Using GIS to Determine the Best Areas for Displacement from Khartoum State to Other States in Sudan

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Abstract

This study tries clarify the process of making decisions with geographic information systems and how to choose the best place for Khartoum State displaced people to relocate to in order to be closer to cheaper places with access to commodities and services. For network analysis, use a unique model. The network analysis tool was dependent on the following information: availability of goods and services, cheap cost, and proximity to the state of Khartoum.in choosing the best state. The study came to the conclusion that, in terms of accessibility, affordability, and availability of products and services, Gezira State is the best state for people who have been displaced from Khartoum State.When developing a new model, we recommend that all GIS users apply the theories of spatial analysis.

Keywords:

GIS; Arc GIS; Map Layers. best state

1. Introduction

By leveraging GIS technology, policymakers and humanitarian organizations can enhance their ability to identify areas suitable for wartime displacement from Khartoum State to other states in Sudan. The integration of various spatial data layers and analytical techniques allows for a comprehensive assessment of factors such as conflict zones, population distribution, infrastructure and environmental considerations. However, challenges such as data availability, technical expertise and ethical considerations should be addressed to maximize the potential of GIS in displacement management. With continuing research, collaboration and technological advances, GIS can play a crucial role in mitigating the negative effects of armed conflicts on civilian populations

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The paper would present a mathematical optimization model, potentially based on Integer Linear Programming (ILP) or location-allocation models, to determine the optimal areas for displacement based on various criteria. The objective function would be formulated to maximize the suitability of selected areas while considering constraints such as proximity to conflict zones, accessibility to essential services , During armed conflicts, once the data layers are prepared, various analytical techniques can be employed. Suitability analysis helps identify areas that meet specific criteria for displacement, such as proximity to essential services or safe distances from conflict zones. Vulnerability assessment evaluates the susceptibility of potential displacement areas to risks and hazards. Accessibility and proximity analysis assess the ease of access to transportation networks, healthcare facilities, and other essential services. Multi-criteria decision analysis combines multiple factors and assigns weights to different criteria, enabling a comprehensive evaluation of potential displacement areas.

The application of GIS in displacement management is not without challenges. Data availability and quality can be a limiting factor, as reliable and up-to-date information may not always be readily accessible. Technical expertise and capacity in GIS may also be required to effectively utilize the technology. Ethical considerations surrounding data privacy and security need to be addressed to ensure the responsible use of sensitive information. Additionally, operational constraints, such as limited resources and time constraints, may impact the implementation of displacement of civilian populations is a critical concern. Identifying suitable areas for the relocation and protection of displaced populations is vital for ensuring their safety and well-being. GIS, a powerful tool for spatial analysis and decision-making, can be applied to address this challenge.

GIS integrates various types of spatial data, such as maps, satellite imagery, demographic information, infrastructure data, and environmental factors, into a unified system. This integration allows analysts to overlay and analyze multiple layers of information simultaneously, providing insights into the most appropriate areas for displacement**.**

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2. Methodology

GIS software has been used as one of the methods of thescientific method with its three packages in the latest versionof program (Arc GIS 10.3) and the three packages are: (Arc map, Arc catalog, Arc toolbox). (See **Figure (1)** analog

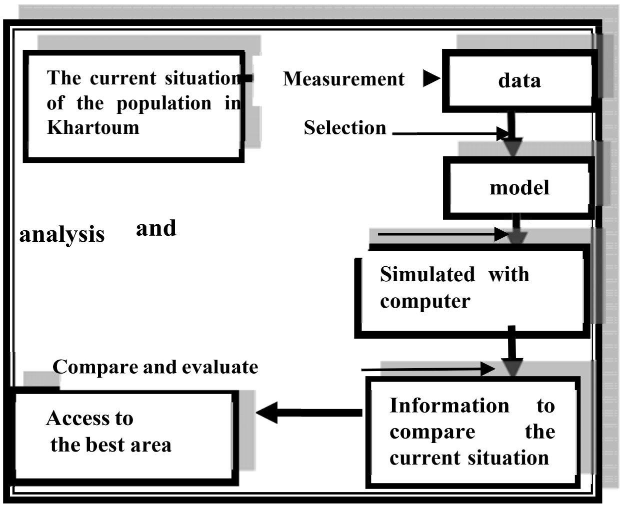


Fig 1: The Diagram Explains the analog model methodology

As (Arc map) is the central application in Arc GIS, it includes a set of important operations in dealing with maps such as addition operations, map analysis, surveying, addition, design and analysis, and provides different waysto display such as viewing geographical data and viewing roads.

The Arc catalog helps in the organization of information collection (GIS) and includes tools to find and display geographic information as well as display, modify and analyze descriptive tables.

Arc toolbox is a simple application that includes most of the GIS tools used, and includes two types of applications:

(1) Complete Arc toolbox, which is present with the program (Arc/Info) with more than 150 transformations and integrated organization.

(2) Lighter is available with Arc view and has about 20 common conversions.

The three applications are designed to work together in anintegrated format. For example, you can search for a map file in (Arc catalog) and then the file can be opened in (Arc map) and we can clear the information through the tools available in toolbox) .The main concern of this effort is to seek to design the best areas for displaced people from Khartoum State and other areas in Sudan.

3. The Theoretical Framework

Geographic Information Systems (GIS) play a crucial role in various aspects related to displacement, especially in aiding decision-making processes when choosing suitable locations for displacement or resettlement. Here's why GIS is important in this context: Spatial Analysis: GIS allows for the analysis of geographical data, including topography, infrastructure, environmental factors, population density, and more. This helps in assessing potential displacement sites based on their suitability and compatibility with the needs of the displaced population.

Risk Assessment and Planning: GIS enables the identification of areas prone to natural disasters, such as flood zones, seismic activity, or areas at risk from climate change. It helps planners and decision-makers choose safer locations for displacement, minimizing risks and vulnerabilities for the affected populations. Resource Allocation and Accessibility: GIS assists in evaluating the accessibility of potential displacement sites in terms of transportation networks, healthcare facilities, schools, and other essential services. This ensures that displaced communities have access to necessary resources.

Stakeholder Collaboration: GIS facilitates collaboration among various stakeholders involved in the displacement process, including government agencies, humanitarian organizations, urban planners, and local communities. It provides a common platform to share and visualize data, fostering better decision-making and coordination.

Demographic Analysis: GIS tools help in analyzing demographic data, including population distribution, cultural factors, and socioeconomic conditions. This information is crucial in understanding the needs and preferences of the displaced population and selecting appropriate locations that align with their requirements.
Land Use Planning and Zoning: GIS assists in evaluating land use patterns and zoning regulations, ensuring that displacement sites comply with legal and regulatory frameworks. It helps in identifying suitable areas for housing, infrastructure development, and community integration .By leveraging GIS technologies, decision-makers can make informed choices when selecting appropriate places for displacement or resettlement, taking into account a wide range of spatial, environmental, social, and infrastructural factors. This helps ensure the well-being and safety of displaced populations while facilitating their integration into new environments .Make the best decision or the most appropriate choice regarding the relocation and protection of displaced populations. Software was used in

this study to build a database to identify the best places for displacement, determine spatial accuracy, and compare preference between three states to determine the most appropriate among them.

In studying the impact of war on transportation lines, these equations can be used to quantify changes in distances, accessibility, costs of travel, flow of goods or people, and the efficiency of transportation networks .
the distance between two points (e.g., cities, strategic locations) can be calculated using the Euclidean distance formula in a Cartesian coordinate system
This equation computes the straight-line distance between two points given their coordinates (x1, y1) and (x2, y2).

Euclidean Distance $d=\sqrt{(X1-X2)2+((Y1-Y2)2}$
Cost-Distance Analysis : In transportation studies, it's often crucial to factor in the cost of traveling between locations. The cost can be based on various factors such as road conditions, terrain,

Cost-Distance Analysis $\mathbf{D}=\sum_{i=1}^{n}\mathbf{C_i}\ \ \mathbf{x}\ \ \mathbf{d_i}$

ci represents the cost associated with each segment of the route
di denotes the distance of that segment

The total cost-distance (D) is the sum of costs for each segment traversed.

Network Analysis: For more complex transportation networks, graph theory and algorithms like Dijkstra's algorithm or the shortest path algorithms are used to find the shortest or most efficient routes between locations. These algorithms involve equations to determine optimal paths based on distance, time, or other constraints. Gravity models : This model estimates the flow of goods or people between two locations based on their masses (population, economic activity) and the distance between them. The equation can take the form:
Model: F=k× M1×M/ d2

Here, F represents the flow of goods or people, M1 and M2 denote the masses of the locations, d is the distance between them, and k is a proportionality constant. The gravity model of migration is a model in urban geography derived from Newton's law of gravity, and used to predict the degree of migration interaction between two places.[1] Newton's law states that: "Any two bodies attract one another with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them." When used geographically, the words 'bodies' and 'masses' are replaced by 'locations' and 'importance' respectively, where importance can be measured in terms of population numbers, gross domestic product, or other appropriate variables. The gravity model of migration is therefore based upon the idea that as the importance of one or both of the location increases, there will also be an increase in movement between them. The farther apart the two locations are, however, the movement between them will be less. This phenomenon is known as distance decay.
The gravity model can be used to estimate :traffic flow migration between two areas , measure accessibility to services (e.x., access to health care).

4. Data analysis

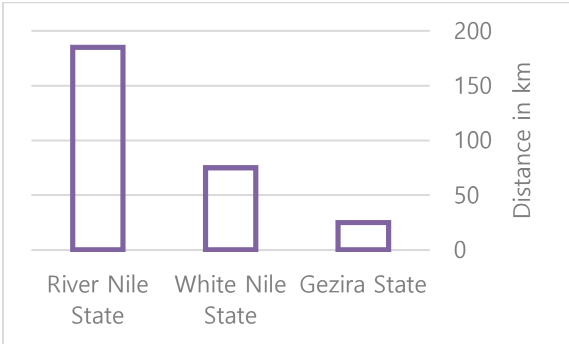


Fig 2 Explains The closest point to Khartoum State

The distance between the three states and Khartoum State is shown in the table above. It should be emphasized that the figures show how close Gezira State is to Khartoum State, the location of the displaced.

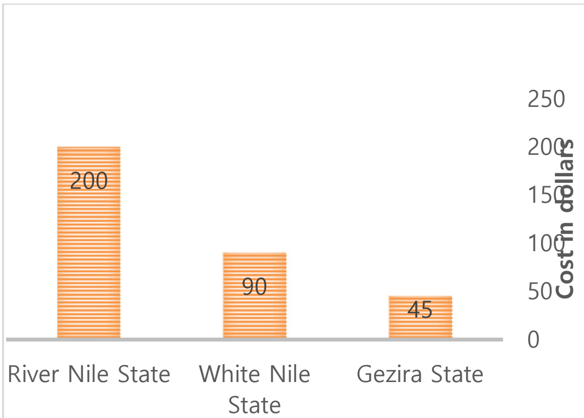


Fig 3: A comparison of the percentage of services available in the three states.

The cost of moving displaced people from Khartoum State to the closest of the three states during a war is shown in Fig. 3. A huge number of people traveled at a high cost per person because there were many checkpoints and there wasn't enough fuel for the transport vehicles.

Table 1

Agricultural projects and services	Personal goods	cattle and livestock goods	Energy goods	Agricultural goods	
81.5	80	77	89	80	Gezira State
56.25	50	50	65	60	White Nile State
61.25	45	65	70	65	River Nile State

The table includes data about the many products and projects that are available in the three states that are closest to Khartoum State. The columns denote various categories of products or services, and each row is a registry of states. Based on the data, we can observe that Al Gezira State has a higher percentage of agricultural products (80), energy goods (89), cattle and livestock (77), and personal goods (80) than other states. Services and projects related to agriculture: 81.5.

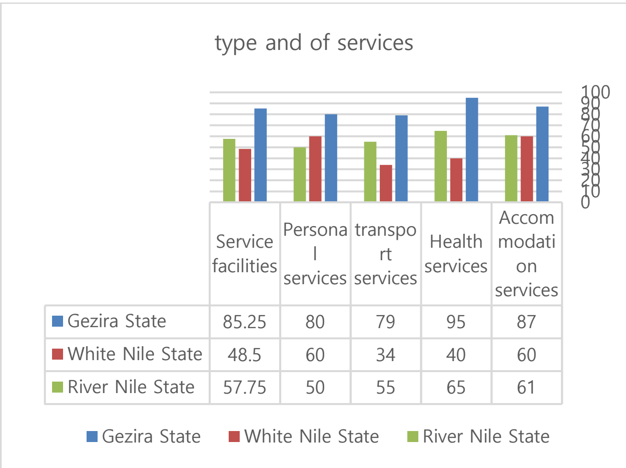


Fig 6 : show type and size of services in the states

The A comparison between the availability of agricultural and livestock projects and the availability of goods , from the data, we notice the extent of the differences in the type and size of services in the three states , data indicate that the state of Al-Gezira is the most attractive to displaced people

Percentage of services available in each state

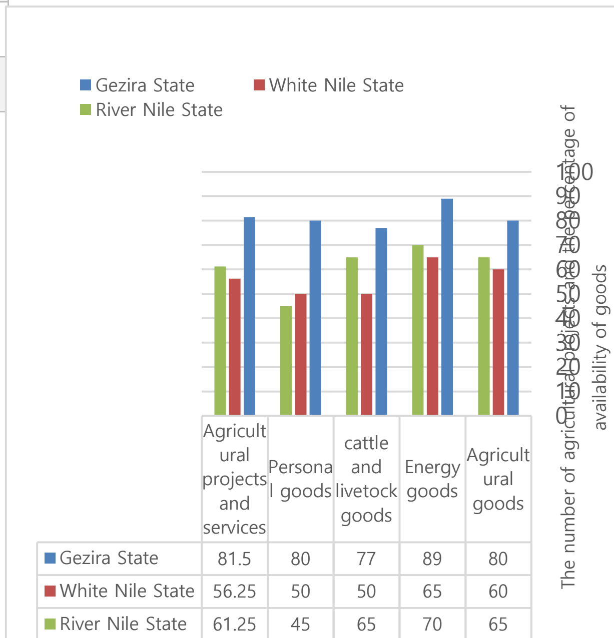


Fig 5: show type of goods.

A comparison of the accessibility of items and projects related to agriculture and livestock. We are able to determine from the data how different the types and sizes of commodities are between the three states, and to what extent.

According to the data, the state of Al-Gezira has the highest abundance; this could be because the Al-Gezira project offers the biggest agricultural initiatives in both the Middle East and Africa.

1. Application framework

(1) Set up Map Layers:

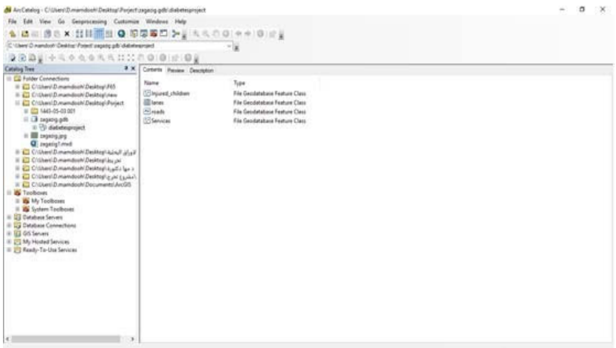


Fig.7: Explains the preparation stage in the Arc Catalog program.

Database setup According to data from the Ministry of Industry and Trade, this stage starts with the preparation of the layers and involves the following factors: attractiveness (the availability of services and goods) and proximity to Khartoum State.

The Figure 7 shows the availability of goods and services in the three states and includes a database of classes (comparing the availability of goods and services, the proximity of the state, and the cost of access the cost of access

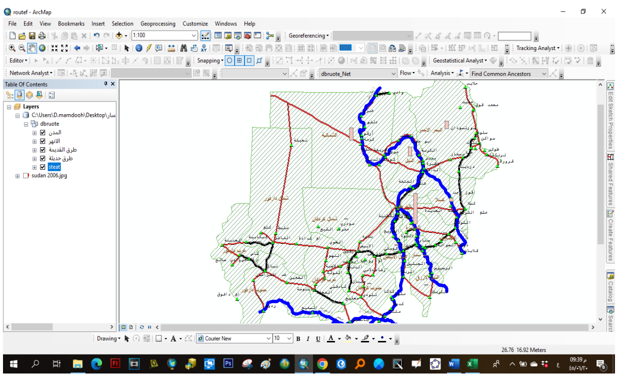
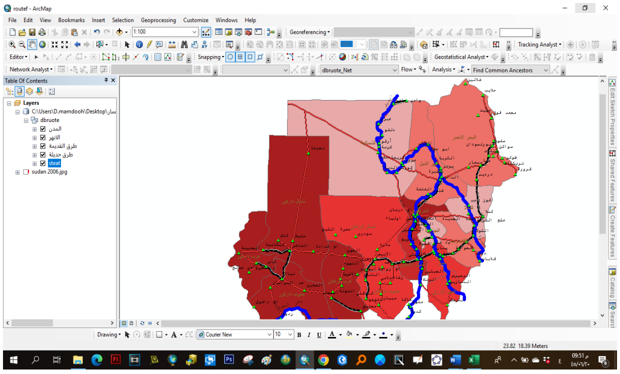


Fig 8: displays the goods and services in each state.

A layer of services and goods follows (distribution of different goods and multiple service centers, prepared in accordance with the guidelines and requirements of the US Geological Survey's National Geospatial Program, taking into account the availability and size of goods and services in terms of their greatest



and least value).

Fig 9: illustrates the suggested states

After the data for all layers has been completed, the first stage is finished, and the second stage starts. During this stage, the two layers are merged to form a single network with a single database that contains the same data from the proposed methods layer. We previously indicated how the GIS aids in decision-making; in this section, we describe how to select the most favorable statistics regarding the supply of goods and services that attract Khartoum State displaced people. Avoid sudden changes in design specifications . Whenchoosing the best stats between the most suitable state - and Khartoum State. This process depends on the database and requires knowledge of the following (the closest road - number of intersections - availability of services - availability of goods)

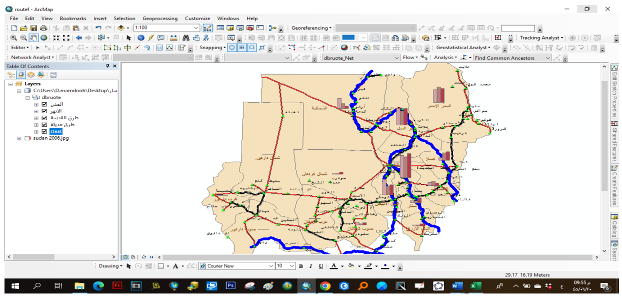


Fig 10: displays the closest road - number of intersections - availability of services - availability of goods

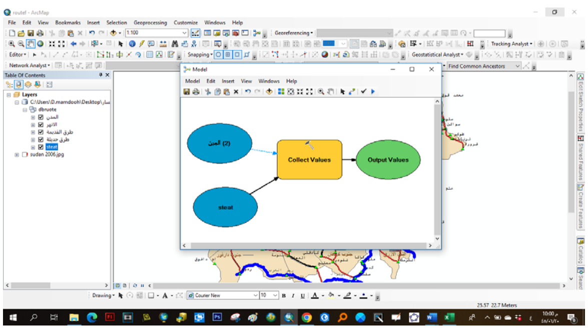


Fig 11: Explain the model

Algorithm:

The Beginning

Define the first state the second state the third state, the best areas andthe best path with numerical variables

Enter the details of the state Enter suggested methods data

Combine state and suggested areas

After merging the areas data, a trade-off was made between the areas

Call function number (1)
Call function (2)

Best areas = (maximum services + maximum goods Lowest cost of access + Nearest state to reach)

If (areas = Best areas))Draw the areas

Or give a message that says there is a mistakeIf neither areas is suitable, draw a new areas The end

Function No. (1) The Beginning

Enter the areas data from the number of points, the lengthof the state and the area of the state

Select the beginning of the state with the number 1
Select the end of the state with a different color
End of function number (1)

Function No. (2) The Beginning

Enter the first state data

Enter services data Select the maximum services of the state . And enter the number of goods data Select the maximum goods of the state .And enter Lowest cost of access choose the Lowest state

And enter the Nearest state to reach choose the Nearest state. Enter the data of the second state

Enter services data Select the maximum services of the state. And enter the goods Select maximum goods

And enter the cost of access choose the lowest cost of access And enter the state to reach choose the nearest state to

Put the second state = the state end of the function number (2)

The algorithm was prepared by the researcher

```
class State:
  def __init_( state1, state 2, state 3, number, area_length, area):
    def function_one(area_points, state_length, state_area):
print("Function No. (1) The Beginning")
  Enter the areas data
print(f"Enter area points: {area_points}")
print(f"Enter state length: {state_length}")
print(f"Enter state area: {state_area}")
  Select the beginning of the state with the number 1
print("Select the beginning of the state with the number 1")
  Select the end of the state with a different color
print("Select the end of the state with a different color")
    print("End of function number (1)")
  def function_two(state_data_1, max_services_1,
  max_goods_1, lowest_cost_1, nearest_state_1,
    state_data_2, max_services_2, max_goods_2,
  lowest_cost_2, nearest_state_2):
    print("Function No. (2) The Beginning")
  # Enter the first state data
    print(f"First state data: {state_data_1}")
  # Enter services data and select maximum services of the state
    print(f"Enter services data for the first state. Maximum
  services: {max_services_1}")
  # Enter number of goods data and select maximum goods
  print(f"Enter number of goods data for the first state.
  Maximum goods: {max_goods_1}")
  Enter Lowest cost of access and choose the lowest state
  print(f"Enter Lowest cost of access for the first state
. Lowest cost: {lowest_cost_1}")
# Enter the Nearest state to reach and choose the nearest
  print(f"Enter the Nearest state to reach for the first state.
Nearest state: {nearest_state_1}")
# Enter the data of the second state
  print(f"Second state data: {state_data_2}")
 # Enter services data and select maximum services
print(f"Enter services data for the second state. Maximum
services: {max_services_2}")
# Enter number of goods data and select maximum goods
    print(f"Enter number of goods data for the second state.
  Maximum goods: {max_goods_2}")
# Enter Lowest cost of access and choose the lowest state
  print(f"Enter Lowest cost of access for the second state.
Lowest cost: {lowest_cost_2}")
  Enter the Nearest state to reach
  print(f"Enter the Nearest state to reach for the second state.
Nearest state: {nearest_state_2}")
  Put the second state = the state end of the function number (2)
  print("Second state = the state end of the function number (2)")
#Define states
 first_state = State(1, 10, "Area A")
 second_state = State(2, 8, "Area B")
 third_state = State(3, 12, "Area C")
 #Enter state details
 function_one(20, 15, "Area X")
 function_two("State 1", 50, 30, 10, "State A", "State 2", 40, 25,
 15, "State B")
```

Algorithm code in Python

6. Implementation and Experimental Results

Every time, a route—that is, a set of cities and centers offering products and services—is entered, together with the cost of transportation from Khartoum State to the target state using the form and the network analysis tool that is connected to all the route-related data using an algorithm. This is how products and services are distributed in the state of Gezira.

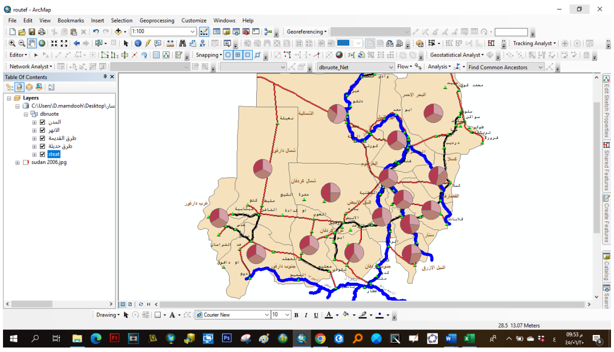


Fig 12: Describes the distribution of commodity locations across the states.

Products' volume of transportation and storage across geographic areas are tracked and visualized in GIS maps as part of the goods distribution process. GIS technology is crucial for enhancing and evaluating the distribution process: Figure (12) displays how goods are distributed throughout the states.

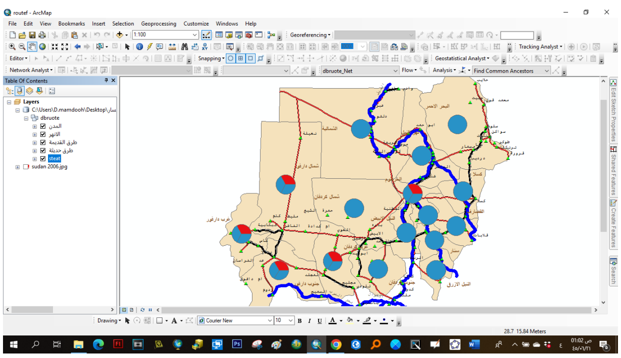


Fig 13: Demonstrates how the number of manufacturing industries in each state is distributed.

After entering the data for the first, second, and third states, the algorithm is tested using a network analysis tool in accordance with the model created by evaluating the services and selecting the best one, or by using the tool and the data entered from the first state and the other states to draw and suggest a new path, the second in terms of (goods and services available; nearest location; least priced location). As seen in Figure (13) and the earlier figures, failing to select the state results in an error message indicating that the state is unsuitable for displaced persons from Khartoum State.

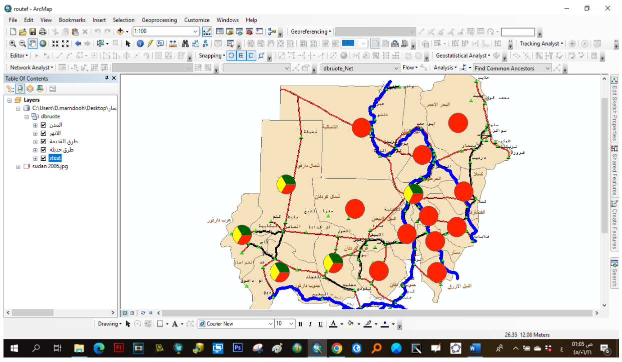


Fig 14: Shows how the number of service centers across the states is distributed.

One crucial component of spatial analysis is the distribution of services in GIS maps. It entails mapping out and evaluating the accessibility and dispersion of different services and amenities within a given region. This can cover everything from housing services to transportation networks to medical facilities. The distribution of services throughout the states is depicted in figure 14.

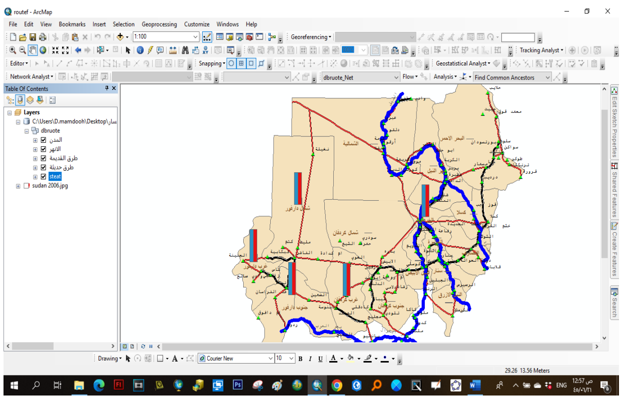


Fig 15: Explains the algorithm uses the network analysis tool to create a new path that connects Khartoum to the best state.

The new link has undergone testing, and it stands out for saving the displaced people a great deal of time, effort, and suffering. This means that the new road is the closest and least expensive, and services are available. As seen in Figure No. (15), the algorithm uses the network analysis tool to determine the path that will lead the displaced to the closest and optimal condition.)

7. Conclusion and future work

GIS provides tools that help in various spatial analysis processes and enable researchers to reach new and useful results. Techniques used in GIS software were used to reach The path for refugees to reach the nearest place where goods and services are available

GIS software enabled me to add special tools in spatial analysis for dealing with network analysis in finding the best assistant. Building the model for the analytical process helps in reaching good results based on spatial data. I was able to use the model to find the closest state that refugees can reach with the shortest route and the most services, goods and manufacturing industries that enable refugees to make the right decision.

The importance of geographic information systems stems from the possibility of creating methods that would exploit informatics with the greatest possible return, in addition to its active role in being a tool that contributes to making the optimal decision and drawing up future policies, and this is evident through the previous narrative on how to choose the best path.resource allocation and accessibility GIS assists in evaluating the accessibility of potential displacement sites in terms of transportation networks, healthcare facilities, schools, and other essential services. This ensures that displaced communities have access to necessary resources.

The paper explained that the best a state that displaced can resort to among the three states closest to the state of Khartoum is the state of the Gezira state through several factors measured and analyzed their data, which are the proximity factor to Khartoum, the cost factor and attractions are represented in the availability of goods and basic services. These factors help organizations, civil administrations, and families to make the right decision and choose the state of Gezira state as the best state for displacement

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