The application of housing land-use patterns to achieve low CO$_2$ emission in Medan City

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Abstract. Planning of housing is related to land-use management the lack of appropriate and adequate facilities also discovered to be forcing residents to travel to other places, thereby, leading to CO$_2$ emissions. This study was, therefore, aimed to determine appropriate land-use patterns to reduce the environmental damages caused by a continued increase in CO$_2$ emissions, especially in residential areas of Medan city. The control policy implemented in Taman Johor Indah Permai Housing I involves studying housing and life structuring in the area to cope with the effects of CO$_2$ emissions. The study was conducted using a mixed-method with the quantitative aspect applied to process data, while the qualitative aspect was applied to analyze the research problem. The sample population included all housing units in Taman Johor Indah Permai I and the data obtained were comprehensively analyzed based on urban housing theory, spatial planning, and CO$_2$ emissions sources. The characteristics of land use patterns were identified, potential factors contributing to CO$_2$ emissions, and their roles in preventing and overcoming they were determined, after which recommendations were made to prepare housing land-use patterns to achieve low CO$_2$ emissions. The results, however, showed a lack of facilities in the housing area to be influencing the distance traveled by the residents thereby causing more emissions. It’s led to the implementation of policies involving mixed use of land and pedestrian walkways in designing low CO$_2$ emissions urban housing.

1. Introduction
The growth of a city is usually marked by an increase in population and development. This required the construction of more housing units, which causes a reduction in green open areas and environmental quality. All human activities are related to energy from the earth's resources, and the excessive use of this energy has negative impacts such as the uncontrolled release of CO$_2$ in the air. It’s consequently led to environmental damage and climate change on a large scale.

Direct use of energy has been discovered to be the most significant contributor to CO$_2$ emissions from transportation, industries, commercial activities, and households. According to the Center of Settlement Research and Development, the process of constructing housing units starting from the production of the materials to the actual construction of the buildings and development emits CO$_2$. This means an increase in housing units can increase all activities involved in the process of construction as well as the CO$_2$ emitted into the air.

One unit of housing in urban areas requires several building materials such as river stone, sand, brick, iron, cement, wood, and tiles. Several studies have, however, showed the process of procuring these materials to be capable of emitting CO$_2$ starting from the raw materials procurement, production stages, the fossil fuels used to the distribution. During the construction phase, CO$_2$ gas is generated and disposed of through the transportation of building materials and respiration by workers [1]. There is also emission during the occupancy stage, with residents reported releasing the gas through daily activities such as cooking, washing, lighting, space conditioning, waste generation, and transportation to and from home. Meanwhile, about the residential land-use in urban areas, [2] suggested land-use should consist of some elements such as Pensions (Wisma), Works (Karya), Likes (Suka), and Perfections (Penyempurnan) or the integration of Marga in an environment and individual relationship.
with each other. [3] and [4] also showed the possibility of controlling CO2 emission in housing pre-construction, construction, and post-construction activities mainly through the consumption of electricity and fuel from household needs.

This study aimed to determine the appropriate land use patterns to reduce the impact of environmental damages due to the continued increase of CO2 emissions in the air, especially in residential areas of Medan city. A control proposed in the form of overcoming the occupant's habits using a sustainable lifestyle in their activities and structuring the circulation system to create a sustainable transportation system. Three structuring concepts were also shown by [5] to be relating to the land division or subdivision in residential areas, which are conventional, cluster, and Planned Unit Development (PUD). The implementation of these concepts was expected to have a positive impact by reducing the CO2 emissions in housing units.

2. Research Method

2.1. Research design

The research was conducted using a mixed-method with the quantitative aspect applied to process data, while the qualitative method was used to analyze the research problems. The procedures followed in this research are stated as follows:

- In-depth assessment of several theories on urban housing, spatial planning, sources of CO2 emissions, and structuring of low-emissions in housing units.
- Identification of the characteristics of housing land-use patterns and CO2 emissions from human activities.
- Analysis of the factors with a potential contribution to CO2 emissions in housing land-use patterns.
- Analysis of the role of factors preventing and overcoming CO2 emissions in housing land-use patterns.
- Recommendations to ensure low CO2 emissions in housing land-use patterns.

2.2. Location

Field data were obtained directly from Taman Johor Indah Permai 1 housing complex in Medan Johor District, which was used as the research object. The area was selected due to the tendency of real estate housing to use more energy and produce a higher quantity of CO2 emissions.

2.3. Populations and Samples

The population includes all the housing units in Taman Johor Indah Permai 1, with a total of 616 houses. A sample of 10% was selected, thereby, having 60 housing units used in this research, which divided based on type with type 45 consisting of 29 respondents, type 70 having 26, and type 100 with five respondents.

2.4. Data collection and analysis methods

The data were collected through observation, interviews, and documents and processed with the focus on land-use and circulation, after which they were analyzed quantitatively and presented in the form of narratives or descriptions, matrices, and diagrams.

3. Results and Discussion

3.1. Characteristics of housing land-use patterns and CO2 emissions

The construction of Taman Johor Indah Permai I housing was started in 1980 and completed in 1985. There are, however, several physical changes made in the housing area and the surrounding environment in line with the development and increase in the needs of the residents. It consequently affects the incidence of CO2 emissions in the area.
The observations showed that one aspect of housing structuring used in forming spaces and found to be influencing housing life systems is land-use patterns and circulation with consequent effects on the residents’ lifestyles.

The Taman Johor Indah Permai I housing was observed to functionally consist of housing area, public facilities, and green open space. One of the problems discovered to have the potential to contribute to CO₂ emissions is the absence of commercial facilities in the area, which forces the residents to travel to meet their daily needs. According to Sastra (2005), a housing area with 200 housing units having environmental provisions such as one lowest education unit like TK/Kindergarten, a stall with 100 m² area, and a playing field with 250 m² area was recommended. Therefore, suggested that the 616 housing units in Taman Johor Indah Permai I be divided into three stalls with commercial functions included in current urban life.

A circulation system is needed to connect the uses of the inter land, and the geographic connectivity between land uses and circulation has been reported to be accessibility. It means good accessibility is required to create comfort and convenience for residents what the same time traveling and making this factor being essential to ensure the adequate functioning of urban housing space structure [6].

3.2. Factors that potentially contribute to CO₂ emissions in housing land-use patterns

Access is considered necessary to making the movement of humans and property between spaces in the housing to be easier and to ensure the optimal functioning of it. Moreover, the circulation system of people and goods is closely related to the placement patterns of all activities, and these have been observed in Taman Johor Indah Permai I housing complex to be strongly influenced by the hierarchy of the existing blocks. The efficient use of energy, and the CO₂ emissions generated by residents, are indirectly related to the carrying capacity of the circulation system.

Some of the circulation system flow include the movement of people, goods, garbage, services, and information, which generally make use of both public and personal motorized vehicles. A sustainable and interconnected circulation system ultimately connected to the main road found to support high occupant mobility, and this further leads to an increase in CO₂ emissions. Furthermore, sidewalk facilities for pedestrians are also observed not to be available, thereby, leading to the resident's dependence on vehicles even to destinations within a comfortable walking distance. It needs to change the lifestyle of the occupants to reduce the CO₂ emissions by ensuring they travel on foot to destination with close distance. It requires designing pedestrian walkways for the residents.

3.3. Factors to prevent and overcome CO₂ emissions in housing land-use patterns

![Figure 1. Mileage of Public and Commercial Facilities in Taman Johor Indah Permai I Housing](image-url)
Figure 1 shows the comfortable walking distance to be approximately 500 m with an average walking speed of 3-4 km/hour. This means it requires 10 minutes on foot to reach 500 m. The main destinations of the residents were observed to be commercial areas such as traditional markets and mosques. It is, however, possible for all residents to reach the mosque comfortably on foot due to its location inside the housing area, at the same time the market is observed to be outside the comfort zone of approximately 80 houses. It means the facilities were positioned in such a way that they have the potential to reduce CO₂ emissions from the use of motor vehicles. Meanwhile, the use of motor vehicles with gasoline fuel for the 500 m distance at 50 km/h speed requires only 1 minute to reach the mosque or traditional market facilities, but 1.59 kg-C CO₂ emission was produced during the short trip because 3.18 kg-C is produced in 1 km. This means it is possible to emit a total of 159 kg-C in a situation 100 houses choose to use motor vehicles to reach these destinations.

This further strengthens the need for a pedestrian walkway to prevent the increased CO₂ emissions from motor vehicles. Quantitative analysis through the survey conducted showed that 60 percent of the residents have the desire to walk if pedestrian facilities in the housing area are well managed and comfortable. Moreover, socialization and counseling are also required to increase the awareness of the residents on the need to reduce the use of motorized vehicles to have low levels of emissions.

The analysis also indicated that the land-use and circulation system in Taman Johor Indah Permai I housing estate is not well organized. An example of this is the lack of commercial activities in the housing area, and this forces the residents to travel outside to meet their daily needs. There are also no pedestrian facilities, thereby, encouraging the use of motorized vehicles. Therefore, there is the need to control the components of land-use patterns, and circulation systems such as land use, roads, pedestrian walkway, and mileage to prevent and manage the increase in CO₂ emission.

Land-use and transportation systems are interrelated, and activities are observed to be the specific system generating and attracting movements. These include the combination of social, economic, cultural, and several other activities strictly related to the regulation of land use patterns and requiring movement as a tool to meet daily needs. It means there is a close relationship between the movement magnitude and the type and intensity of these.

The movement of both people, and, or goods requires adequate transportation mode or facilities, and media or infrastructure such as an efficient road network system. This is important due to the effect of a safe, fast, convenient, and inexpensive movement regulated by the traffic engineering system, and proper management of the environment. The transportation system is also closely related to its closeness and connectedness to several public facilities and infrastructures existing in and around the residential.

The recent attention in the transportation sector was not only oriented towards guaranteeing population mobility but also to improve the quality of life and welfare of the people as well as to ensure environmental preservation. The focus of the environmental impacts of transportation has become important since the discovery of motor vehicles using fossil fuels that were observed in Taman Johor Indah Permai I housing estate.

Field observations and analysis showed the land in Taman Johor Indah Permai I housing complex is only used for residence, public facilities, and green open space without any commercial activity, and forces the residents to move out of the area to shop or meet other needs. It was also discovered to have made 100% of the residents have either two-wheeled or four-wheeled vehicles to travel, thereby, causing high CO₂ emissions.

Therefore, there is, the need for land use management strategy and environmentally-friendly transportation system to reduce the CO₂ being emitted into the air in Taman Johor Indah Permai I housing area. It’s expected to include:

- Spatial arrangements to reduce motor vehicle movement and Non-Motorized Transport (NMT).
- Development of mass transportation and supporting strategies.
- Vehicle inspection and maintenance to control the emissions.
The effort to manage the road pattern was expected to focus on separating the vehicle, and pedestrian lanes, and this is implemented by using the following criteria:

- A higher amount of public space and placement of houses close to each other and the road to creating better social interaction between residents.
- Adjustment of the road dimensions in the design to provide comfort and safety for the residents.
- Design friendly pedestrian paths in the form of sidewalks on roads and alleys between houses’ backyards to reach public transit points, thereby, reducing dependence on motorized vehicles.

Low CO$_2$ emission housing was created when the mileage and changes always involve the entire system, such as the arrangement, economy, environment, and inherent ecological processes. Understanding this interaction is not only useful in preventing, and overcoming CO$_2$ emissions but also efficient in creating sustainable urban housing, and preserving the ecosystem. The system implemented in Taman Johor Indah Permai I only refers to efforts made to fulfill the needs of the middle-upper community.

3.4. Recommendations to ensure low CO$_2$ emissions in housing land-use.

A policy to prevent and overcome the generation of CO$_2$ emissions needs to adopt the objectives of sustainable housing development. The new urban housing management policy does not have the potential to prevent and mitigate the generation of CO$_2$ emissions in its design.

One of the policies to implement is applying mixed land-use functions to shorten the travel distance from one area to another to ensure it is walkable. However, it can reduce CO$_2$ emissions generated from motor vehicles. The implementation of this policy, therefore, requires designing pedestrian walkways on all sides of the road in the housing area to create non-motorized transportation.

4. Conclusion

This research had conducted to describe the impact of environmental damage caused by the continuous increase in CO$_2$ emissions, especially in the housing areas, and to find an appropriate solution to mitigate the problems. The formation of structured housing arrangement characteristics is related to land-use, and circulation patterns. The factors considered to have the direct and indirect potential for emissions include:

- The existence of public, social and commercial facilities,
- Road and pedestrian sidewalks,
- Hierarchy of roads and access, and
- Mileage.

Land-use had discovered to be playing a significant role in determining the distance from one area to another, and this is very important to any control model to prevent the generation of CO$_2$ emissions. Therefore, the policy to be applied was expected to mix land-use functions to shorten the travel distance to be walkable towards reducing CO$_2$ emissions generated from motor vehicles.

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