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Understanding the Dynamics Location of Very Large Populations Interacted with Service Points

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Abstract

This paper offers preliminary work on system dynamics and Data mining tools. It tries to understand the dynamics of carrying out large-scale events, such as Hajj. The study looks at a large, recurring problem as a variable to consider, such as how the flow of people changes over time as well as how location interacts with placement. The predicted data is analyzed using Vensim PLE 32 modeling software, GIS Arc Map 10.2.1, and AnyLogic 7.3.1 software regarding the potential placement of temporal service points, taking into consideration the three dynamic constraints and behavioral aspects: a large population, limitation in time, and space. This research proposes appropriate data analyses to ensure the optimal positioning of the service points with limited time and space for large-scale events. The conceptual framework would be the output of this study. Knowledge may be added to the insights based on the technique.

Keywords

Information on Geographic Systems (GIS), Large-Scale Events, Hajj Pilgrimage, Data Mining Tools, System Dynamics, Agent-Based Modeling, Discrete-Time Event

1. Introduction

The Hajj pilgrimage, held yearly at Makkah, is a significant occasion in Saudi Arabia. Over 3 million Muslims attend this event each year. Hajj takes place on specific dates, at specific times, and in specific locations [1]. It starts on the eighth day of the final month of the Islamic year (Dhu Al-Hijjah) and ends on the twelfth or thirteenth day, depending on personal choice. The pilgrims have to visit four "geographical" areas: Makkah, Mina, Muzdalifah, and Arafat route stations. They go to Mina on 8th (1st day,) standing at Arafat, and Muzdalifah on 9th (2nd day,) stoning the devil at Jamarat Bridge on 10th to 12th (3rd - 5th day,) and then, leaving Mina on 13th (6th day). The Domestic pilgrims can perform the Hajj in one day, and the international pilgrims can choose to perform the Hajj over four or five days, depending on their health status.

The Saudi organizers, whose job is to make sure the event works well, face several administrative obstacles as a result of the population's age, color, linguistic, and cultural variety. Researchers can investigate and provide contemporary administration techniques as well as control ways to coordinate such a sizable gathering [1]. Such event might create logistical challenges because big audiences are restricted to specific places for a short period, where they might stay for a few days. The presence of numerous restricted individuals made the provision of specific resources necessary; people require services like information, security, food, drink, commodities, mementos, etc. As a result, depending on what the organizers have planned for those spots and what they will provide, they could be selling points, security points, or checkpoints.

Determining the best position to place resources for large crowds for major events like the Hajj, or other such events involves enormous service potential [2] [3] [4] [5]. Understanding how to execute services in such situations could help in identifying the best sites for the deployment of resources to take advantage of these wide spaces surrounding the event, meet needs, and protect people [4] [6] [7]. As a result, maintaining temporal service points might also reflect the influx of people, various entry points along potential routes, and people's likely service requests. The most evident uncertainty in the locations model is probably the uncertainty of demand, explaining the relation between variables and constraints on the system dynamics simulation model.

Deciding the best solutions for locating space-time resources comes with many challenges as there are a variety of factors that need to be taken into account, such as the flow of people. Furthermore, there are frequently multiple routes to a region of investigation, and individuals may arrive at various times prior to the start of an event. As a result, maintaining temporal service points might also reflect the influx of people, various entry points along potential routes, and people's likely service requests. This is a crucial problem because the more time points presented, the more difficult the logistical challenges become. This article considers methods for dealing with the high level of complexity while working within the limitations of time and resources and dealing with a huge population in a short place [8] [9] [10] [11].

In addition, in this study, the relevant period is the entire duration of the event, as well as some time before it. Over the overall amount, there will be changes in the number of attendees at the event at any one time and throughout its duration arriving is somewhere between a thousand and a million, up to the starting events' deadline. Therefore, the time available to set up the temporal point is relatively short till the event ends. With regards to the time constraints, this study will analyze previous data to identify the peak and off-peak periods to ascertain the ideal time necessary to get to the service points' locations and arrive on time before the event starts.

The suggested approach seeks to address some concerns about the ideal placement of particular resources such as the locations of temporary services or sites of interest, set up of service stations, and the periods in time that the organizers should define these temporal points. The solutions were results based on the research questions:

- What are the limits or constraints of the location when establishing a point of service when the percentage of the population fluctuates as time goes on?
- What is the relevant solution for determining the placement of service points in situations where the number of visitors fluctuates with time?

Therefore, this study will consider the different approaches to resolving the high complexity in the circumstances with limited time, resources, and large population size. Data mining techniques particularly relevant to this research are strategic system dynamics models that facilitate such governance and decision-making processes [2] [9] [12] [13]. This study advances suitable data analyses to ensure the optimal positioning of the service points due to time constraints, space constraints, and time-varying population growth over the duration of this mega-event. The main outputs of this research are intended to be methods and algorithms for identifying composite constrained indicators. The approach may provide a comprehensive insight for regulators to apply in solving similar issues.

2. Research Background and Literature Review

2.1. Management of Large Scale Population

This section aims to explore and review existing literature on monitoring complex large-scale population dynamics in real-time within a constrained space and the deployment of data management techniques. It links data analytics approaches using constrained data mining simulation modeling methods. [14] proposed a Big Data processing application model. The presented model combines sources of handy information, exploration of data, and analytical analysis, as well as security and privacy concerns [15] identified various data sources, large data collection, and the distinction between two kinds of data used by industry.

According to [16], accurate traffic-forecast approaches are required for the "Intelligent Transportation System" to function properly (ITS). The three most common approaches in the Crowd-Modeling, are modeling by flow, entity, and agent. To simulate pedestrian crowd movement in variable types of scenarios, models of cellular-automaton are also recommended [17]. [18] used simulation to model safety standards for great crowds and discussed key elements influencing people's protection and conveniences, such as design, routing, street signs location, and the straight connection between crowd density and population flow. [16] emphasized the connection between the amount of crowd density and the rate of flow of population, for static crowds and traveling crowds, to avoid crowd disasters, event organizers must keep crowd density and flow within safe limits, as well as minimize unexpected crowd mobility. It is still difficult for mobility departments to select a suitable predictive technique for their applications; organizers have to be able to effectively use the forecasting models' disseminated information. The forecasting process uses model-driven or data-based methodologies, such as "deep learning", "Machine-Learning", "Computational Intelligence", and hybridized algorithms. These advanced techniques use arithmetic approaches for key performance parameters in traffic prediction.

2.2. Evaluation and Adaptation of Data Mining Constraints

Since the implementation of these service points is still new in the area of study, there is little data on a detailed plan defined that specifies all of the scheduled tasks to be completed as well as the resources needed to complete them. The literature highlights many issues and difficulties that arise as a result of data mining constraints, including how to integrate constraint-based data mining techniques with various interest measures [2] [19]. The present research aims to address this gap through the identification of three-dimensional constrained data mining (population, space, and time) to develop an algorithm based on data analytic classification models and clustering methods of mining databases.

The earlier research also addressed the problem of space limitations in sports stadiums [4] [5] as confined spaces within which services are provided. However, in this study, the scope extends from a stadium, which has five entry points, to an open area in which there are multiple routes and entrance points, which involves additional complexity when it comes to determining where to distribute interest points along the route. For instance when situating retail stations. [20] stresses the value of proximity to the entire distance of the area of concern. In their study, the space constraint was addressed after selecting the location by dividing the area of concern into different zones to allocate the position of retail stations and then using simulation to evaluate the population's behavior within the proposed positioning. The present research similarly intends to divide the geographic area into equal-sized zones in simulation to capture the flow of people changing over time. In addition, analyzing previous data and using a data mining approach to determine the optimal placement and positioning of interest points is a further step.

The literature review examined the approaches used to manage the constraints imposed by large numbers of people. For example, in the PLATO project [4] [5], one issue was that people were supposed to wait no more than three minutes in the queuing area to check-in. However, the study did address the large numbers of people arriving via different routes, which represented a constraint. Yet, part of that constraint related to the management of people from an operational process perspective. This research thus intends to address the problem of managing a large volume of people within a confined space by using data analytics approaches to expect the number of people who are likely to attend, based on previous attendance data, and to determine the expected movement of those people within the relevant area. It will be necessary to break down the population flow within the geographical area in order to predict how many service points are needed to be established.

Furthermore, the need to analyze and predict the behavior of people over both time and space was also highlighted. One approach used to manage the arrival and flow of spectators at the Olympic Games was based on assumptions of volume and presence of people at 15-minute intervals to allocate people to specific times and spaces. Similarly, [20] used three constant average consumer base numbers to assess behavior and allocate temporal and spatial resources. The Dynamics of people in time and space have been largely studied in the literature due to the difficulty of combining these two factors for analysis [21]. Although it is difficult to include time as a dynamic component, it is possible to approximately represent time dynamics by counting the number of persons in a given space over several time frames and showing them consecutively. Similar patterns of behavior in time and space are produced by the building of various combinations of time and space's constituent elements. Analyzing data related to time and space in connection to geographical information is made possible by abstracting a route data model. Thus, this enables the use of time and space data to ascertain what has occurred before or after a particular moment in a particular area. With regards to the time constraints, this study will analyze previous data in order to identify the peak and off-peak periods to calculate the shortest possible time to get there, service points and to be on time before starting the event.

2.3. Evaluation and System Dynamics Modeling Adaption

The three most popular approaches for the three types of crowd modeling are agent-based, entity-based, and flow-based [22] [23]. For the purpose of modeling pedestrian traffic in diverse contexts, cellular automaton models have also been proposed [17]. Using simulation, [18] highlighted key elements affecting people's comfort and safety, including design, route, the placement of street signs, and the connection between crowd density and flow. For both stationary and moving crowds, a correlation between crowd density and crowd flow rate. To avoid crowd disasters, event organizers must keep crowd density and flow within safe limits, as well as minimize unexpected crowd mobility.

In order to visualize the movement of pilgrims to the Jamarat region spatially and temporally, [23] presented remedies to the issue of overpopulation. In order to visualize the movement of pilgrimage groups to and from Jamarat from their tent camps, a method called geographic information systems (GIS) is used. Event management can benefit from simulating the movement and behavior of such a large audience. Current development in modeling and simulation is agent technology.

3. Research Methodology

A Geographic Information System (GIS) is a device for collecting, maintaining, analyzing, and displaying geographic data to inform placement decisions. Geographic Information System (GIS) layers for the study area were collected from the Saudi government. About spatial alternatives, 20 layers were related to Mina, Muzdulafh, and Arafa; these include accommodation, hotels, Jamarat Bridge, buildings, facilities, road edges, the center line network roads, landmarks, and zones, stairs, fire pipes, WCs, tanks, and tents. The GIS system is best accomplished by constraint-extraction, where the user supplies constraints to guide a search and find the result [24] [25]. Euclidean space corresponds well to experienced reality, resulting in navigable 12 maps and cartographic displays [25]. It can improve the efficiency of knowledge inference by enabling a query optimizer to provide powerful and stimulating mining conditions that promote exploration and analysis. To begin, it ought to offer an ad-hoc extraction query language, a logical high-level language comparable to Query language for relational database systems. Users can express themselves using a declarative mining language [24].

Furthermore, a modeling technique called system dynamics is used to understand complex systems better, find the root causes of policy opposition, and create effective policies. They include software for causal mapping and simulation modeling (systems thinking), such as Vensim PLE 32, used in this study to analyze the dynamics, forecast decision strategy, operational scenarios, and mitigate risks [26]. AnyLogic 7.3.1 software was used as a visual agent that interacted with the location. The scaling model is used as an agent-based model using discrete space and time. Discrete-time has also been used to evaluate population movement, and the population served. However, collecting database dated back from the period 1984 to 2018 with different categories, which consist of the profile for arrival patterns of Hajj pilgrims during the time, various transportation patterns before and during the Hajj period, and distribution of pilgrims in accommodation has been provided.

3.1. Research Design

The field study is based on simulation. At this stage, the conceptual model defines the model's purpose, its key variables, and the system's limitations. **Figure 1** illustrates the simulation models used for the case study.

3.2. The Analysis Process

This research utilizes three-dimensional constrained methods to determine the best placement of temporal resources, the optimal time to put resources in place, and how many points need to be established. This research examines specific restrictions regarding space, time, and people. This section will discuss four methods used to analyze the problem.

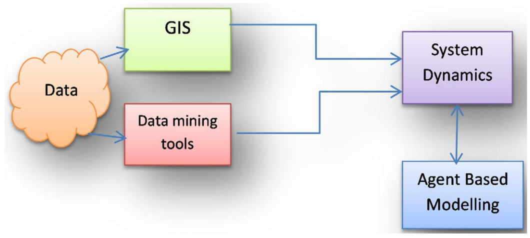


Figure 1. Presents the methodology for this research.

3.2.1. Geographic-Database for an Information System and GIS Layers

Regarding "Geographic-Information-System database" and "GIS" layers, this study examines three areas for which all the relevant data sets have been obtained. These areas are Mina, Muzdalifah, and Arafat. The three areas are open and can be accessed via different modes of transport such as trains, buses, and on foot. Many people enter each area via different routes over a set period. Reducing unwanted or redundant dimensions presented within the GIS Arc Map 10.2.1 software database layers were used to identify desirable locations to position the service points. It matches better requests to the user's intent, and an Ad-hoc data collection systems that are "query-driven" may be more beneficial and efficient [24].

3.2.2. Discrete Time Event

This method explains how space-time streamlines the complexity of spatial and temporal data in structures and components that capture relevant information embedded in data [27]. It has been modified to use the discrete-event technique to determine the order of Hajj events linked to an incident in space and time and how one incident flows into another over time.

3.2.3. Models of System Dynamics

An analysis is almost based-on answering the question of the study problem, namely, "what is the optimal solution for setting up service points, given that the number of people fluctuates over time?" Before determining the appropriate scope and level of pedestrian facilities, it is mandatory to assess demand for such facilities by estimating the population density levels during the schedule for the performing of Hajj worship. Such estimates can be obtained using system dynamics. As stock and flow diagrams display feedback loops in which policies are incorporated, they are a useful way of demonstrating how event-focused and open-loop-mental models that have a simple chain of causality can lead to policy resistance [28]. The chosen language relies onstock and flow theory, as demonstrated in the map that illustrates interdependent factors, causality, and nonlinear correlations [29].

3.2.4. Agent Based Modeling Simulation

In modeling based upon agents-simulate, representing the system visually as a real environment that may have its dynamics is completely logical. Thus, the behavior emerges later, out of many concurrent instances of individual behavior.

Behavior is described in the context of rules executed on the events [22]. Within this study, the model is used to calculate the flow of people within the proposed locations for service points over different periods.

4. Data Analysis Processes

Regarding GIS layers, the study looks at three areas for which it has all the relevant data sets. These areas are Mina, Muzdalifah, and Arafat. The three areas are open and interact with different modes of transport. Each has many people entering them via different routes over a set period. **Figure 2** depicts the area. There are temporary accommodations in these areas in Mina and Arafat. As seen on the map, there are many transportation networks. Brainstorming and observation have been used to allocate the desired places for the position of the service points. The interview with the Saudi authorities highlighted the need to provide service points on pedestrian routes. Therefore, the research shows the usual footpaths used by pilgrims commuting from Mina to Arafat and the potential spots individuals pass. By answering the questions, where and when can service points be placed, it is possible to identify patterns.

4.1. The Analysis of Space Constrains "Where"

Spatial Data Model

This section will attempt to answer the research question, "where can service points be placed?" and provide some answers to the research question, "what are the limitations/constraints of the positioning of service points?" A spatial representation of the study area has been created by applying the Geographic Information System database GIS. It contains 21 database layers which made the analysis of data much simpler. It can specify the Geographic Information System database GIS as a data mining query [24]. This query is input to the system dynamics, which will be used later. Data mining query task primitives include knowledge utilized in the investigation process, pattern evaluation measures and thresholds, and representation to visualize the discovered patterns.

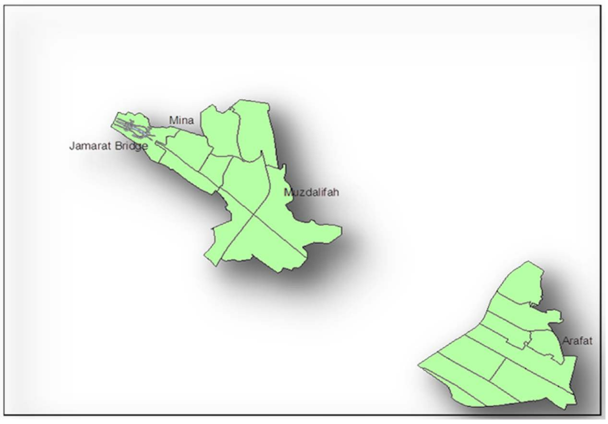
This Arc Map 10.2.1 software communicates interactively with the Information

Figure 2. Shows a map of the study area.

System database GISuse the data collection to glean important information a structured query language (SQL). This is not only used for visualizing maps but also for calculating distances and extracting analyses. The following section will explain how Geographic-Information-System database GIS analysis was utilized to analyze pedestrian footpaths for this research. The goal of this analysis is to define the optimal locations to set up service points. The modeling elements and simulator design will be presented below.

The study area extends to approximately 13 kilometers, between the latitudes of 21.4133 and 21.3547 and longitudes of 39.8933 and 39.984. Figure 3(a) shows the green areas of Mina (867.1 hectares), Muzdalifah (927.5 hectares), and Arafat (1660.8 hectares). Figure 3(b) highlights the areas in which pilgrims can be accommodated, where they are divided according to nationality. The Jamarat Bridge in Mina is also shown.

Figure 4 shows the transport network links between Mina and Arafat, including vehicle roads, fast highways, bridges, and pedestrian roads. Transportation mobility can potentially be tracked, Classification for the area of concern



(a)

(b)

Figure 3. (a) Portrays the geographic locations of the main population centers, indicated with place names; (b) depicts the pilgrims' accommodation in Mina, Muzdalifah and Arafat.

into stop and movement transportation networks were carried out and used to identify desirable locations to position the service points. The movement of transportation throughout the event period can be analyzed to identify movement patterns and stopping areas.

In Figure 5, the green lines indicate pedestrian roads—these correspond to the walking area. The lengths of these footpaths are given in Figure 6.

In the database, 279 footpaths were recorded; the shortest is 18.585693 meters, while the longest is 5912.510829 kilometers and has been divided into smaller segments. Footpaths over 1km were then selected; the results of this election show that 12 footpaths are over 1km in length. The selected footpaths are shown in Figure 7. Several roads were not selected because they are too narrow, and setting up service points there could lead to congestion.

Longitudinally, the pedestrian roads are divided into sub-routes; the longest routes are Road 1, Road 2, Road 4, and Road 6. Road 1 and Road 4 are pedestrian underpasses, almost are equipped with an up-to-date system for tracking pedestrians (mentioned roads are shown in green in Figure 8 and Figure 9).

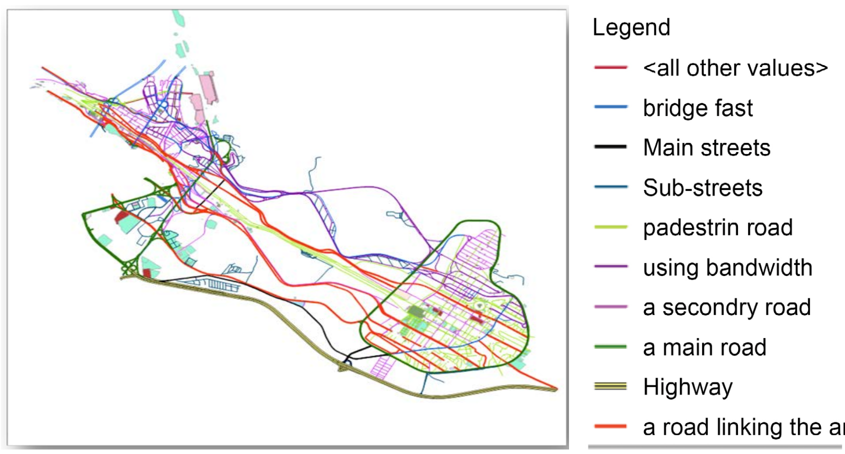


Figure 4. Characterizesthe transportation network in the study area.

Figure 5. Describes thepedestrian walking routes.

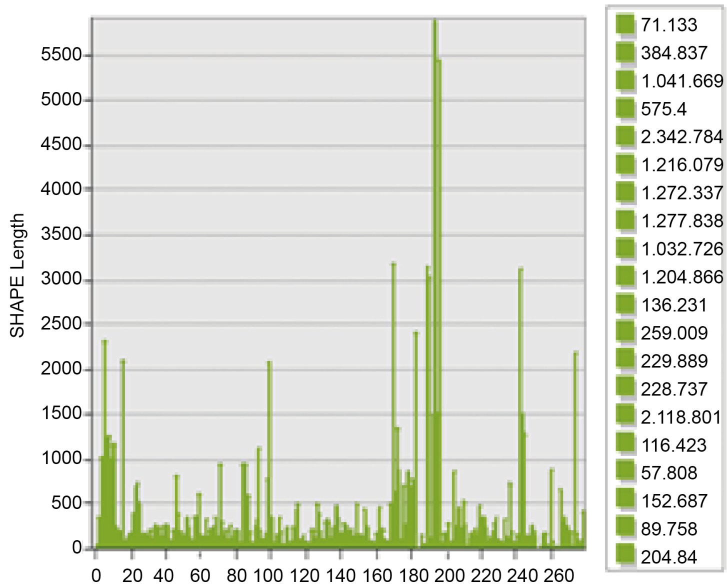


Figure 6. Shows the lengths of pedestrian footpaths.

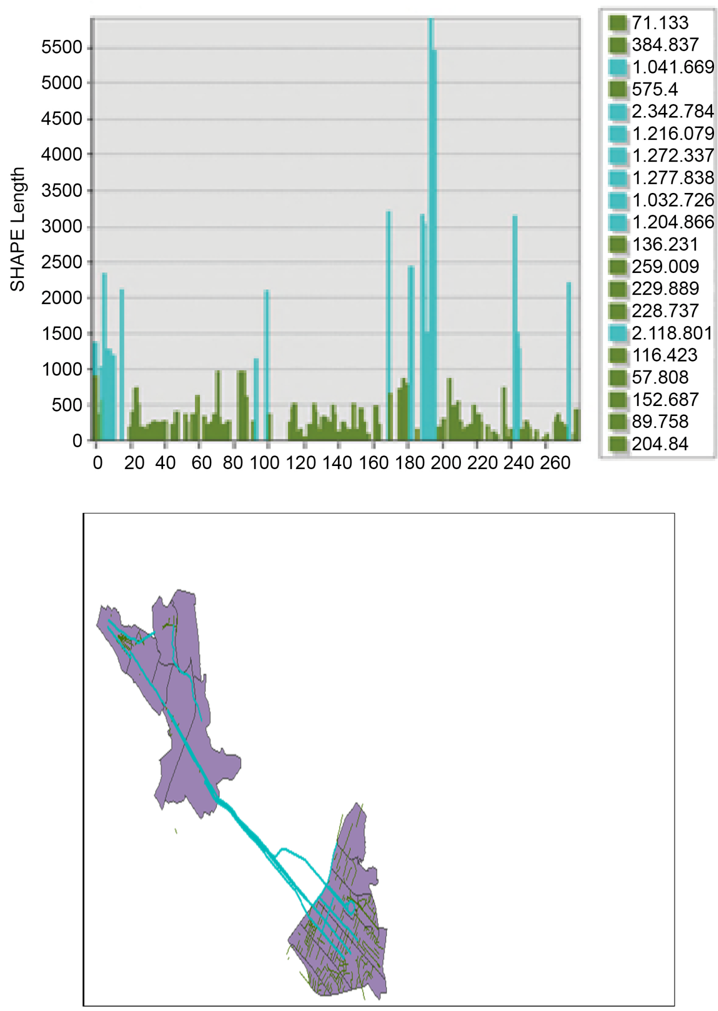


Figure 7. Identifies the footpaths over one kilometer in length.

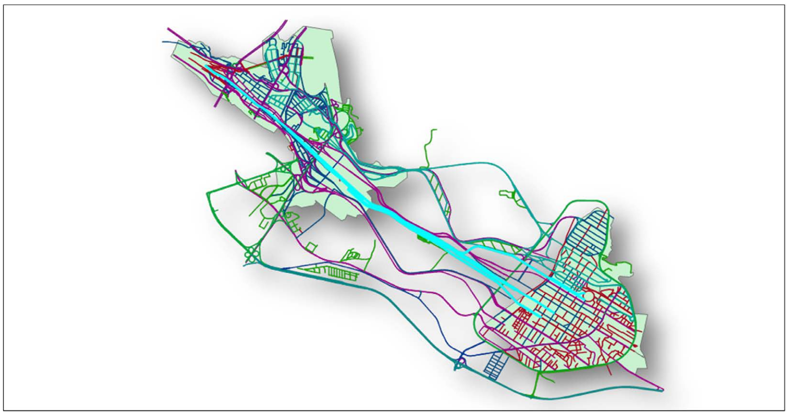


Figure 8. Portrays the interaction of transportation networks and pedestrian roads selected for the study.

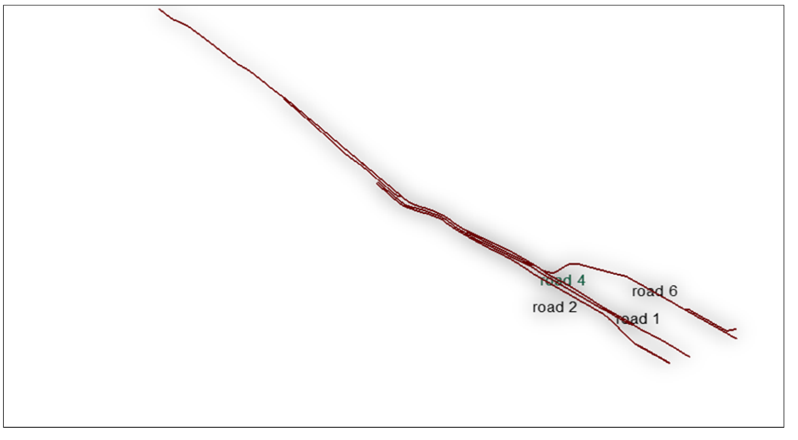


Figure 9. Shows the pedestrian roads and their lengths.

After selected these four roads for the study, it is necessary to check that service facilities along those roads did not already exist. Figure 10 highlights service facility layer for the study area and Figure 11 shows roads with already established service facilities.

Initially, there is a need to establish service points along these four routes. Analytical spatial data created a location-allocated model to identify the optimum sites for these service points. The route distance, road, walking, and queuing area are defined.

4.2. The Analysis of Time Constrains "When"

Discrete Time Event

This research utilizes three-dimensional constrained methods to determine the best placement of temporal resources, the optimal time to put resources in place, and how many points need to be established. This research examines specific restrictions regarding space, time, and people. This section will discuss the time restriction. An interval time for the ritual practice to begin and time to last will be discussed.

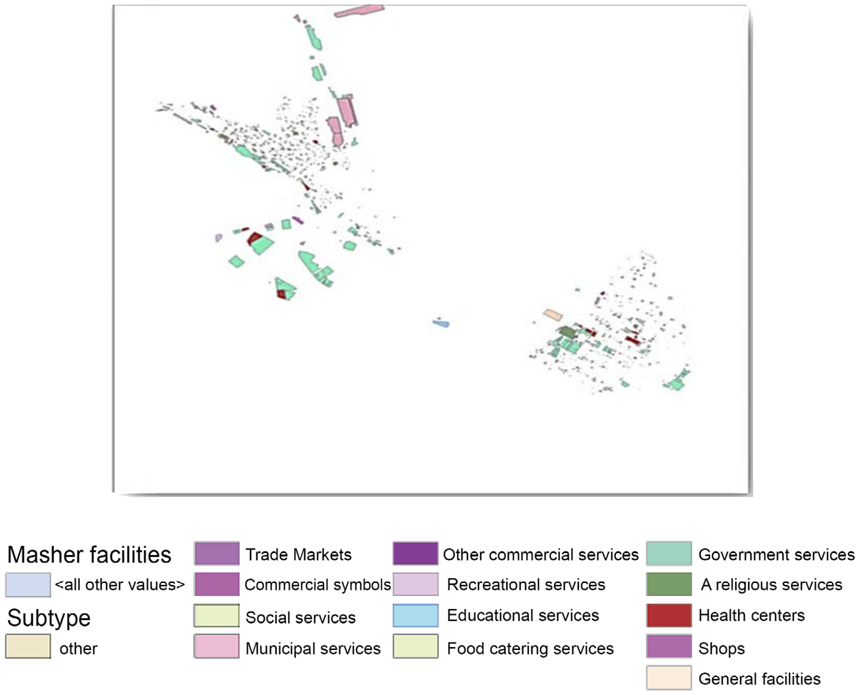


Figure 10. Presents the service facility layer for the study area.

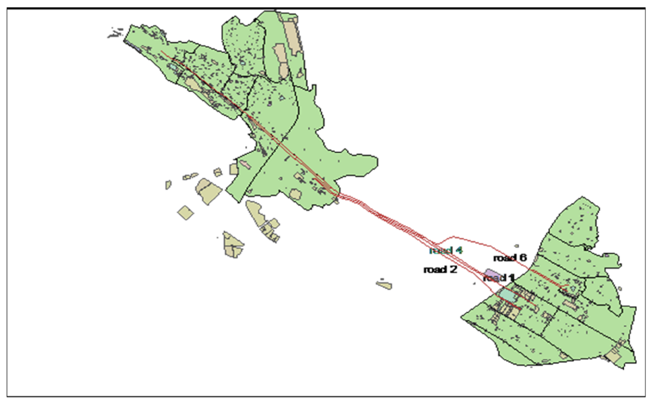
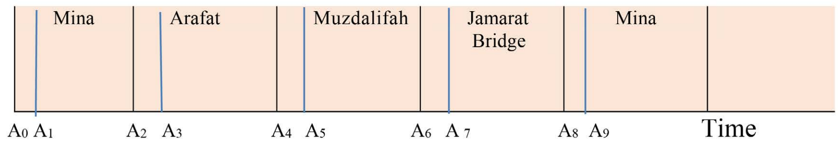


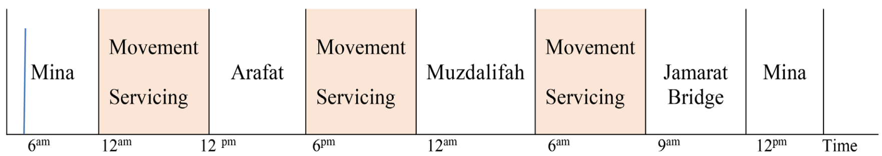
Figure 11. Describes the main selection of pedestrian roads intersecting with facilities already available.

The discrete-event approach has been adapted to identify the sequence of Hajj events linked to an incident in space and time and how one incident flows into another as time goes on. Movement is defined as a process: in which pilgrims attend to go to the scheduled locations and buildings (Arafat) at the specified time. The movements with congruent patterns present a proper formulation of time and space models for population dynamics over time. Figure 12 shows that through "semantic-segmentation" of the Hajj ritual practice, paths (and trajectories) are defined in timelines. This schedule relates to those performing the Hajj in one day and the first and busiest day of the Hajj period. A_0 etc., refers to the time at which a ritual begins. The specific time constraint is that, before starting the next event, pilgrims must reach the target place by a specified time.

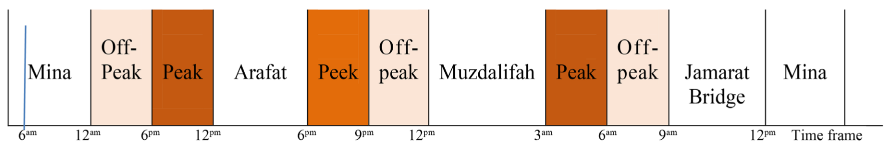


Date	Ritual time	Interval	Incident
8th	6 am - 12 am	A_0-A_1	Gathering in Mina
9th	12 am - 12 pm	A_2-A_3	Going to Arafat
9th	12 pm - 6 pm	A_3-A_4	Staying at Arafat
9th	6 pm -12 am	A_4-A_5	Going to Muzdalifah
9-10th	6 pm - 6 am	A_5-A_6	Staying at Muzdalifah
10th	6 am	A_6-A_7	Going to Jamarat Bridge
10th	15 minutes	A_7-A_8	Throwing stones
10th		A_8-A_9	Going to Mina

(a)



(b)



(c)

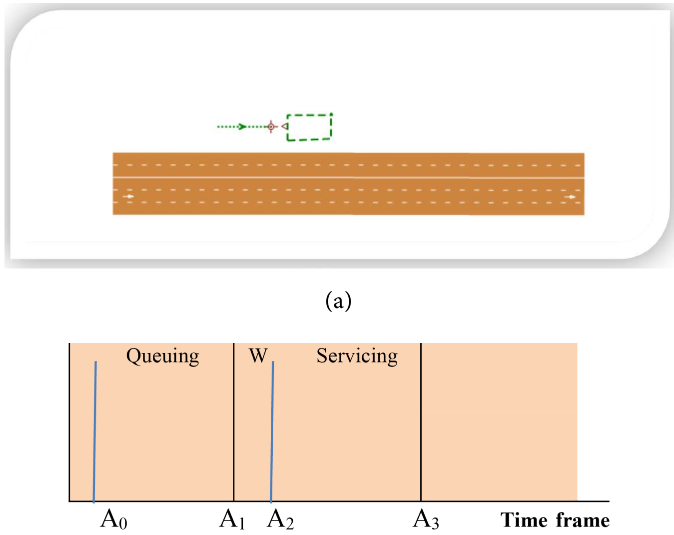
Figure 12. (a) Depicts the Hajj clock, adapted from [27]; (b) identifies the time period for setting up service points; (c) presents the classification of time periods (peak and off-peak times).

To determine where service points can be established, it should be noted that the Hajj is assumed to begin when pedestrians move from Mina to Arafat, via Muzdlifah. Then, they return to Jamarat Bridge in Mina, before eventually going on to their accommodation. Therefore, across the four footpaths, there will be locations where it would be appropriate to place services points for pilgrims. **Figure 12(b)** shows the time available for the placement of these service points.

The classification of time period patterns into peak and off-peak times was determined according to the average population movement, which was calculated based on empirical observations (see **Figure 12(c)**).

With regard to the placement of the points, the suggestion assumes that they should be situated on both sides of pedestrian lanes. So, they are able to create a safe public road for pilgrims with sufficient walking spaces that are completely separated from the vehicle roads and highways.

It has been suggested that to ensure no risk to pilgrims, a reasonable number of service points should be spread out. According to the proximity rule, service points are distributed regarding distances measured to the origin of the whole



(a)

(b)

Figure 13. (a) Depicts the location of service points along the footpath; (b) Shows customer behavior at an interest point. Adapted from [27].

road [20] [30]. Consequently, this study required the deployment of quantitative methods for analyzing both the movements of the population and the time that they spend queuing for services.

Customer behavior: **Figure 13(b)** shows the customer's behavior at service points. A_0 refers to the arrival time for the customer. The interval time A_1-A_2 is waiting time or queuing time, and A_2-A_3 is the service time.

With the help of abstraction of discrete-time model analysis of space and time data, it is possible to get a clear view of what is happening in the situation before the certain moment and even after that at a particular place.

4.3. System Dynamics Model

First of all, demand evaluation is important for pedestrian standards by estimating the population density levels during the schedule for the performing of Hajj worship, then can decide on the proper extent and facilities' pedestrian standards. Such estimates can be obtained using system dynamics, as described below.

Stock and population flow charts show loops of feedback that are embedded in all policies; they are an excellent way of demonstrating how an event that is completely oriented "open-loop" mental models that have a simple chain of causality can lead to policy resistance [28]. The chosen language relies on the concept of stocks and flows, shown in the map that illustrates interdependent factors, causality, and nonlinear correlations [29].

4.3.1. Demand Estimation

This section will briefly describe how historical data was used to reach a rough estimate of how many pilgrims will arrive in Saudi Arabia for the Hajj and will also provide the results of the case study analysis. Before constructing the simulation model, looking at the historical data from previous years dating back the period 1984 to 2018, which consist of the profile for arrival patterns of Hajj pilgrims during the time. Figure 14 illustrates the figures. It shows the figures for the numbers of pilgrims coming to Hajj. The number of pilgrims has grown steadily since 1984, but there was a later decrease in the number of pilgrims; this was in the area where the Hajj takes place and to accommodate the increasing numbers of pilgrims shortly. The motive of this chart is to create a structure that displays the schedule of arrivals of a large population prior to the commencement of the Hajj event. Reference figures are given for the 45 days before the start of the Hajj; this seems to be a reasonable time frame. The sample model will have a population of 1000 people—a value it calls the initial volume of arrivals. The estimated number of arrivals in the Hajj season (in 2015) was 2,000,000.

Figure 15 shows the key variables are: density, population arrivals, and also the arrival rate. This model is centered on a level representing the total population arrivals being analyzed. The population arrival level is increased by the arrival rate.

An average demand is 2,000,000 pilgrims, with an average potential arrival rate of 15%, this amount to 44444 arrivals per day (See Figure 16).

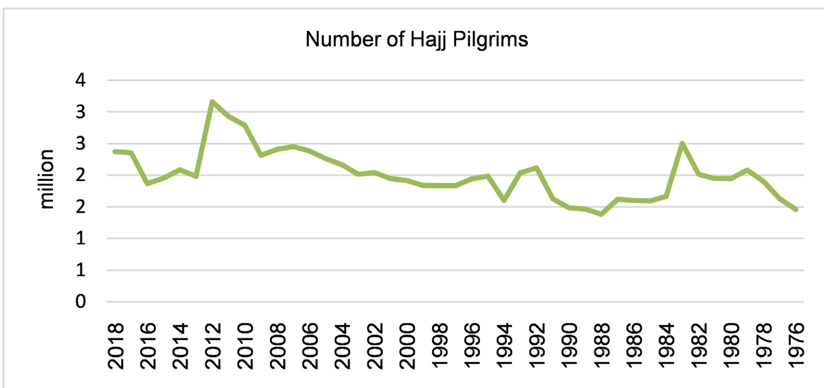


Figure 14. Characterizes the historical profile of Hajj pilgrims coming to perform Hajj (average arrival demand of pilgrims has been aggregated in two - yearly intervals.)

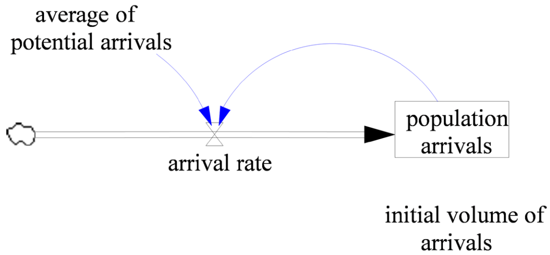


Figure 15. Pictures the basic mechanism of the pilgrims system in the stock and flow diagram.

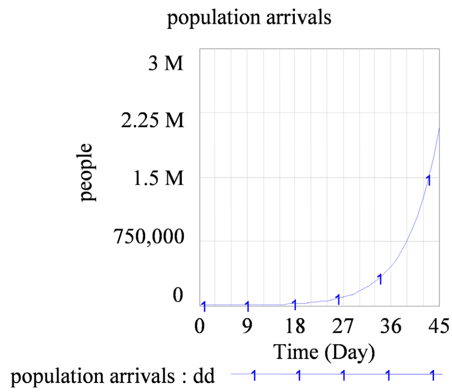


Figure 16. Positive increase in arrivals.

4.3.2. Network Transportation Model

Transportation network flows can be used to evaluate the spatial distribution of demand after the starting of the Hajj schedule. For the first day, this model estimates the total number of people who will move during the morning peak period from Mina (gathering point) to Arafat (starting place). In the figure below, the model is used to estimate the demand for each method of transportation (bus, metro trains, or walking) from Mina to Arafat. Figure 17 illustrates the population dynamics using metro trains to move from Mina to Arafat and back to Muzdulafh. The population is stock, and the traveling rate is the outflow. The average number of people traveling by metro is a fraction of the population traveling over time. The sample model will have a total number of arrival populations of 1,000,000 people—this value called the estimated volume of travelers by metro. The population arrivals estimated from the season of Hajj in 2015 was 2,000,000, and half of the total population would use the train. (The traveling rate = population * the average number of population traveling by metro). Key variables regarding Metro transportation are the number of arrival population, the average number of population traveling by metro, traveling rate, train capacity, and the number of trains per person per hour required.

The busiest period of the Hajj is the morning. During peak hours of the first day, from 12 am to 12 pm. This assessment framework developed was used to study "the number of requests". The given loading model of the network can prepare an approximate rate of the capacity of metro trains to transport 50% of the total population that would use the trains. Figure 18 shows that, during the period under consideration, the pedestrian flows decay. The behavior shown in this figure is called exponential decay. The implicit goal is to reach zero. This means all populations move from the gathering position to the target place. It is assumed that one million people can travel by train is influenced by 8 %, which is an average number of population traveling by metro per hour. Since the trains have a capacity of around 3000 people, the total number of trains required is almost 334. The demand for the trains per hour is approximately 28 trains to load 83,000 people per hour. This number could be acceptable. Figure 18 shows the reduction of the average number of population traveling by metro to 5%.

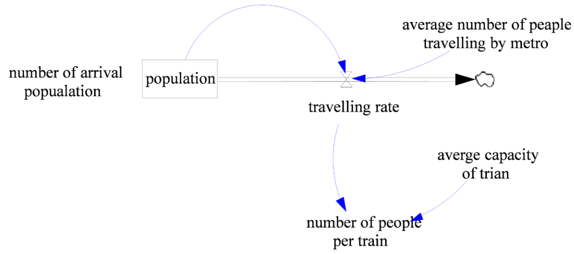


Figure 17. Portrays the metro transportation model.

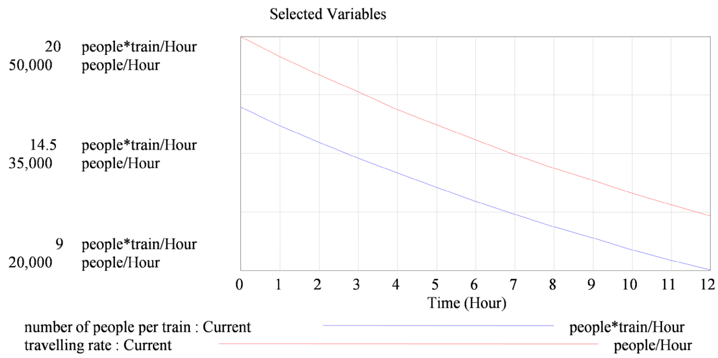


Figure 18. Identifies the estimated number of passengers transferring during the peak period on the first day.

The development of a 5% reduction of the average number of population traveling shows the demand for the trains per hour is approximately 20 trains arrive and depart to load 50,000 people per hour. The population density in the trains can be used to estimate train arrivals and loading time to be inboard. The time to align would be 3 minutes to accept the perceived level of service.

4.3.3. Road Network Capacity Model

The model in **Figure 19** presents the capacity of the population to travel by bus. The population is stock, and the traveling rate is outflow. The average number of people traveling by coaches is the fraction of travelers, which is 30% per hour. The basic model will have a total arrival population of 600,000 people—a value called the estimated volume of travelers by buses. The population arrivals estimated from the Hajj season in 2018 was 2,000,000, and 30% of the total population used the coaches. (The traveling rate = population * average number of population traveling by coaches). Key variables regarding road capacity are the arrival population, traveling rate, average number of people traveling by coaches, number of people per coach, number of coaches, number of road paths, and number of coaches per path.

It is assumed that 30% of the population, *i.e.*, 600,000 individuals, can travel by coach on one of the nine road paths. Typically, this demand is influenced by the average number of people traveling by coaches, which is 30% per hour. Given that each coach can carry around 30 people, almost 20,000 coaches are required. Therefore, the population capacity is around 50,000 per coach per hour.

Thus, the model assumes that users will choose their route by finding the nearest road to their accommodation. Due to the additional assumption of constant speeds, this is equivalent to taking the shortest path (see Figure 20).

Figure 21 shows the influence of changing the value of an average number of population traveling by coaches to increase it from 3% to 30% per hour to see how influence would affect the road paths. It is assumed that the population, equal to 600,000 individuals, can travel by coach on one of the nine road paths. Given that each coach can carry around 30 people, the ability of infrastructure is almost 1,000 coaches are required. The population capacity is around 30,000 per hour and 200 coaches per path per hour. Figure 22 portrays the simulations for different values of average number of population travelling by coaches (3%, 4%, 5%, and 6% per hour.

4.3.4. Periodic Flow Patterns

There is a general need to get a better understanding of the demand for pedestrian travel within the area of study. Figure 23 reveals that the population is stock, and the traveling rate is outflow. The average number of people traveling

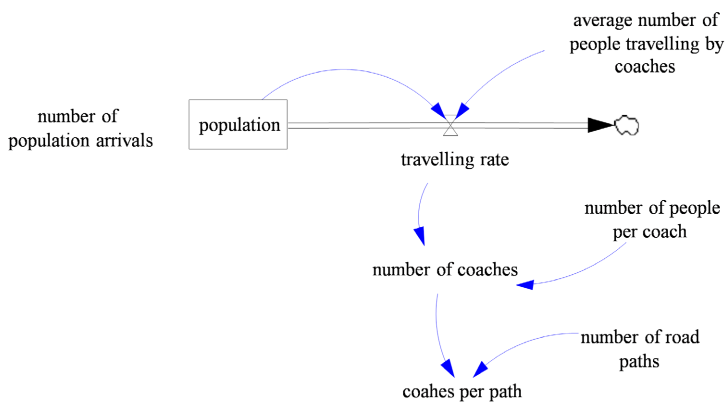


Figure 19. Depicts the vehicle routes model.

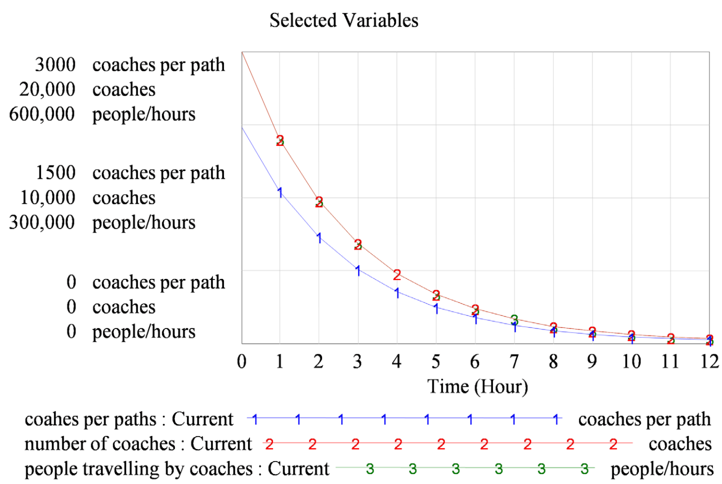


Figure 20. Characterizes hourly passenger demand when travelling by bus.

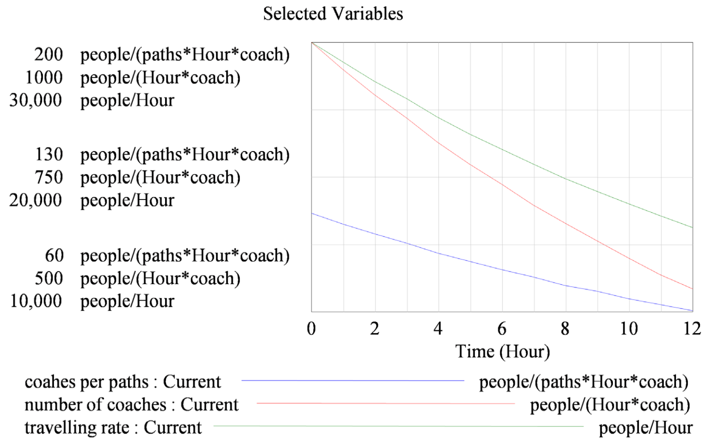


Figure 21. Illustrates the simulations for different values of average number of population travelling by coaches (30% per hour).

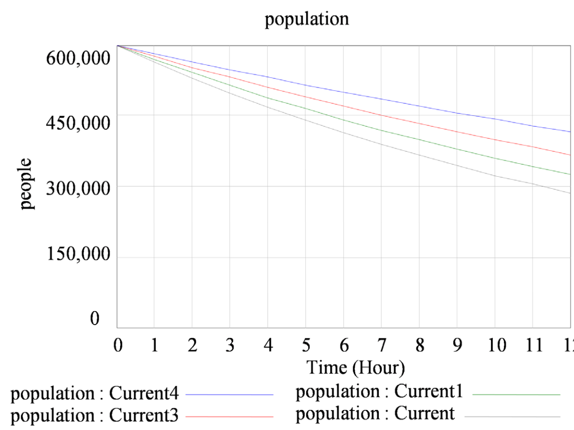


Figure 22. Portrays the simulations for different values of average number of population travelling by coaches (3%, 4%, 5%, and 6% per hour).

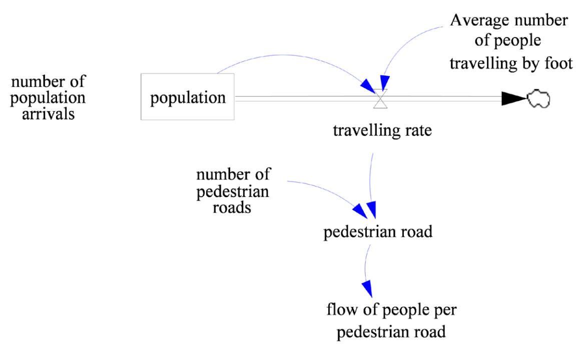


Figure 23. Shows the flow of pedestrians over time.

by foot is the fraction of commuters which is 20% people per hour. The basic model will have a total arrival population of 400,000 people—a value it called the estimated volume of travelers by foot. The population arrivals estimated from the Hajj season in 2015 was 2,000,000, and 20% of the total population would walk by foot. (The traveling rate = population * average number of population traveling by foot). The key variables are traveling rate, the average number of people traveling by foot, the number of pedestrian roads, pedestrian roads, and the flow of people per pedestrian road.

It is assumed that 20% of the population, *i.e.* 400,000 individuals, can walk. Typically, this demand is influenced by the average number of people traveling by foot, which is 20% per hour. It is assumed that the origin, destination, and path of all pedestrians are provided at the aggregate level. The model slightly underestimates the level of congestion during the peak period. The period during which this behavior occurs roughly corresponds to the interval between 12 am and 12 pm on the first day of the Hajj period, where pilgrims must reach Arafat by the afternoon because a ritual begins at that time (see **Figure 24**).

4.4. Agent Based Modeling

If the solution is valid, it is crucial to identify the optimal locations at which service points can be set up with minimal risk. This technique for locating service points is practical, as it takes the spatial distribution of the population into account. In order to test the optimal location for future service points, this study considers ten factors. The key factors relating to movement are pedestrian density, the speed at which pedestrians travel, pedestrian arrivals, road area, distance, and travel time (see **Figure 25**).

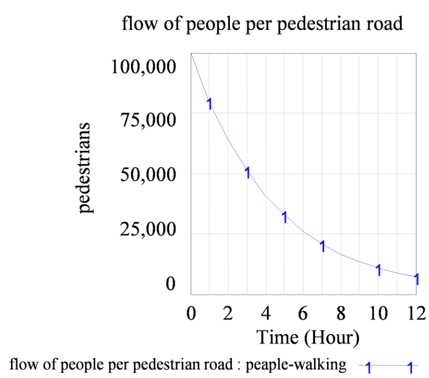


Figure 24. Represents the flow of pedestrians over time.

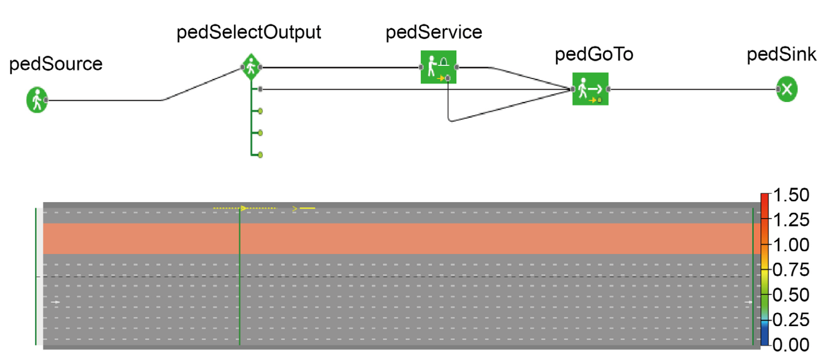


Figure 25. Describes the pedestrian discrete event model based on Agent based model.

In addition, we consider that pedestrians typically prefer to walk in straight lines. Speed of walking is presumed to be distributed completely normal. The speed of 10 m/s, and the standard for deviation is 0.34 m/s. The model assumes that 10% of pedestrians will ask for a service to be provided, and the remainder will carry on walking. Customers will depart from the service point and continue walking as soon as they have been served.

The results show the available service points along the pedestrian route, the expected demand for people, and the expected service offered. All are affected by the assumptions made about the arrival rate of people and the facility service rate. The representation of calculating travel time is considered the relation between occupations when arrivals start moving (per source) to the ending point (pink). The data will be collocated in the form of a database for 100 arrivals.

Servicing

Figure 26 shows, the model presents the question of how many people can be served. Therefore, it will primarily address two issues. Firstly, the number of people can be served. The second issue is the effect on people when there is an increase in serving individuals at station points. The behavior of this model expects that once the maximum queue length reaches this maximum of 15 in a queue, the arrivals will turn away, and the waiting in queue line will be impatient. Customers leave the place before getting the service. The effect on arrival demand controls the length of the queue, not more than 15.

5. Results

This research, which is based on three constraints, uses data mining methods in order to reach an analytical solution for the optimal placement of service points, taking into account the fluctuations in population dynamics over time and satisfying time and space constraints.

- Events: refers to temporal aspects related to the time constraints for the event
    - Time sequence for event
    - Peak and off-peak time

Factor: Travel Time

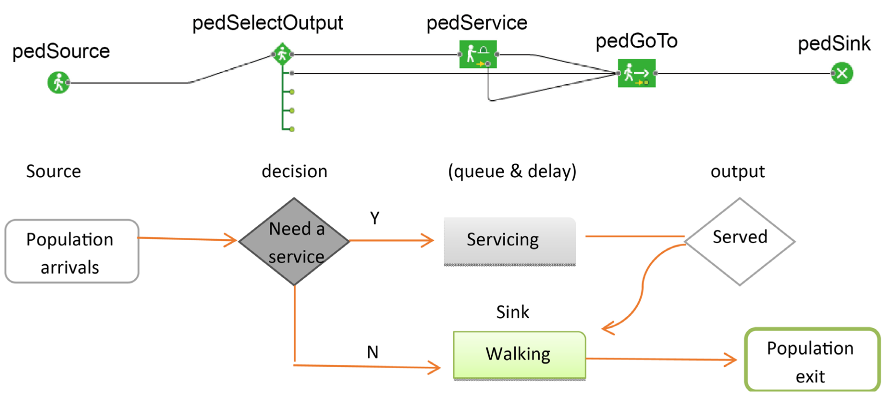


Figure 26. Presents the discrete event model.

An average demand is 2,000,000 pilgrims, with an average potential arrival rate of 15%, this amount to 44444 arrivals per day. Those who reside locally can perform the Hajj in one day. However, international pilgrims have the choice of performing the Hajj over four or five days, depending on the state of their health. The busiest period of the Hajj is the morning. During peak hours of the first day, from 12 am to 12 pm.

- Routes: refers to spatial aspects related to space constraints for the place
  - Accessible footpath routes
  - Distance

Factor: Space capacity

The study area extends to approximately 13 kilometers, Mina (867.1 hectares), Muzdalifah (927.5 hectares), and Arafat (1660.8 hectares) (**Figure 3(b)**). 279 footpaths were recorded; the shortest is 18.585693 meters, while the longest is 5912.510829 kilometers and has been divided into smaller segments. Footpaths over 1km were then selected; the results of this election show that 12 footpaths are over 1km in length (**Figure 7**).

Four routes have been selected for the study, which are the longest routes (Road 1, 2, 4, and 6.) The study concluded that there is a need to establish service points along these four routes. Analytical spatial data created a location-allocated model to identify the optimum sites for these service points (**Figure 10**).

- Arrivals: refers to potential arrivals using different transportation (airport, metro, buses and foot):
  - Pedestrians
  - Customers for service points

Factor: Distribution demand

It is assumed that 50% of the population, *i.e.*, 1000,000 individuals, can travel by train. The average number of population traveling by metro is reduced to 5%. The development of a 5% reduction of population traveling shows the demand for the trains per hour is approximately 20 trains arrive and depart to load 50,000 people per hour. The time to align would be 3 minutes to accept the perceived level of service. It is assumed that 30% of the population, *i.e.*, 600,000 individuals, can travel by coach on one of the nine road paths. It is assumed that 20% of the population, *i.e.* 400,000 individuals, can walk.

- Services: refers to the need for quick delivery of services. (no delay)
  - It takes little time to give services
  - Specific services needed within specific time window (no delay)
  - Services needed for all customers (ex. ticketing)
  - Services needed for wide spatial distribution (ex. Security checking)
  - Services needed for specific requirements (numbers of staff or queue)

Factor: Facility capacity

The problem considers proposing a solution for allocating more than one new service points. The solution can be obtained by system dynamics. The representations of geographic locations for service point placement are the discrete entities with an acceptable flow of people. With the help of abstraction of discrete-time model analysis of space and time data, it is possible to get a clear view of what is happening in the situation before the certain moment and even after that at a particular place.

The model assumes that 10% of pedestrians will ask for a service to be provided, and the remainder will carry on walking. Customers will depart from the service point and continue walking as soon as they have been served.

The results show the available service points along the pedestrian route, the expected demand for people, and the expected service offered. All are affected by the assumptions made about the arrival rate of people and the facility service rate. The representation of calculating travel time is considered the relation between occupations when arrivals start moving (per source) to the ending point (pink).

The behavior of this model expects that once the maximum queue length reaches the maximum of 15 in a queue, the arrivals will turn away, and the waiting in queue line will be impatient. Customers leave the place before getting the service. The effect on arrival demand controls the length of the queue, not more than 15.

Variables to construct the system dynamics model (Distance)

The pedestrian footpaths have extracted the optimal sites for the placement of service points where the service point needs to be placed.

Variables used to build the dynamic system model (total population arrival)

Extraction of the total population arrivals from the database and used to feed the simulation model. Therefore, the functionality of GIS is mainly restricted to overlay operations to identify locations that have over time interacted with population flow while satisfying several site requirements.

Variables to feed system dynamics model (Distribution Demand-Travel Time - Space Capacity - Facility Capacity)

System Dynamics Simulation can supplement GIS's limited capabilities for analyzing data on decision preferences.

6. Discussion

In order to answer the first research question: What are the limitations/constraints about location when setting up a service point if the number of visitors fluctuates over time?

The key to the data correlation is integrating the nature of the best placement of the event, identifying where the best placement to place service points, taking into account the flow of people interacting at the location—analyzing data associated with space via dimensional analysis of the Geographic Information System (GIS) to define the location of concern in terms of transportation movement and stop stations [31]. All the acceptable routes to the event location are defined; this allows the identification of suitable places to position the service points along pedestrian routes. Designing pedestrian behavior interacting with the location behavior of service points in this context highlights interesting issues that have been fully unaddressed in the literature. The nature of the placement showed potential identification of suitable places to position the service points along pedestrian routes. Define the location of concern in terms of transportation movement and stop stations.

7. Conclusions

This research provides initial work on system dynamics and data mining tools. The projected data were analyzed using Vensim PLE 32 modeling software, GIS Arc Map 10.2.1 and AnyLogic 7.3.1 software regarding the possible position of temporal points of service, considering the three dynamic constraints and behavioral aspects: large population, temporal and spatial constraints. This study suggests suitable data analyses to ensure the optimal positioning of the service points with time constraints and space limitations for large-scale events. The conceptual framework would be the output of this study. The conceptual framework is the product of this study.

The study concluded that discrete-event simulation modeling allows for spatially explicit and event-driven situations and takes the form of a process flowchart. Abstraction to a route data model offers new opportunities for analyzing data related to a dynamic population over time and space in a system dynamics simulation. In agent-based modeling, simulation modeling helps to predict complexities and to ensure that the result is valid. The model's content estimates the number of people walking along the pedestrian roads that interacted with service points during the Hajj. As a result, three models have been constructed in order to develop an artifact and to examine the three constraints: limited time, limited space, and the changes in population dynamics over time, with the outputs. They have been prepared by the simulated model for the various scenarios and flow of people over periods. This form provides assistance to those in charge of the Hajj in Saudi authority to make appropriate decisions to set the required service points that can cover the time following the proper level of service. A method that can enhance the learning process and gain a better understanding of complicated systems and to designing the efficiency policy is the "system dynamics model". It helps to provide recommendations for event organizers in placing temporal points to provide such services, to establish temporal points for a short and limited time bounded spaces, and a great population that fluctuates as time goes on, and develop an analytic method and technique.

Implication Contribution

Create a method for establishing temporal points for situations with a finite amount of time, a finite amount of space, and a huge number of individuals that change with time.

Research Limitations

Geographic information systems (GIS) are used to store, alter, analyze, and show geographic data. The ability of GIS, however, is primarily constrained to overlay operations to create areas that simultaneously satisfy several site requirements while interacting with population flow over time. The limited ability of GIS to analyze data on decision preferences can be improved through simulation. Simulation offers a way of guiding the decision by identifying values that are pertinent to the choice circumstance and by describing the assessment criteria's relationship with the placement of service stations and people flow.

Future Work

The study will continue to develop a data mining model based on the analytical result for this study to capture more behavior for location services. There are different types of customer groups, so it is necessary to design the process for all service points, and to determine the requirements in terms of availability of traveling over time, space capacity, demand distribution, service type, and facility capacity. The decision for placement is based on the relationship between these variables, which comprised the research problem.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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