.com/2020/11/15/antisipasi-pohon-tumbang-di-kota-bandung-ini-yang-dilakukan-upt-penghijauan-dan-pemeliharaan-pohon (In Indonesian)

[6] Lopes A, Oliveira S, Fragoso M, Andrade J A and Pedro P 2007 Wind risk assessment in urbanenvironments: the case of falling trees during windstorm events in Lisbon Bioclimatology and Natural Hazards (Polana nad Detvou, Slovakia, September 17 - 20, 2007) (London : Springer)

[7] Rosłon-Szeryńska E 2013 The protection of urban trees and the perceived safety hazard Sustainable Development Applications 4 52-65

[8] Varras G, Andreopoulou Z, Tasoulas E, Papadimas C H, Tsioriannis I, Myriounis C H and Koliouksa C H 2016 Multi-purpose internet-based information system ‘urban’: urban tree database and climate impact evaluation Journal Of Environmental Protection And Ecology 17 380-386

[9] Kadir A 2003 Pengenalan sistem informasi [Information system introduction] (Yogyakarta: ANDI) (In Indonesian)

[10] Kristianto A 2008 Perancangan sistem informasi dan aplikasinya [Information system design and the application] (Yogyakarta: Gava Media) (In Indonesian)

[11] Sutedjo B 2002 Perencanaan & pembangunan sistem informasi [Information system development and design] (Yogyakarta: ANDI) (In Indonesian)

[12] McLeod R and Schell G P 2004 Management information systems 9th edition (New Jersey: Prentice-Hall)

[13] Sulistiyantara B, Hidayat I W, Taher A N, Isdiyantoro and Kastolani A 2006 Pembangunan sistem informasi manajemen rth taman dan jalur hijau wilayah kotamadya Jakarta Timur [Development of an open space management information system for parks and green lines for the East Jakarta municipality] (Jakarta: Pemerintah Daerah Kotamadya Jakarta Timur Suku Dinas Pertamanan dan Departemen Arsitektur Lanskap Fakultas Pertanian Institut Pertanian Bogor) (In Indonesian)