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DEVELOPING AN ENTITY–RELATIONSHIP DATA MODEL FOR GIS-BASED ANALYSIS OF RECREATIONAL PARK ACCESSIBILITY AND DISTANCE FROM RESIDENTIAL AREAS

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Abstract:

Recreational parks play an important role in promoting physical activity, social interaction, environmental sustainability, and healthy urban environments. The assessment of recreational park accessibility requires the integration of spatial and non-spatial datasets representing parks, residential areas, transportation networks, access points, and accessibility indicators. However, existing GIS-based recreational park accessibility studies have predominantly focused on accessibility measures, spatial equity, network analysis, and accessibility indices, while comparatively less attention has been given to the conceptual database structures required to organise and integrate the datasets underpinning these analyses. This study therefore develops an Entity–Relationship Data Model (ERD) as a conceptual GIS database structure for assessing recreational park accessibility and spatial distance between recreational parks and residential areas in Seri Iskandar, Perak. The proposed ERD is specifically designed to represent the spatial and

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attribute relationships required for park accessibility and distance/proximity assessment rather than to conduct the accessibility analysis itself. The database development process comprises the identification of required spatial and non-spatial datasets, formulation of entities and attributes, and identification of relationships among entities using Chen's ERD notation. Five (5) core entities are identified: Recreational Park, Residential Area, Road Network, Park Access Point, and Accessibility Assessment. The resulting model establishes primary and foreign key relationships and provides a structured foundation for storing park characteristics, residential information, transportation network data, access locations, and accessibility assessment attributes such as distance and travel time. The proposed ERD is designed to support subsequent GIS-based proximity and network accessibility analyses. The primary contribution of this study is therefore a conceptual GIS database model that improves the systematic organisation, consistency, and integrity of data required for recreational park accessibility assessment. The model can be further implemented and adapted to support recreational park planning and accessibility assessment in other study areas.

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Keyword:

Entity–Relationship Data Model, Geographic Information System, Residential Area, Recreational Park Accessibility, Recreational Planning, Spatial Proximity

Introduction

As key elements of urban green infrastructure, recreational parks comprising vegetated areas, water features, and other natural habitats play a pivotal role in advancing sustainable urban development. Their contribution extends beyond environmental conservation to encompass social well-being, public health enhancement, and the promotion of resilient and liveable urban environments (Chen et al., 2024; Liu et al., 2022). Recreational parks constitute a fundamental component of urban green infrastructure and are increasingly recognized as essential public amenities that contribute to environmental sustainability, public health, and social well-being. The classification of recreational parks is generally determined by the size of the urban population and the level of accessibility provided to surrounding communities. Beyond their ecological functions, recreational parks serve as multifunctional urban assets that contribute substantially to sustainable urban development. These spaces provide essential ecosystem services, such as microclimate regulation, air purification, stormwater management, flood attenuation, and carbon storage, while simultaneously supporting social cohesion, recreational opportunities, active lifestyles, and mental well-being. These benefits have led to recreational parks being viewed as important elements of healthy, resilient, and liveable urban environments (Andersson et al., 2022; Pasanen et al., 2023; Chen et al., 2024). The vegetation

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found in these spaces can also help mitigate climate change by capturing and storing carbon, while contributing to local efforts to reduce greenhouse gas emissions. In this context, opportunities for recreation and leisure are closely linked to the availability of parks that are adequately distributed and easily accessible to residents.

Park accessibility is an important consideration in encouraging recreational activities and providing urban services more equally among residents. The distance between residential areas and recreational parks, together with the ease of reaching them, can influence how often people use these spaces and the social, physical, and psychological benefits they obtain from them. Previous studies have found that when recreational parks are located within a reasonable distance of residential areas, residents are more likely to participate in outdoor activities and maintain an active lifestyle (Dai et al., 2022; Jeon and Jung, 2023; Chen et al., 2024). In particular, access to parks within approximately 300 metres of residential areas has been associated with positive outcomes for mental well-being (Liu et al., 2022; Jeon and Jung, 2023). This evidence is consistent with the contemporary "15-minute city" planning concept, which promotes access to essential facilities, including parks and recreational spaces, within a short walking or cycling distance from where people live (Vale and Lopes, 2023; Liu et al., 2022).

Despite the growing recognition of the importance of equitable access to recreational parks, differences in the distribution of recreational spaces remain evident in many urban areas. Some neighbourhoods have sufficient park provision within convenient reach, while others have fewer options because recreational parks are not evenly distributed (Wang et al., 2023; Dai et al., 2022; Jeon and Jung, 2023). This raises an important question about whether the existing distribution of recreational parks is sufficient to meet residents' everyday recreational needs and provide comparable access across different communities. For this reason, assessing park accessibility requires more than simply measuring Euclidean distance. Other factors, including service coverage, travel distance and time, and network-based accessibility, should also be considered. Taking these factors into account can provide a more realistic representation of accessibility by reflecting the structure of transportation networks, the characteristics of park destinations, and differences in the spatial provision of recreational services (Zhou et al., 2023; Mao et al., 2023; Spangler et al., 2023).

Geographic Information System (GIS) provides a useful means of examining accessibility by bringing together the management, visualisation, and analysis of spatial information (Chen et al., 2024; Hashtarkhani et al., 2024). In the context of recreational parks, GIS can be used to examine factors such as proximity, service coverage, travel distance, travel time, and distance thresholds, allowing differences in access between residential areas to be identified (Hashtarkhani et al., 2024; Wang et al., 2021). The development of GIS-based methods has further expanded these capabilities by allowing accessibility to be considered in relation to travel routes, service areas, and spatial equity. Such information can assist planners and decision-makers in evaluating the distribution of public facilities and making better-informed decisions about urban development (Chen et al., 2024; Wang et al., 2021). Nevertheless, the quality and usefulness of GIS-based accessibility analysis are influenced not only by the methods used but also by how the spatial and non-spatial data are structured, organised, and integrated within the database.

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Existing GIS-based studies of recreational park accessibility have primarily concentrated on the development and application of analytical approaches, including network-based accessibility, service-area analysis, spatial equity measures, and enhanced Two-Step Floating Catchment Area (2SFCA) models (Wang et al., 2023; Dai et al., 2022; Jeon and Jung, 2023). While these approaches provide valuable methods for measuring accessibility, comparatively less attention has been given to the conceptual database structure required to systematically organise the spatial and attribute datasets that underpin these analyses. In particular, the relationships among recreational parks, residential areas, road networks, park access points, and accessibility assessment records are not always explicitly represented within a unified conceptual database model. This gap is important because poorly organised spatial and non-spatial datasets may lead to data redundancy, inconsistent relationships, and difficulties in retrieving and integrating information for subsequent GIS analysis. A structured conceptual database model can provide a logical representation of the entities, attributes, and relationships required before the database is implemented within an operational GIS environment.

Entity–Relationship Data Model (ERD) provides a systematic approach for representing entities and their relationships within a database structure. In GIS applications, conceptual database modelling can assist in organising spatial and non-spatial information and establishing relationships among interconnected geographic features (Apeh & Abdul Rahman, 2023; Bagui & Earp, 2022). By defining entities, attributes, primary keys, foreign keys, and relationships, an ERD can provide a conceptual foundation for subsequent database implementation and GIS analysis. Therefore, the objective of this study is to develop an ERD that provides a conceptual database structure for GIS-based assessment of recreational park accessibility and spatial distance between recreational parks and residential areas in Seri Iskandar, Perak. The model is designed to organise the relevant data and define the relationships among the elements required for accessibility assessment. In doing so, it provides a structured database that can support both distance- and network-based analyses within a GIS environment. The study's primary contribution is the development of a conceptual GIS database model specifically designed for assessing recreational park accessibility and analysing spatial distances. Rather than developing new accessibility algorithms or comprehensive decision support systems, this study presents a structured database framework that can be implemented on GIS platforms and has the potential to be expanded to support future accessibility assessments and recreational park planning.

Literature Review

This literature review provides the theoretical and empirical framework of this study by reviewing previous studies about the accessibility of recreational parks and the development of GIS-based databases. It is divided into three (3) main parts. The discussion begins with the concept and significance of recreational parks in encouraging sustainable urban development. Furthermore, the concepts and analytical methods of evaluation of accessibility of recreational parks and their relation to residential areas are discussed. The review concludes with an examination of the application of the ERD in developing conceptual databases to support GIS-based spatial analysis. Together, these discussions establish the conceptual framework for the development of the proposed GIS database model.

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Recreation Park

Recreational parks are a significant component of Urban Green Infrastructure (UGI) which is composed of interconnected natural and semi-natural spaces designed to offer environmental, social and economic benefits for urban environments. While other forms of green infrastructure are meant to facilitate sustainable urban development, recreational parks are especially designed to encourage public recreation, social well-being, and responsibility toward the environment. These parks provide multiple ecosystem services, including carbon sequestration, urban heat mitigation, stormwater regulation, biodiversity conservation, and air quality improvement, making them essential infrastructure for resilient cities (Andersson et al., 2022).

In addition to performing ecological functions, recreational parks are important for public health and social sustainability. Natural environments have been associated with reduced psychological stress, improved mental health, increased physical activity and enhanced community interaction. Pasanen et al. (2023) reported that regular contact with urban green spaces improves both physical and psychological well-being, while Liu et al. (2022) demonstrated that accessible green-blue spaces encourage active lifestyles through walking, cycling, and outdoor recreational activities. Thus, the role of recreational parks as a public infrastructure improving the quality of urban life and contributing to sustainable development is increasingly recognized. Planning authorities define Urban Green Spaces (UGS) into hierarchical levels according to their physical size, catchment areas and service functions, so that recreational facilities are adequately implemented by different population groups. The hierarchy of categories enables the planners to distribute recreational facilities systematically in order to ensure each urban community has equal access. As shown in Table 1, the Malaysian Planning Guideline for Open Spaces classifies recreational parks into several hierarchical levels according to their planning standards and service coverage (PLANMalaysia, 2021)**.** Each category differs in terms of minimum land area, service radius, recreational facilities, and target population, enabling recreational services to be provided efficiently according to community needs.

Table 1: Hierarchy of Green Spaces Based on the Malaysian Planning Guideline for Open Spaces

	Typical Size	**Service Radius**	**Primary Users**
Pocket Park	Small	Walking distance	Immediate neighbourhood
Neighbourhood Park	Medium	Local residential area	Neighbourhood residents
Local Park	Larger	Several neighbourhoods	Local communities
District Park	Large	District level	District population
Regional Park	Very Large	City or regional level	Entire urban population

Source: PLANMalaysia (2021)

Of these categories, recreation parks are the green spaces in which the most significant human intervention has been made. They are specifically designed and managed to encourage recreation and to provide recreation opportunities for the local population. Unlike natural forests or ecological reserves, recreational parks incorporate recreational facilities, pedestrian pathways, sports infrastructure, playgrounds, landscaped areas, and supporting amenities that encourage frequent public use. Their strategic location within or adjacent to built-up residential

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areas enables residents to access recreational opportunities conveniently, thereby strengthening social interaction and promoting healthier urban lifestyles (Chen et al., 2024). Despite their recognised importance, many cities continue to experience unequal spatial distribution of recreational parks because of rapid urbanisation, land scarcity, and historical development patterns. Consequently, some neighbourhoods enjoy convenient access to high-quality recreational facilities, whereas others remain underserved. These disparities have shifted research attention beyond the physical provision of parks towards evaluating whether residents can access recreational parks equitably and within reasonable travel distances. Therefore, understanding the characteristics and planning hierarchy of recreational parks provides the conceptual foundation for evaluating accessibility. Assessing whether recreational parks are appropriately distributed relative to residential areas requires spatial accessibility analysis, which is discussed in the following section.

Recreational Parks: Accessibility and Distance from Residential Area

Accessibility is widely recognised as one of the most important indicators for evaluating the effectiveness of recreational parks because the benefits provided by green spaces can only be realised when residents are able to reach them conveniently. Rather than referring solely to physical distance, accessibility is a multidimensional concept that reflects the ease with which individuals can travel from their residences to recreational parks. Contemporary studies emphasise that accessibility should incorporate spatial, temporal, economic, and social dimensions to provide a comprehensive assessment of park service provision (Chen et al., 2024; Mao et al., 2023). The spatial accessibility is mainly influenced by the spatial relationship between the residential areas and the recreational parks. Euclidean (straight-line) distance has traditionally been utilized to measure accessibility because of its simplicity and computational efficiency. However, straight-line distance is frequently used to overestimate the actual accessibility without considering physical barriers, transportation networks and pedestrian movement patterns. Consequently, recent GIS-based studies advocate the use of road-network distance and travel-time analysis, which better represent actual travel behaviour and provide more realistic estimates of accessibility (Wang et al., 2021; Mao et al., 2023; Zhou et al., 2023). Accessibility is also affected by travel time and convenience of transport, in addition to spatial distance. Residents' access to recreational parks depends on the availability of public transportation, cycling infrastructure, pedestrian pathways and interconnected road networks. Liu et al. (2022) demonstrated that parks located within approximately 15 minutes of walking or cycling encourage greater participation in recreational activities and contribute to healthier urban living. Likewise, the concept of the 15-minute city has reinforced the importance of locating recreational facilities within convenient travel distances to promote equitable access and sustainable urban mobility (Vale and Lopes, 2023). The accessibility of recreational parks is also affected by the attraction of recreational parks. Park quality affects residents' visiting choice and the physical accessibility of a park is defined as spatial proximity to residents. Factors contributing to the attractiveness of parks and increased visitor frequency include recreational facilities, landscape quality, vegetation, safety, cleanliness, and functional diversity. Chen et al. (2024) argued that accessibility assessments should therefore consider both spatial accessibility and service quality, since nearby parks with limited facilities may provide fewer benefits than slightly more distant parks offering diverse recreational opportunities. Moreover, socioeconomic and demographic user characteristics affect accessibility. Population density, age structure, household income, mobility and affordability of travel all influence the demand for, and individuals' ability to access, recreational spaces. Dai et al. (2022) demonstrated that neighbourhoods with similar numbers of parks may still

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experience substantial inequalities in accessibility because demographic characteristics and transportation opportunities differ across communities. Similarly, Jeon and Jung (2023) reported that evaluating floating populations alongside residential populations provides a more comprehensive understanding of spatial equity in recreation park accessibility.

Several analytical approaches have been developed to evaluate recreational park accessibility. These approaches can generally be categorised into four (4) main methods which are statistical indicator-based assessments, integrated accessibility indices incorporating travel distance or travel time, shortest-path and network-based accessibility analysis, and gravity-based models that examine the relationship between population demand and the supply of recreational parks. Among these approaches, network-based accessibility analysis has become increasingly popular because it incorporates actual transportation routes and travel impedance, thereby providing more realistic representations of accessibility than conventional Euclidean distance measurements (Wang et al., 2021; Mao et al., 2023; Zhou et al., 2023). With the development of accessibility assessment methods, an enhanced Two-Step Floating Catchment Area (2SFCA) method has also been introduced to provide a more comprehensive evaluation. This method integrates factors such as travel impedance, service capacity, and population demand, thereby enabling planners to assess spatial equity more effectively (Wang et al., 2023; Dai et al., 2022; Jeon and Jung, 2023). The importance of accessibility is not limited to transportation efficiency. It also has a direct influence on public health and community well-being.

However, previous studies have largely focused on measuring accessibility and the analytical methods used, while less attention has been given to the conceptual database structure required to support the integration of relevant datasets. Recreational Park accessibility analysis involves several interconnected datasets, including recreational parks, residential areas, transportation networks, park access points, and accessibility indicators. Without a clear conceptual structure, these datasets may be difficult to integrate systematically and consistently within a GIS database.

Therefore, the development of a conceptual database model can be considered an important component that complements GIS-based accessibility analysis. In this context, the ERD is not intended to replace existing accessibility assessment methods. Instead, it provides a logical foundation for organising the entities, attributes, and relationships among the datasets required to support these analytical methods.

Entity–Relationship Data (ERD) Model for GIS-Based Analysis

The use of GIS in urban planning has expanded the ways in which recreational park accessibility, spatial equity, and service coverage can be examined. By combining spatial and attribute data, GIS allows planners to map park locations, assess travel networks, model accessibility, and support planning decisions based on spatial evidence. However, the usefulness of these analyses is closely related to the quality and organisation of the underlying geospatial database. A database that is poorly structured may contain redundant or inconsistent information, make data retrieval more difficult, and affect the accuracy of subsequent analysis, regardless of the GIS techniques applied (Bagui & Earp, 2022). For this reason, conceptual database design is an important step in developing a GIS database, as it provides a structured representation of the geographic features, attributes, and relationships that will later be implemented in the database.

Among the different approaches used for conceptual database modelling, the Entity–Relationship Diagram (ERD), originally proposed by Chen, is commonly used to describe the structure of a database. It represents entities, their attributes, and the relationships between them in a visual form, making it easier to understand how different types of information are connected. This can help both database developers and domain experts identify the required data and clarify the structure of the database before implementation (Bagui et al., 2022; Hampel, 2022). The role of conceptual modelling is particularly relevant in GIS, where datasets often contain spatial and non-spatial information that are linked to one another. In the case of recreational park accessibility, for example, parks, residential areas, road networks, park access points, accessibility measures, and administrative boundaries may be related in different ways. Defining these relationships at the conceptual level helps ensure that the required information is organised coherently and can be translated into a suitable database structure for subsequent GIS-based analysis.

Apeh and Abdul Rahman (2023) highlighted the role of suitable conceptual spatial data models in improving data interoperability by bringing different types of spatial datasets together within a common database structure. Having the datasets organised in this way can make spatial queries and data management more efficient and provide a more consistent basis for GIS analysis. Recent research also points to the value of ERDs in organising database components and improving the overall management and quality of information. Palinggi et al. (2024) reported that an ERD facilitates communication between database designers and system users by providing clear visual representations of data structures and logical relationships. Likewise, Skavantzos and Link (2025) highlighted that conceptual data models remain fundamental for maintaining data integrity, semantic consistency, and interoperability, particularly as database technologies evolve towards increasingly complex graph-based environments. These findings indicate that conceptual database modelling remains relevant despite advances in database technologies and intelligent information systems.

Although previous studies on recreational park accessibility have developed increasingly advanced GIS-based analytical methods, relatively limited attention has been given to the conceptual organisation of the datasets required to support such analyses. This gap forms the basis of the present study, which focuses on developing an ERD based on the spatial and non-spatial data requirements for recreational park accessibility analysis and the assessment of distance between residential areas and recreational parks.

In this context, the proposed ERD serves as a conceptual model rather than an accessibility analysis method itself. Instead, it provides a foundational structure for organising the entities, attributes, and relationships among the required datasets. This structure can subsequently support the implementation of GIS-based analyses, including proximity assessment, network analysis, and accessibility modelling, once the relevant datasets and analytical procedures have been developed.

Methodology

Research Approach

This study adopts a conceptual database design approach to develop an ERD to support GIS-based assessment of recreational park accessibility and spatial distance between residential areas and recreational parks. The methodology focuses on three (3) main aspects which are

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identifying spatial and non-spatial data requirements, defining the relevant entities and attributes, and establishing relationships between entities to systematically represent the study domain. Seri Iskandar, Perak, Malaysia, was selected as the study area and provides the geographical context for determining the data requirements related to recreational parks, residential areas, transportation networks, and park access points. To support the implementation of spatial analysis at a later stage, the identified spatial datasets should be prepared and managed using suitable GIS software or platforms, such as QGIS or ArcGIS Pro.

The ERD was developed using Chen's Entity–Relationship notation, which provides a standardised approach for representing entities, attributes, and relationships within a database environment. Chen's notation is widely applied in conceptual database modelling due to its ability to provide clear visualisation of data structures and their interrelationships, thereby supporting data integrity, consistency, and efficient database implementation. The development of the database structure in this study is based on the ERD approach using Chen's notation, which is widely recognized as a fundamental conceptual data modelling technique for database design. Chen's ERD notation provides a systematic and comprehensive representation of entities, attributes, and relationships, enabling the clear visualisation of data requirements and their interactions within a database environment (Rosli et al., 2023). Its reliability and flexibility have contributed to its widespread adoption for conceptual database modelling across various application domains (Hampel, 2022; Pulungan et al., 2023). The adoption of Chen's ERD notation in this study facilitates the development of a structured database framework for GIS-based analyses of recreational park accessibility and spatial proximity to residential areas. By explicitly defining entities and their interrelationships, the ERD serves as a conceptual foundation for organising spatial and non-spatial data, ensuring data consistency, integrity, and efficient management within the database system, (Skavantzos and Link, 2025; Palinggi et al., 2024). The model also supports the integration of multiple datasets required for accessibility assessment and spatial analysis, thereby enhancing the reliability of decision-support processes in recreational planning (Skavantzos and Link, 2025). An ERD provides a visual approach to database design by showing the main data entities, their attributes, and the relationships between them. This visual representation makes it easier for people with different technical and organisational backgrounds to discuss database requirements and develop a shared understanding of how the data should be structured (Palinggi et al., 2024; Afiifah et al., 2022). For a GIS database, the ERD should clearly identify the data required for the intended application and how the different components are related. A properly designed ERD can therefore help ensure that the relevant entities, attributes, and relationships are captured before the database is implemented, providing a suitable structure for GIS-based recreational park accessibility analysis (Bagui & Earp, 2022; Palinggi et al., 2024).

Table 1: ERD Notation

Components	Explanation
Entity	An entity refers to a distinct object, concept, or phenomenon within a particular domain that can be identified and described using a set of attributes. It forms one of the basic components of a database model and can represent real-world elements such as people, places, facilities, or events. The attributes associated with an entity describe its characteristics and help distinguish it from other entities in the database. By representing real-world elements and their relevant properties in a

	structured way, entities provide a basis for organising, storing, and managing information within a database.
Attributes	An attribute refers to a specific piece of information used to describe the characteristics or properties of an entity. It provides details about an entity and helps define the type of information that needs to be stored in the database. Attributes may include an identifying value, such as an ID that distinguishes one entity instance from another, as well as descriptive values that provide further details about the entity. For example, a recreational park may have attributes such as Park_ID, Park_Name, Park_Type, and Park_Size. Clearly defining the required attributes helps maintain consistent data, supports data retrieval, and ensures that relevant characteristics of real-world objects are properly represented in the database.
Relationship	A relationship describes the connection between two or more entities in a database. It shows how different entities are associated with one another and helps link related information within the database structure. For example, a recreational park may be connected to its access points, while an accessibility assessment can link a residential area to a particular park. Defining these relationships helps organise related data and reflects how the corresponding elements are connected in the real world. It also supports the consistent storage and retrieval of information across related entities. The proper specification of relationships is therefore essential for achieving data consistency, integrity, and efficient database performance in both conceptual and logical database design.

Source: Rosli et al., 2023.

Data Requirements

The database structure requires both spatial and non-spatial datasets. The spatial datasets represent the geographic locations and geometries of the study components, while non-spatial datasets describe the characteristics and attributes associated with those spatial features.

The spatial datasets identified for the proposed database include:

i. Recreational Parks;
ii. Residential Areas;
iii. Road Network;
iv. Park Access Points; and
v. Administrative Boundaries.

ERD Development Process

The development of the ERD database structure for GIS-based analyses of recreational park accessibility and spatial proximity to residential areas requires a comprehensive understanding of the study domain and data requirements (Rosli et al., 2023) To ensure a systematic and robust database design, the database development process was conducted through three (3) main stages, namely;

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i. **Stage 1**: Identifying the spatial and non-spatial data required to support accessibility and proximity analyses,
ii. **Stage 2**: The entities and their associated attributes are defined based on the data requirements of the recreational park and residential area database,
iii. **Stage 3**: The relationships between the identified entities are established to describe how the different data components are connected within the database.

Together, these stages provide the conceptual structure for developing an integrated GIS database. The resulting structure supports the systematic organisation of spatial and non-spatial data and provides a basis for subsequent accessibility and spatial proximity analyses related to recreational park planning and management.

Results and Discussions

The resulting ERD consists of five (5) core entities: Recreational Park, Residential Area, Road Network, Park Access Point, and Accessibility Assessment. These entities collectively represent the main spatial and non-spatial components required for recreational park accessibility and spatial distance assessment:

i. **Recreational Parks**: entity represents the destination location and contains information on park identity, type, size, and facilities.
ii. **Residential Areas**: entity represents the residential origin and contains information on residential identity, population, and housing type.
iii. **The Road Network**: entity represents the transportation infrastructure connecting residential locations and recreational parks.
iv. **Park Access Points**: entity represents the actual entrance locations of recreational parks.
v. **Accessibility Assessment**: entity functions as an associative entity between Residential Area and Recreational Park and provides fields for storing distance, travel time, and accessibility classification.

The database modelling process resulted in the establishment of clear relationships among the five (5) entities through the use of primary and foreign keys. For example, Park_ID serves as a unique identifier for each recreational park and is used as a foreign key in the Park Access Point and Accessibility Assessment entities. Similarly, Residential_ID links residential area information with the corresponding accessibility assessment records. This structure establishes logical connections between origins, destinations, transportation networks, access locations, and assessment records, providing a well-organised foundation to support GIS modelling and analysis.

Each entity represents a specific component of the recreational park accessibility system and contains the spatial and attribute data required for GIS-based analysis. The relationships among these entities allow spatial features, transportation networks, park access points, and accessibility indicators to be organised within a single database structure. This integrated structure facilitates the management and linking of spatial and attribute data in a GIS environment, while providing a foundation for proximity assessment, service area analysis, network analysis, and decision-making related to equitable access to recreational parks. The development of the ERD database structure was conducted through three (3) stages,

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incorporating both spatial and attribute data required to support GIS-based analyses of recreational park accessibility and spatial proximity to residential areas.

Stage 1: Identifying The Spatial and Non-Spatial Data Required to Support Accessibility and Proximity Analyses.

The first stage in developing ERD database structure involves identifying the spatial and non-spatial datasets required to support GIS-based analyses of recreational park accessibility and spatial proximity to residential areas. The quality and completeness of these datasets are critical because they determine the capability of the database to support spatial analysis, accessibility assessment, and evidence-based planning decisions. Recent studies have emphasized that the integration of spatial and attribute data forms the foundation of GIS-based accessibility modelling, enabling researchers and planners to evaluate the distribution, coverage, and accessibility of public facilities within urban environments (Chen et al., 2024; Jeon and Jung, 2023).

Spatial Data

Spatial datasets provide information on the location and characteristics of geographic features within the study area. Recreational Park data are used to define the location and extent of each park, which serve as the main destinations in the accessibility analysis. These data also help to examine how recreational parks are distributed within the study area. Residential Area data are also essential as they represent the locations from which residents' access and use these recreational facilities. Residential Area data are important for examining the distribution of recreational parks in relation to the communities they serve. These data can be used to determine whether residents have reasonable access to recreational facilities based on acceptable travel distances (Wang et al., 2023; Dai et al., 2022). Road Network data are also important in the accessibility assessment, particularly when travel routes are considered instead of measuring straight-line distances. Factors such as road connectivity, route length, and travel impedance can be incorporated into GIS network analysis to provide a more realistic estimate of accessibility between residential areas and recreational parks. The data can therefore be used to determine travel distances, service areas, and route-based accessibility measures that support recreational planning (Hashtarkhani et al., 2024; Wang et al., 2023). Park Access Point data are included to represent the actual entrances used by visitors to enter recreational parks. Using these locations instead of the centre point of a park can provide more realistic results when measuring accessibility and defining service areas. Administrative Boundary data, meanwhile, provide a spatial reference for organising and presenting the analysis results according to different planning areas, such as districts, municipalities, or neighbourhoods. This information can also assist in comparing accessibility conditions and supporting planning and policy decisions. (Refer Table 2)

Table 2: Spatial Dataset for the Proposed ERD

Dataset	Function
Recreational Parks	Identify Park boundaries and spatial locations
Residential Areas	Represent residential locations and population served
Road Network	Represent transportation routes
Park Access Points	Identify actual park entrance locations

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Administrative Boundaries	Provide geographical framework for planning and reporting

Non-Spatial Data

In addition to spatial datasets, non-spatial or attribute data are needed to describe the characteristics of the geographic features included in the database (Chen et al., 2024; Hashtarkhani et al., 2024). For the Recreational Parks entity, attributes such as Park_ID, park name, park type, area, and available facilities describe the main characteristics of each park. These details allow the database to distinguish between parks based on their location, type, size, and available services (Wang et al., 2023; Chen et al., 2024). For Residential Areas, attributes such as Residential_ID, population, and housing type provide information about the communities located around the parks and can be used when comparing accessibility across different residential areas or population groups (Jeon and Jung, 2023). The Road Network entity includes attributes such as Road_ID, road classification, and road length, which provide the information required for route-based analysis and travel distance calculations (Hashtarkhani et al., 2024; Wang et al., 2023). Meanwhile, the Park Access Point entity records information about individual entrances and their characteristics, allowing access to the parks to be considered from actual entry locations. Together, these spatial and non-spatial attributes provide the data needed to organise recreational park accessibility information within the GIS database. They also inform the development of the ERD by defining the main entities, their attributes, and the relationships between them. This arrangement allows the relevant data to be connected and managed consistently, providing a suitable structure for subsequent proximity and accessibility analyses.

Table 3: Non-Spatial Attributes for the Proposed ERD

Entity	Attributes
Recreational Parks	Park_ID, Park_Name, Park_Type, Park_Size, Facilities
Residential Areas	Residential_ID, Residential_Name, Population, Housing_Type
Road Network	Road_ID, Road_Name, Road_Type, Length
Park Access Points	Access_ID, Park_ID, Access_Type
Accessibility Assessment	Assessment_ID, Residential_ID, Park_ID, Distance_m, Travel_Time, Accessibility_Level

Clearly defining the attributes helps maintain an organised and consistent database by specifying the information required for each entity. However, the conceptual ERD presented in this study should not be taken as evidence of improved analytical accuracy. Any improvement in analytical performance would need to be assessed after the database has been implemented and the resulting GIS analyses have been tested and compared with other approaches.

Stage 2: Formulation Of Entities and Their Associated Attributes, Representing the Key Components of the Recreational Park and Residential Area Database System.

The second stage in the ERD development process focuses on identifying the entities required for the study and defining the attributes associated with each entity. At the conceptual level, entities represent the real-world objects or phenomena relevant to the study, while attributes provide information about their characteristics. Identifying these components carefully is important because they determine what information will be captured and how it will be organised within the database. Previous studies have also highlighted that clearly defined entities and attributes can contribute to greater consistency, data integrity, and interoperability, particularly when databases are used to support analysis and decision-making (Palinggi et al., 2024; Avignone et al., 2025).

Within the proposed GIS database, the **Recreational Park** entity represents the main destination considered in the accessibility assessment. It consists of several attributes, namely Park_ID, Park_Name, Park_Type, Park_Size, and Facilities. Park_ID serves as the primary key and provides a unique identifier for each park in the database. Park_Name is used to identify the park, while Park_Type describes its position within the planning hierarchy, such as local, neighbourhood, or district park. This classification is relevant because parks at different levels of the hierarchy may serve different catchment areas and user groups. Park_Size records the area of each park and may provide an indication of the amount of space available for recreational activities. The Facilities attribute records the amenities provided within each park, allowing the database to capture information about the services available in addition to the park's location. Previous studies suggest that park characteristics and the range of facilities provided can influence how people use recreational spaces and how accessibility is experienced, indicating that park assessment should consider factors beyond distance alone (Chen et al., 2024; Jeon and Jung, 2023). Refer table 4.

The **Residential Area** entity represents the location of the population from which park accessibility is assessed. Its main attributes are Residential_ID, Residential_Name, Population, and Housing_Type. Residential_ID acts as the primary key and provides a unique identifier for each residential area, while Residential_Name is used to identify the respective residential zone. The Population attribute provides an indication of the number of people potentially served by nearby recreational parks and can be used in analyses that consider differences in access between residential areas. Housing_Type describes the characteristics of the residential development and may provide additional context when examining patterns of park access and recreational needs. Including population and residential characteristics in the GIS database also allows accessibility to be examined from a spatial equity perspective, particularly when comparing access among different residential areas and population groups (Dai et al., 2022; Jeon and Jung, 2023). Refer table 4.

The **Road Network** entity represents the transportation infrastructure that connects residential areas with recreational parks and provides the basis for route-based accessibility assessment. Its main attributes include Road_ID, Road_Name, Road_Type, and Length. Road_ID serves as the primary key for identifying individual road segments, while Road_Name and Road_Type provide information about the roads and their classification within the study area. The Length attribute records the extent of each road segment and can be used as part of travel distance calculations when route-based analysis is carried out. Unlike straight-line distance, network-based accessibility assessment considers the available road connections and actual travel routes between locations, providing a representation of accessibility that is more closely related to movement through the transportation network (Hashtarkhani et al., 2024; Wang et al., 2023). Refer table 4.

The **Park Access Point** entity represents the physical entrances through which recreational parks can be accessed. Its attributes include Access_ID, Park_ID, and Access_Type. Access_ID serves as the primary key, while Park_ID functions as a foreign key linking access points to the corresponding recreational parks. The Access_Type attribute differentiates between various entrance categories, such as main entrances and secondary entrances. The inclusion of access point information improves the accuracy of accessibility analyses because park entrances represent actual locations where accessibility occurs rather than generalized park centroids (Zhou et al., 2024; Jeon and Jung, (2023); Wang et al., 2023; Rigolon et al., 2022). Refer table 4.

The **Accessibility Assessment** entity represents the relationship between residential areas and recreational parks and provides fields for recording assessment outputs. Its attributes include Assessment_ID, Residential_ID, Park_ID, Distance_m, Travel_Time, and Accessibility_Level. Assessment_ID uniquely identifies each accessibility record, while Residential_ID and Park_ID function as foreign keys that establish links between residential areas and recreational parks. Distance_m records the travel distance between origin and destination locations, whereas Travel_Time measures the estimated duration required to reach a park. Accessibility_Level provides a classification of accessibility conditions, such as high, medium, or low accessibility. The incorporation of these attributes enables the database to store analytical outputs and supports subsequent evaluations of spatial accessibility, service coverage, and recreational equity (Skavantzos and Link, 2025). Refer to Table 4.

Users and transportation modes are not included as independent entities in the current ERD because the present study focuses on the conceptual relationship between recreational parks, residential areas, road networks, park access points, and accessibility assessment. If user behaviour or multimodal accessibility is incorporated in future research, additional entities may be introduced to represent these dimensions. Based on the identified datasets, Table 4 shows the entities and attributes of recreational park accessibility and distance from residential areas database structure.

Table 4: Entities and Attributes of Recreational Park Accessibility and Distance from Residential Areas Database Structure

Entities	Attributes	Description
Recreational Park	Park_ID (PK)	Unique park identifier
	Park_Name	Name of park
	Park_Type	Local, neighbourhood, district
	Park_Size	Area (ha)
	Facilities	Available facilities
Residential Area	Residential_ID (PK)	Unique identifier
	Residential_Name	Name of residential area
	Population	Total population
	Housing_Type	Housing classification
Road Network	Road_ID (PK)	Road identifier
	Road_Name	Road name
	Road_Type	Classification
	Length	Road length
Park Access Point	Access_ID (PK)	Entrance identifier
	Park_ID (FK)	Linked park
	Access_Type	Main entrance, secondary entrance
Accessibility Assessment	Assessment_ID (PK)	Accessibility record

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Residential_ID (FK)	Residential area
Park_ID (FK)	Recreational park
Distance_m	Distance travelled
Travel_Time	Estimated travel time
Accessibility_Level	High, Medium, Low

Spatial Dimension of the Seri Iskandar Study Area

The spatial aspect of this study is represented by the relationships among recreational parks, residential areas, road networks, and park access points in Seri Iskandar, Perak. These components provide the basic data structure needed to examine the distance and accessibility between residential areas and recreational parks. However, this study focuses only on developing the conceptual database and does not include actual results for distance, travel time, or accessibility at specific locations in Seri Iskandar. Instead, the Accessibility Assessment entity includes the attributes Distance_m, Travel_Time, and Accessibility_Level. These attributes can be used to store the results once the proposed database is implemented and the relevant GIS analyses are carried out.

Stage 3: Identifying The Relationships Among the Entities to Accurately Represent the Interactions and Dependencies Within the Database

The final stage involves identifying the relationships between the entities included in the database model. These relationships show how the different entities are connected and interact with one another, helping the database structure represent the relationships found in the real-world setting. In ERD modelling, relationships are commonly expressed through verbs that describe the nature of the connection between two entities. Establishing appropriate relationships is essential for maintaining data integrity, reducing redundancy, and supporting efficient database operations. The relationships identified in this study are presented in Figure 1.

i. The **Recreational Park** entity is associated with **Park Access Point** through a one-to-many (1:M) relationship because one recreational park may contain multiple access points.
ii. The **Accessibility Assessment** entity establishes the relationship between **Residential Area** and **Recreational Park**. This represents the many-to-many relationship in which one residential area may be associated with multiple recreational parks, while one recreational park may serve multiple residential areas.
iii. The **Road Network** provides the transportation infrastructure required for route-based distance and travel-time assessment.

These relationships establish the conceptual data structure required for subsequent GIS-based proximity and network analysis. However, the ERD itself does not perform these analyses; rather, it provides the database structure in which the relevant spatial data and analytical results can subsequently be organised and stored.

Following the identification of entities and attributes, the database structure was conceptualized using Chen's ERD notation. This graphical modelling technique provides a clear and organised way to show the data components and how they are connected using standardised symbols.

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This makes the database structure easier to visualise and understand. The conceptual ERD generated in this study is illustrated in Figure 1.

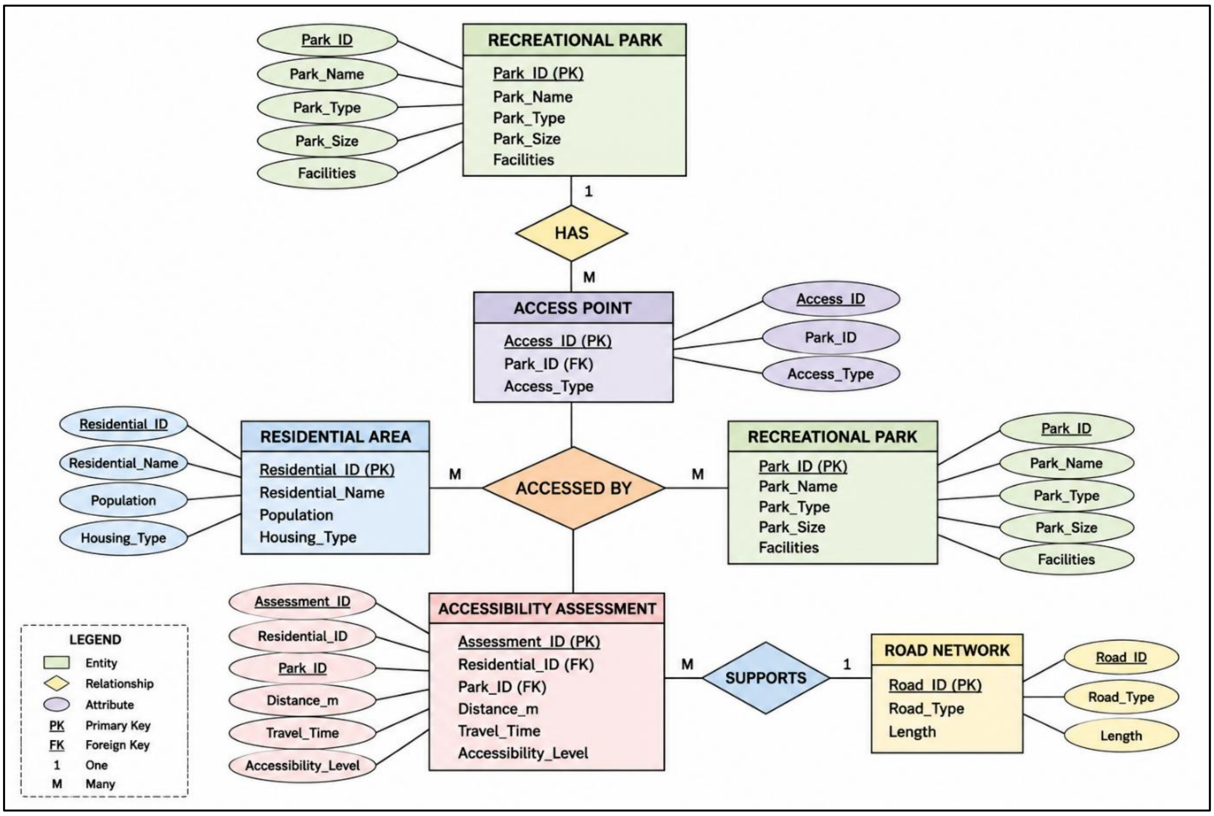

Figure 1: Entity–Relationship Data Model for GIS-Based Analysis of Recreational Park Accessibility and Distance from Residential Areas

The main contribution of this study is the development of a conceptual GIS database model, rather than the creation of a new accessibility algorithm or a fully operational decision-support system. The model provides a structured representation of the entities, attributes, and relationships required to organise data for recreational park accessibility and spatial distance assessment. The model contributes in three (3) main ways. First, it provides a systematic structure for integrating spatial and non-spatial datasets. Second, it explicitly defines the relationships among recreational parks, residential areas, road networks, park access points, and accessibility assessment records. Third, it provides a conceptual foundation for subsequent implementation within a GIS environment. The contribution should therefore be interpreted primarily in terms of improved database organisation, consistency, and integrity rather than empirically demonstrated improvements in analytical accuracy.

Conclusion

This study developed an ERD as a conceptual GIS database structure for recreational park accessibility and spatial distance assessment in Seri Iskandar, Perak. The proposed model consists of five (5) core entities: Recreational Park, Residential Area, Road Network, Park Access Point, and Accessibility Assessment. The explicit definition of entities, attributes, primary keys, foreign keys, and relationships provides a systematic structure for organising the spatial and non-spatial datasets required for subsequent GIS analysis. The proposed ERD integrates recreational park locations, residential areas, road networks, park access points, and

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accessibility assessment records within a single database structure. The Accessibility Assessment entity contains attributes such as distance, travel time, and accessibility level, allowing the database to accommodate the outputs generated from subsequent spatial analyses. It is important to clarify that the ERD does not itself carry out proximity, network, or multi-criteria analysis. Rather, it defines the data structure and relationships required for these analyses to be carried out after the database is implemented in a GIS environment. The main contribution of the model is therefore its organisation of the relevant spatial and non-spatial datasets and the definition of relationships that support consistent data management. While this structure provides a basis for subsequent analysis, any improvement in analytical accuracy would need to be established through database implementation and comparative GIS testing. Overall, the study proposes a conceptual ERD-based GIS database model that provides a structured basis for analysing recreational park accessibility and spatial distance from residential areas. The proposed model provides a structured basis for future implementation in a GIS environment and supports the integration of the datasets needed for recreational park planning. It can also be adapted to other study areas with similar planning needs by modifying or extending the entities, attributes, and relationships to suit local data availability and planning objectives. This flexibility makes the model applicable to different contexts where park, residential, transportation, and access-point data need to be brought together within a common database structure. However, further work is needed to assess its practical application. Future research should implement the proposed ERD in an operational GIS database, carry out proximity and network-based accessibility analyses using actual spatial data, and evaluate the resulting database structure through empirical testing.

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