Journal of Computer and Communications, 2022, 10, 57-90
https://www.scirp.org/journal/jcc
ISSN Online: 2327-5227
ISSN Print: 2327-5219

Location Based Navigation Service Technology: Development of an Optimization Algorithm for Multivariate Contextual Cartographic Content in Location Based Navigation Service

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How to cite this paper: Wasomi, C.B., Waithaka, E.H., Gachari, M.K. and Kuria, D.N. (2022) Location Based Navigation Service Technology: Development of an Optimization Algorithm for Multivariate Contextual Cartographic Content in Location Based Navigation Service. *Journal of Computer and Communications*, **10**, 57-90.
https://doi.org/10.4236/jcc.2022.101004

Received: November 20, 2021
Accepted: January 23, 2022
Published: January 26, 2022

Abstract

User response or reaction to navigation applications is influenced by relevance in geographic information, in terms of cartographic context and content delivered within a definite time, providing a direct impact to outcome or consequence based on decision making and hence user reaction. Location Based Navigation Services (LBNS) have continuously advanced in cartographic visualization, making maps interpretation easy and ubiquitous to any user, as compared to pre-historic times when maps were a preserve of a few. Despite rapid growth in LBNS, there exist challenges that may be characterized as technical and non-technical challenges, among them being process of conveying geospatial information to user. LBNS system deliver appropriate information to a user through smartphone (mobile device) for effective decision making and response within a given time span. This research focuses on optimization of cartographic content for contextual information in LBNS to users, based on prevailing circumstances of various components that constitute it. The research looks into Geographic Information Retrieval (GIR), as a technical challenge centered on a non-technical issue of social being of user satisfaction, leading to decision making in LBNS, hence response and outcome. Though advanced technologically, current LBNS on information sourcing depends on user manual web pages navigation and maneuver, this can be painstaking and time consuming that it may cause unnecessary delay in information delivery, resulting to delayed information response time (DIRT).

This in turn may lead to un-appropriate decision making with erroneous reaction or response being taken, resulting in loss of opportunity, resources, time and even life. Optimization in LBNS is achieved by a mathematical relationship developed between user status, mobile device variables against cartographic content. The relationship is in turn applied in LBNS android application to fulfill optimization solution for user consumption.

Keywords

Location Based Services (LBS), Smartphone, Mobile Device, Mobile Phone, Location Based Navigation Service (LBNS), Kenya, Cartographic Content, Cartographic Visualization, Cartographic Contextual Content, Cartographic Optimization, Optimization Algorithm

1. Introduction

Background

Location Based Navigation Service (LBNS) is a mobile system which helps its user to make decision based on position and other supplementary information tagged to it, to implement a task at hand [1]. It constitutes a user who consumes data or information from LBNS for decision making, Internet service which conveys data through the world wide web to mobile devices, telecommunication services that are capabilities to transfer specific set of user-information to a group of users through the air waves broadcast, mobile device which is any small electronic device that uses wireless communications and has general computing capability and can be carried around much easily, geospatial data stored as coordinates and topology where cartography captivates user cognition [2] and GNSS/GPS systems for positioning as illustrated in **Figure 1** [3] [4].

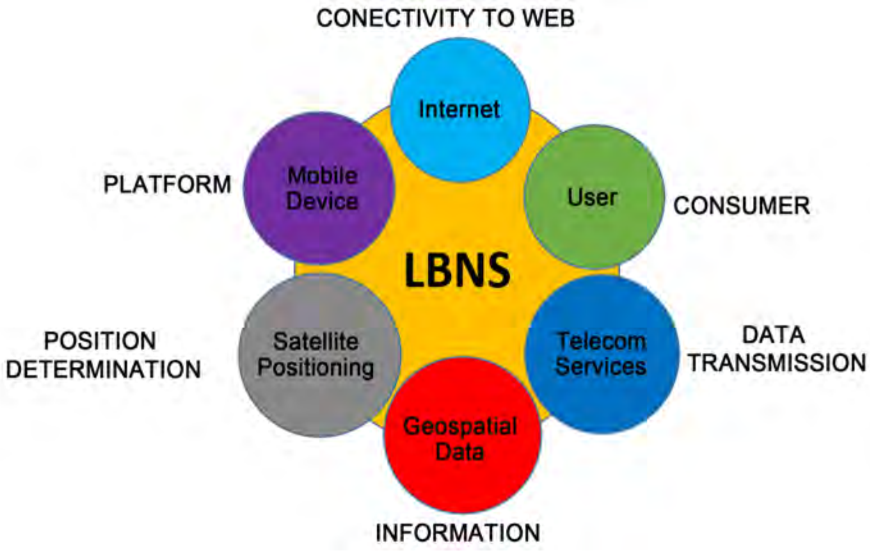

Figure 1. Main components of LBNS.

Huang *et al*. (2018) categorize challenges in LBS into technical and non-technical [1], these in turn fall in "Positioning, Modelling, Communication, Applications, Analysis of LBS-generated data, with social and behavioural implications" as non-Technical of which all are LBNS constituent components. With great advancement in LBS, challenges still exist [1] despite earlier prediction of high growth from previous studies [3]. This is revealed in a quantitative survey carried out in Nairobi CBD Kenya, which indicated that LBS technology had not been accepted and adopted yet [5]. From the study, LBS awareness was at 84% while actual usage was at 16%, clearly showing huge disparity between awareness by mobile phone user, on existence of navigation applications on their devices. Low acceptability points at underlying issues on this technology, leading this research to investigate on Geographic Information Retrieval (GIR), for user decision making [6]. Pegged on information interpretation and recognition by LBS user, featured as among the many challenges that keep on existing [7], leading to the research question on whether it is among other challenges hindering adaptation and acceptance of this technology within this region. The study manipulates GIR, using multiple database sources for distribution, of correct/right/appropriate cartographic visualization content, of geographic environment to a user based on dynamic circumstances that exist [8].

This paper is structured into six parts, the first part considers background knowledge on LBS and challenges that exist, it also highlights on a quantitative study carried out to test on this technology acceptance and adoptions in Nairobi CBD. The second part is literature review on user cognition process, GIR towards user of LBNS implementing user-specific features in cartographic systems. This is mainly with the aim of knowing the extent of user cognition for a given cartographic visualization. This part points out at challenges faced by LBNS in this area and states on solution from this study. The third part provides an optimization system design, outlining how it operates based on geographic Information retrieval (GIR) and how it impacts on user decision making and eventual reaction or response to information delivered. This section also provides conceptual architecture of the optimization system. Part four discusses on methods and material used in the process of formulating a mathematical algorithm for optimization process. The process of determining dependent and independent variables is discussed and ranking of various variables is also elaborated. Cartographic content variables are linked to user status and fickle variables of mobile device, to provide for an optimizing solution in LBNS application through a prototype LBNS development, which was coded to implement the optimization solution. Part five is on prototype LBNS constituents, whereas part six is conclusion and recommendation on the study.

2. Literature Review

To have a clear perspective of GIR, user cognitive characteristics need to be understood. Geographic Information Retrieval (GIR) is closely associated with recognition of information conveyed to a user through user cognitive task process [8]. Cognitive task requires a set of cognitive activity from a user, such as decision-making which should define a course of action, purposely preferred from a set of alternatives to achieve a definite goal [9]. This requires problem-solving, the need of working through details of a difficult issues, to reach a solution either through mathematical or systematic operations [10]. Memory information through the ability by which the mind program, hoard, hold and subsequently recollect information and past experiences in a person's brain are essential. Finally, attention and judgement where attention is a state of being aroused, a behavioral and cognitive process of decisively concentrating on distinct aspect of information, whether considered biased or not in total disregard of any other perceivable information takes over. On the other hand, judgement is mental acts in which affirmation or denial of concepts from another forming an opinion or conclusion [11]. Cognitive task performance will largely depend on differences between novice and expert users [12], whereas cognitive task process requires one to go through goal setting, action content, action approach and consequence.

Goal setting is the object of a person's ambition or effort, aimed at desired result where it will involve defining measurable goals and setting them, for accomplishing within a set time-frame as illustrated in **Figure 2**. Action content involves planning process, which helps to focus on ideas and to decide what steps to take to achieve particular goals that may have been set. Action approach involves reasoned-action approach or attitudes towards determined intentions. Outcome/Consequence is the way thing turns out or a result or effect [13].

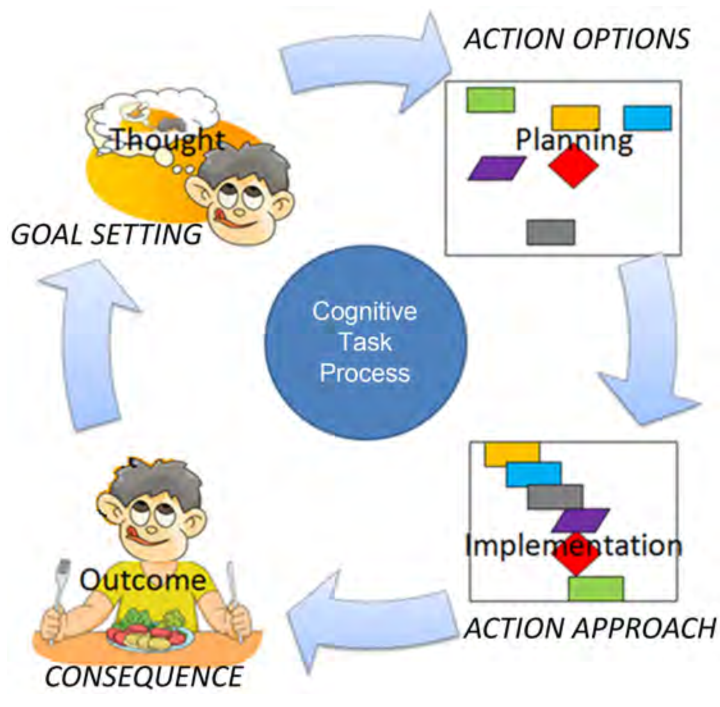

Figure 2. Cognitive task process.

Any action or response to information/data will largely be a result of decision making, which is a culmination of how information has been gathered, how alternative solutions have been identified, how the solutions have been weighted, how the choice among the alternatives have been arrived at, hence the quality of the outcome based on cartographic product and precision of a software, as well as hardware characteristics [14].

Decisions can have so many different effects on situations, processing time will depend on the number of choices available as they may require different actions. Delays in responses can make the difference between winning and losing, life or death, gain or loss of opportunity. **Figure 3** below illustrates GIR, feeding information to user that will assist in decision making within a time frame thereby affecting the outcome.

Current LBS technology is marred by inefficiency and delivery of irrelevant content, consumed information is dependent on manual navigating web pages for relevant information through hyperlinks, hypertext and hypermedia as indicated in **Figure 4**. This can be painstaking step by step process and time consuming that it may cause unnecessary delay in information delivery, resulting to misinterpretation and delayed response or un-appropriate decision leading to wrong reaction and bad consequence, which may be loss of resources, time and even life as illustrated in **Figure 5**. This is supported by Lobben (2009), who chart out challenges in this technology and quantifies the cost of getting lost as momentous, due to not receiving relevant cartographic information for decision making [15].

3. System Design on Geographic Information Retrieval (GIR)

With difference in LBNS user needs and aspirations, together with the dynamic nature of mobile device variables, a multivariate contextual optimization algorithm for cartographic content in LBNS, to address user satisfaction in information retrieval and delivery was developed. Cartographic content variables were determined and assigned values based on assumed preference status. Fickle

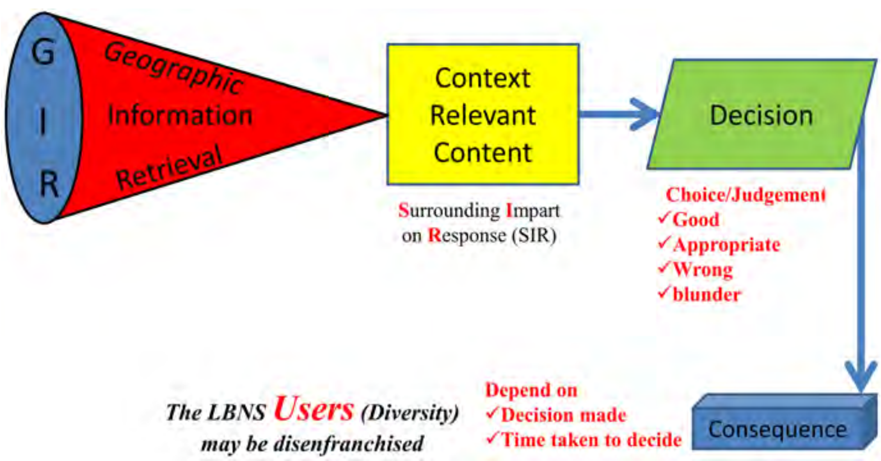

Figure 3. Decision making based on Geographic Information Retrieval (GIR).

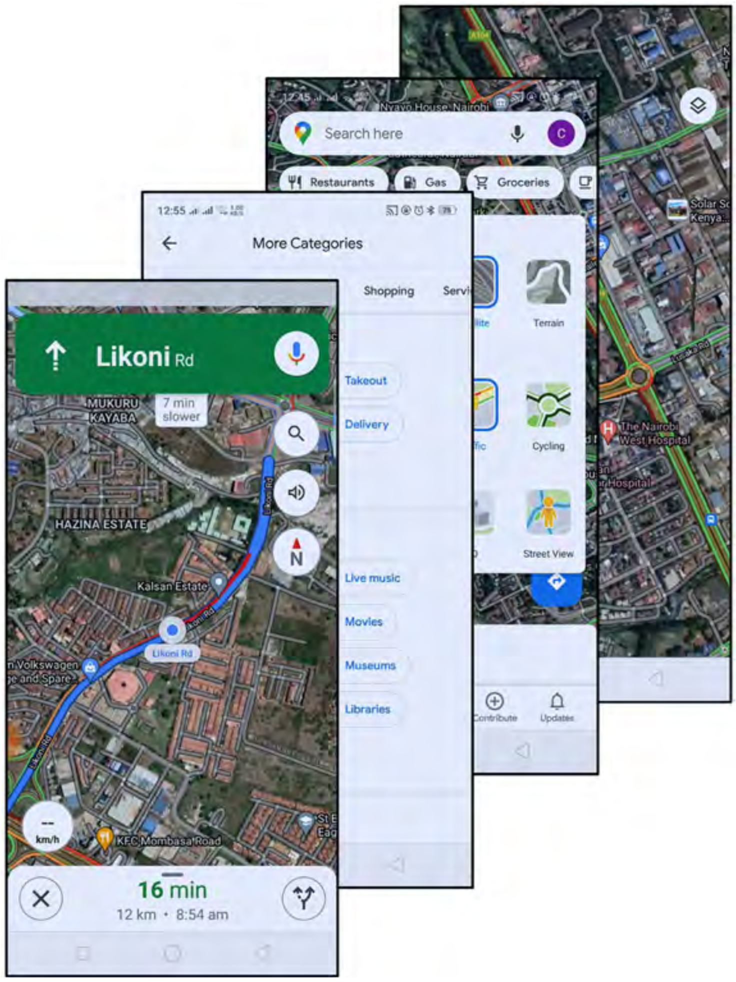

Figure 4. Web Navigation through hyperlinks hypertext and hypermedia in LBS.

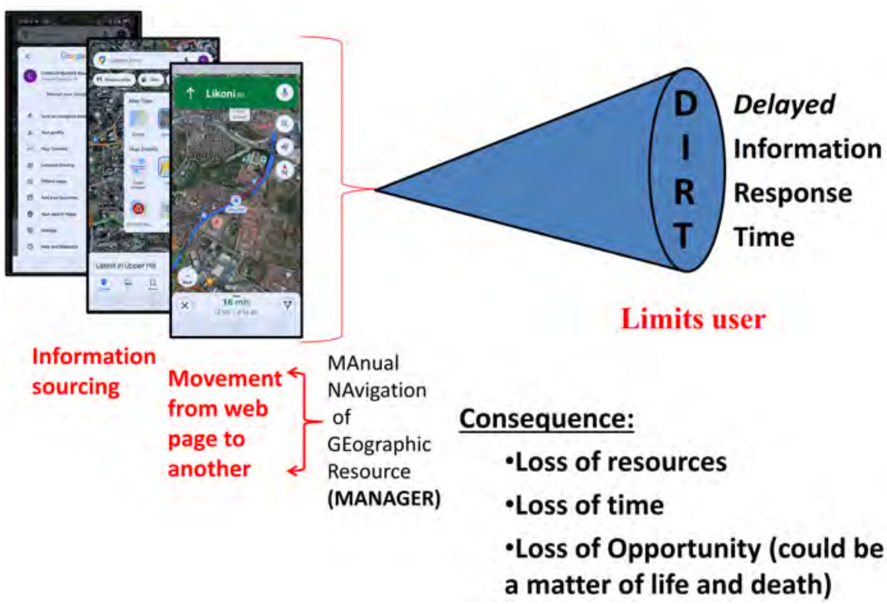

Figure 5. Current web navigation and user limits.

mobile device characteristics were also decided upon based on assumed measurable parameters. Both cartographic content and fickle mobile device variables were later to be calibrated through a quantitative research survey to a knowledgeable group of respondents in the field of Geomatic and Geospatial Information Systems in Jomo Kenyatta University of Agriculture and Technology (JKUAT).

GIR was implemented through a "lift up" process, as opposed to a "staircase" step by step method of web navigation as illustrated in **Figure 6**. This was to improve on decision making and reaction time, hence improved outcome.

The lift up approach for GIR eliminates Manual Navigation of Geographic Resource (MANAGER), and introduces a function that optimizes variables that prevail in LBNS, improving on response as depicted in **Figure 7**. Optimized

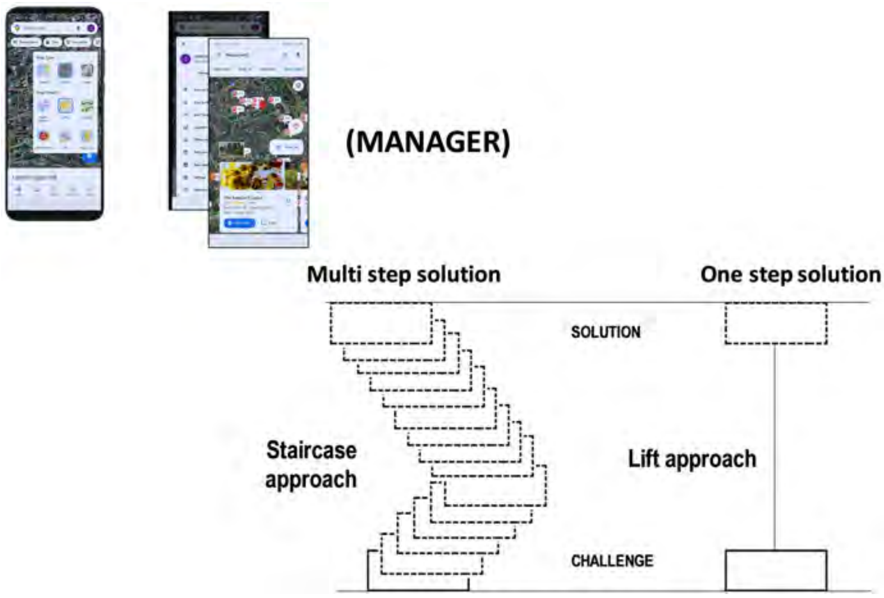

Figure 6. GIR lift approach verses staircase approach.

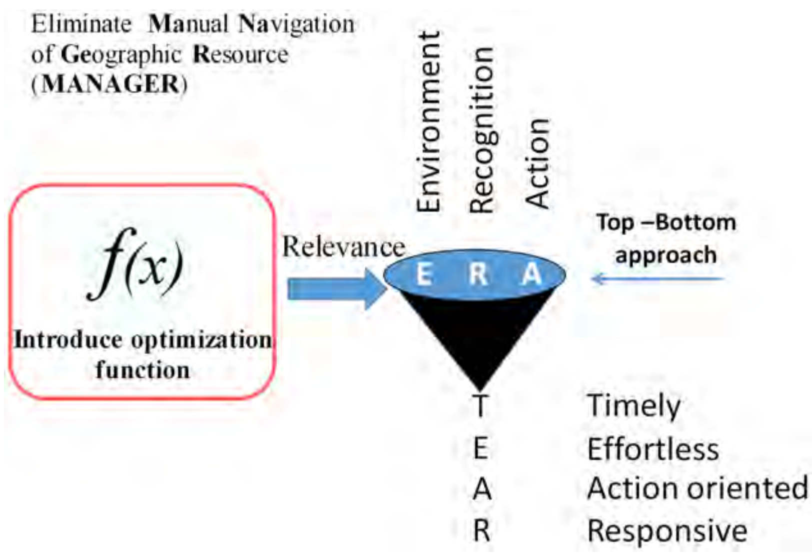

Figure 7. Optimization solution to GIR.

solution for GIR is to provide relevant information, that is recognizable to a user within suitable time, guarantying a timely, effortless, action-oriented response or reaction (TEAR).

3.1. System Architecture

A client server mobile system is a typical design for most applications exhibiting a three-tier architecture, which consists of a mobile application, internet www, web server and a geodatabase as illustrated in **Figure 8**. Three-tier architecture is a well-established software application architecture, that organizes applications into three logical and physical computing tiers: the presentation tier, or user interface; the application tier, where data is processed; and the data tier, where the data associated with the application is stored [16]. In this architecture, information is requested through internet to the server and database, where it is packaged and sent back through the same process to a user interface of a mobile device.

Conceptual System Architecture

Optimization solution in LBNS results in a rich client web architecture, with capability to source for relevant information from several independent databases that provide many options on information delivery. This research intended for high bride four-tier architecture as indicated in **Figure 9**, that constitute a rich

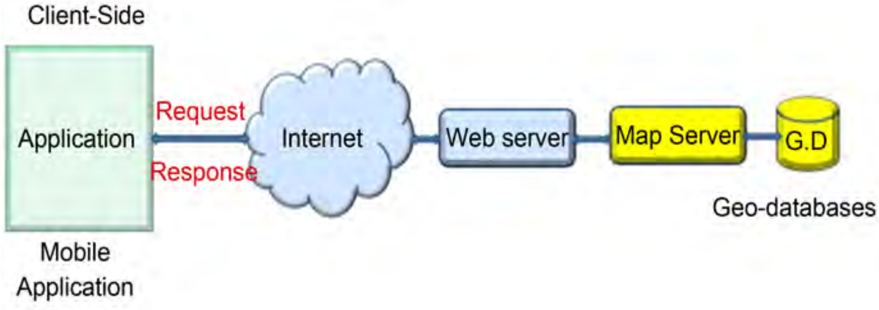

Figure 8. Client server architecture.

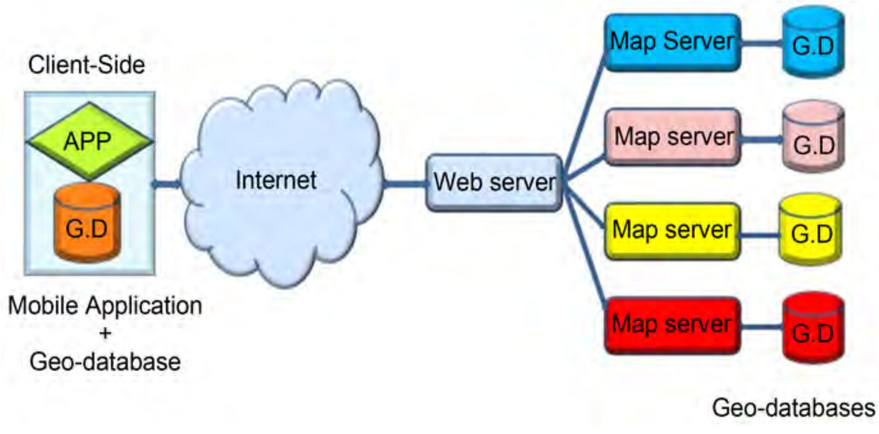

Figure 9. Conceptual system architecture.

client mobile architecture which offers service through a dynamic mobile application, constantly processing suitable cartographic content based on prevailing circumstances, linked to multiple geodatabases from which content can be requested to provide user efficient and relevant information. It also links to the internet and web server [17].

4. Material and Methods

An optimization algorithm was developed between user status, fickle mobile phone features as independent variables and cartographic content as dependent variables. A mathematical relationship between user and fickle features together with ranked cartographic visualization content, were developed through the process outlined in the methodology flowchart in **Figure 10**.

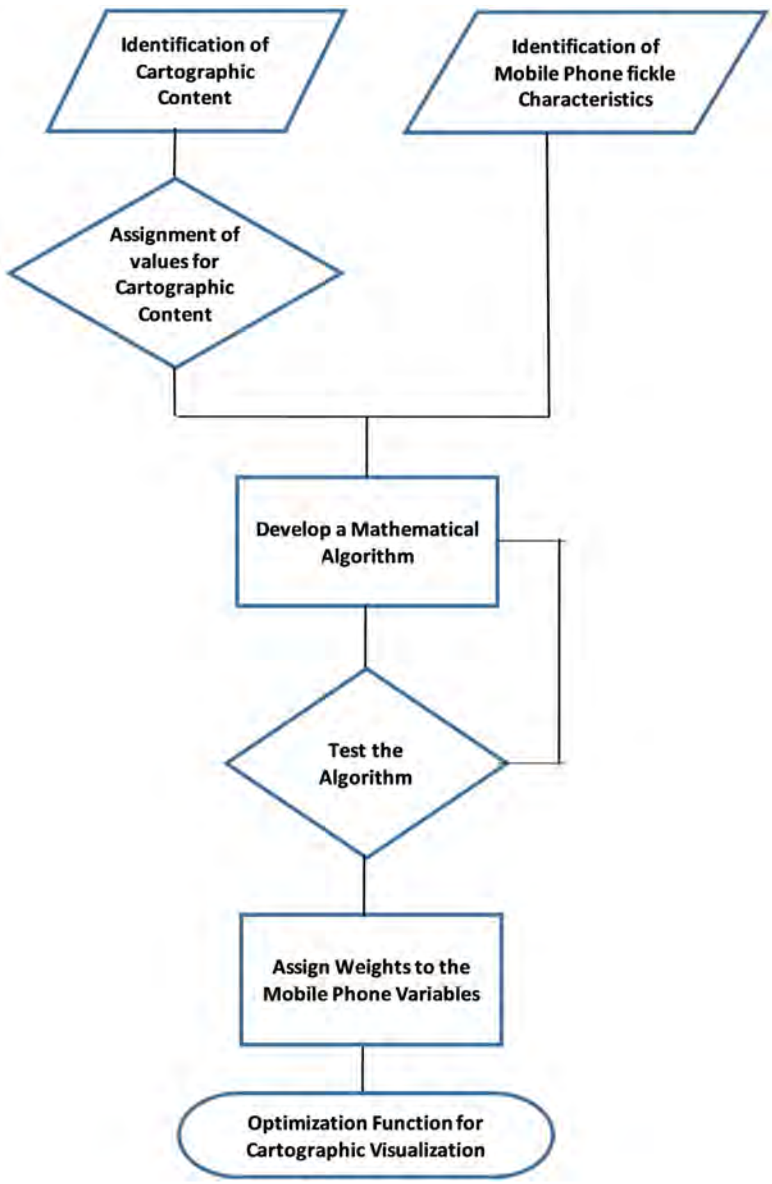

Figure 10. Methodology flow chart.

4.1. Cartographic Content as Dependent Variants

Cartographic visualization content was determined from geographic environment, that could present a user of mobile device to interpret and recognize the surrounding, guarantying swift decision making based on spatial information delivered through LBNS. These include; Line map, terrain map, satellite imagery, Google maps, pictorial representation (photographs & panoramic views), video clips (3D video, motion pictures), live camera feeds/stream, 3D models, 3D virtual reality models.

Line map contained lines and symbol, with street, building and estate names, whereas terrain maps are line maps with an indicator of terrain nature. Satellite imagery are images of location on the earth surface taken from space, with Google map being a link to Google maps with all its functionalities presented as geo-database that can be linked to deliver geospatial information. Pictorial and panoramic views are images of important land marks within geographic space, whereas video clips are motion pictures for land marks and surrounding space. Live feed/stream are images of real time video captured life in a physical geographic environment, with 3D models and virtual reality models being simulated virtual world that one can tour inside and view some geographic space, some of which are represented in **Figure 11**.

Figure 11. Cartographic visualization content captured.

Cartographic visualization content elements were ranked based on order of perceived ease to interpret, with the least represented by a lower value as shown in Table 1. Pictures, panoramic view and video clips were captured within the premise of Jomo Kenyatta University of Agriculture and Technology (JKUAT) main campus, owing to determination of specification, calibrate and evaluation of the optimization system based on response from student and staff in the field of Geomatics and Geoinformatics, who have knowledge in this area of study.

4.2. Fickle Mobile Phone Features as Independent Variants

Independent variables were determined as user status and fickle features of mobile phone and application, these included; battery power, data volume, signal strength, time for delivery and distance to destination, all which are measurable in the mobile device as indicated in Table 2.

A mathematical algorithm was developed between independent variables as relates to dependent variables, where the outcome was a dependent variable, presented as cartographic visualization content to a user, with each of the fickle features varying from 0% to 100% as indicated in Table 3. Computations for coefficients and constants in the function were determined and applied in the algorithm.

Table 1. Cartographic variants assigned values.

Visual Variant	Assigned Value
No map	1
Line map	2
Terrain	3
Satellite Imagery	4
Google maps	5
Pictorial	6
Motion pictures	7
Live camera feeds	8
3D models	9
Virtual reality models	10

Table 2. Fickle mobile phone characteristic.

Parameters	Description
User Status	Familiarity with destination geographic environment
Battery Power	Mobile device battery power available
Data volume	Random access memory (RAM) data volume available
Signal strength	Transmission signal strength
Time of Delivery	Time limit error of application
Distance	Distance to destination

Table 3. Independent variables deviation.

Parameters	Variation											
User Status	0	10	20	30	40	50	60	70	80	90	100	(Familiarity to location in %)
Battery Power	0	10	20	30	40	50	60	70	80	90	100	(Mobile Phone Power available in %)
Data volume	0	10	20	30	40	50	60	70	80	90	100	(Information Data volume in %)
Signal strength	0	10	20	30	40	50	60	70	80	90	100	(Transmission Signal strength in %)
Time of Delivery	0	10	20	30	40	50	60	70	80	90	100	(Run time for application in %)
Distance to Destination	0	10	20	30	40	50	60	70	80	90	100	(Distance to destination in %)

User status describes personality characteristics associated towards geographic environment of destination, whether acquainted or unfamiliar with it. Mobile device battery power is the amount of battery energy stored in a mobile device that may be available for use. RAM data volume being volume space available for incoming and outgoing information being processed by application in the mobile device. Signal strength refers to transmission power output as received by mobile device from a transmitting service provider. Time limit error being time limit application is to process information and deliver response. Distance is a numerical measurement of how far apart the mobile device is to destination location.

4.3. Cartographic Content Simulation

4.3.1. User Status

Table 4 shows User status varying from 0% to 100%, based on the knowledge and familiarity of user on destination. The degree of acquaintance determines possible cartographic content that presents spatial information on LBNS. At 0% a user does not know the locality, hence cartographic content to be presented should be rich hence superior for ease of interpretation and recognition. Likewise at 100%, a user is very familiar with destination geographic environment, and can be presented with information from most inferior to most superior content. The simulation model indicates 0 for not showing and 1 for showing cartographic content. The critical pairing points from this simulation modeling are as follows; (0, 6), (10, 6), (20, 6), (30, 6), (40, 5), (50, 4), (60, 4), (70, 4), (80, 3), (90, 2), (100, 1), being cartographic visualization content for different level of user status.

Using a regression analysis, the best line fit for critical values on user status is represented in Figure 12, it reveals an inversely proportional relationship with

Table 4. Cartographic content as influenced by user status.

Visual Cartographic Content	Assigned Rank											
Non	1	0	0	0	0	0	0	0	0	0	0	1
Line map	2	0	0	0	0	0	0	0	0	0	1	1
Terrain	3	0	0	0	0	0	0	0	0	1	1	1
Satellite Imagery	4	0	0	0	0	0	1	1	1	1	1	1
Google maps	5	0	0	0	0	1	1	1	1	1	1	1
Pictorial	6	1	1	1	1	1	1	1	1	1	1	1
Motion pictures	7	1	1	1	1	1	1	1	1	1	1	1
Live camera feeds	8	1	1	1	1	1	1	1	1	1	1	1
3D models	9	1	1	1	1	1	1	1	1	1	1	1
Virtual reality models	10	1	1	1	1	1	1	1	1	1	1	1
		0	10	20	30	40	50	60	70	80	90	100
		User Knowledge of Locality (%)										

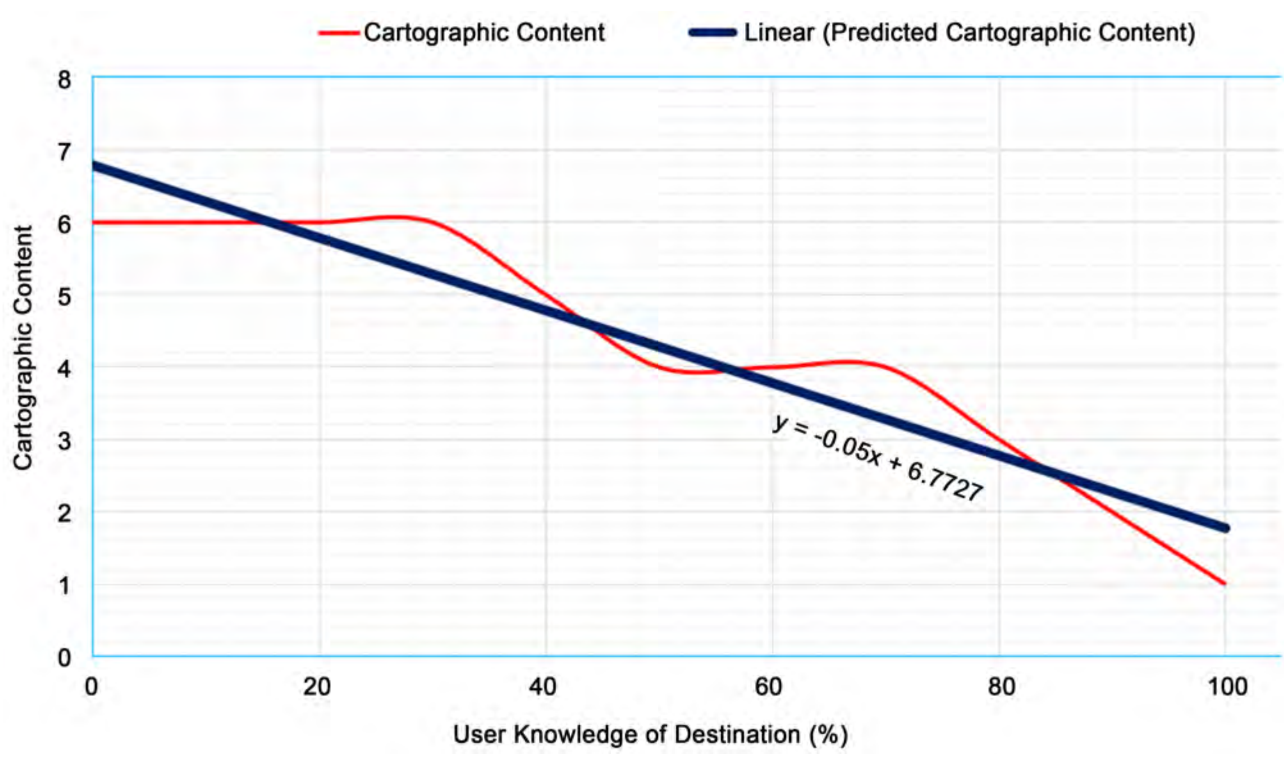

Figure 12. Cartographic content influenced by user status.

level of user status giving a decreasing richness in cartographic content. The gradient is a negative value of 0.05 with a coefficient of 6.772.

The shaded region in **Figure 13**, indicate cartographic content that can be shown based on the variation of user status on familiarity of destination. It is a linear relationship with predicted content greater than or equal to linear relationship of negative 0.05 gradient and coefficient of 6.772.

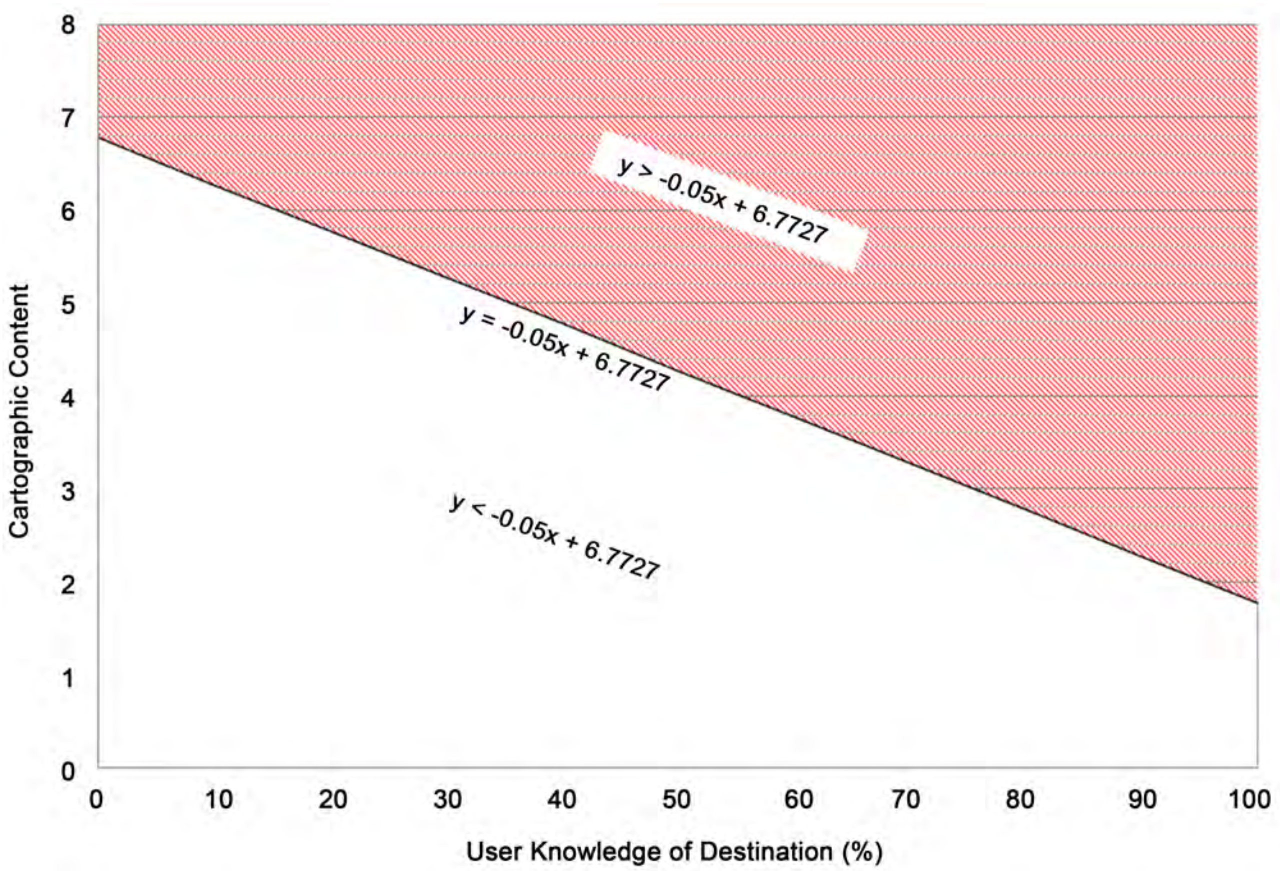

Figure 13. Predicted region for cartographic content as influence by user knowledge status.

4.3.2. Mobile Device Battery Power

Table 5 shows mobile device battery power as it varies from 0% to 100% based on energy available for use in the device. These determined possible cartographic content that present spatial information on LBNS, whereby at 0% of mobile device battery power available, no presentation can be offered. At 10% of mobile device battery power, cartographic content should be light in data volume or size not to consume the available power before presentation, implying inferior content choice comparable to line map. With mobile device battery power available at 100%, all cartographic content can be presented, hence superior content can be available likewise inferior cartographic content. The simulation model indicates 0 for not showing and 1 for showing content, obtaining critical pairing for modeling summarized as follows; (0, 0), (10, 2), (20, 2), (30, 3), (40, 4), (50, 5), (60, 7), (70, 7), (80, 9), (90, 10), (100, 10), being optimal content for mobile device battery power variation.

Figure 14 shows a regression best line fit for critical values of mobile device battery power available against cartographic content, giving a linear relationship where battery power is directly proportional to cartographic content, with a positive gradient of 0.1036 and coefficient of 0.1818.

Figure 15 shows the shaded region of cartographic content that can be offered with varying mobile device battery power. It exhibits a linear relationship with

Table 5. Cartoghraphic content as influenced by mobile device battery power.

Cartographic Content	Assigned Rank											
Non	1	1	1	1	1	1	1	1	1	1	1	1
Line map	2	0	1	1	1	1	1	1	1	1	1	1
Terrain	3	0	0	0	1	1	1	1	1	1	1	1
Satellite Imagery	4	0	0	0	0	1	1	1	1	1	1	1
Google maps	5	0	0	0	0	0	1	1	1	1	1	1
Pictorial	6	0	0	0	0	0	0	1	1	1	1	1
Motion pictures	7	0	0	0	0	0	0	1	1	1	1	1
Live camera feeds	8	0	0	0	0	0	0	0	0	1	1	1
3D models	9	0	0	0	0	0	0	0	0	1	1	1
Virtual reality models	10	0	0	0	0	0	0	0	0	0	1	1
		0	10	20	30	40	50	60	70	80	90	100
		Device Battery Power Available (%)										

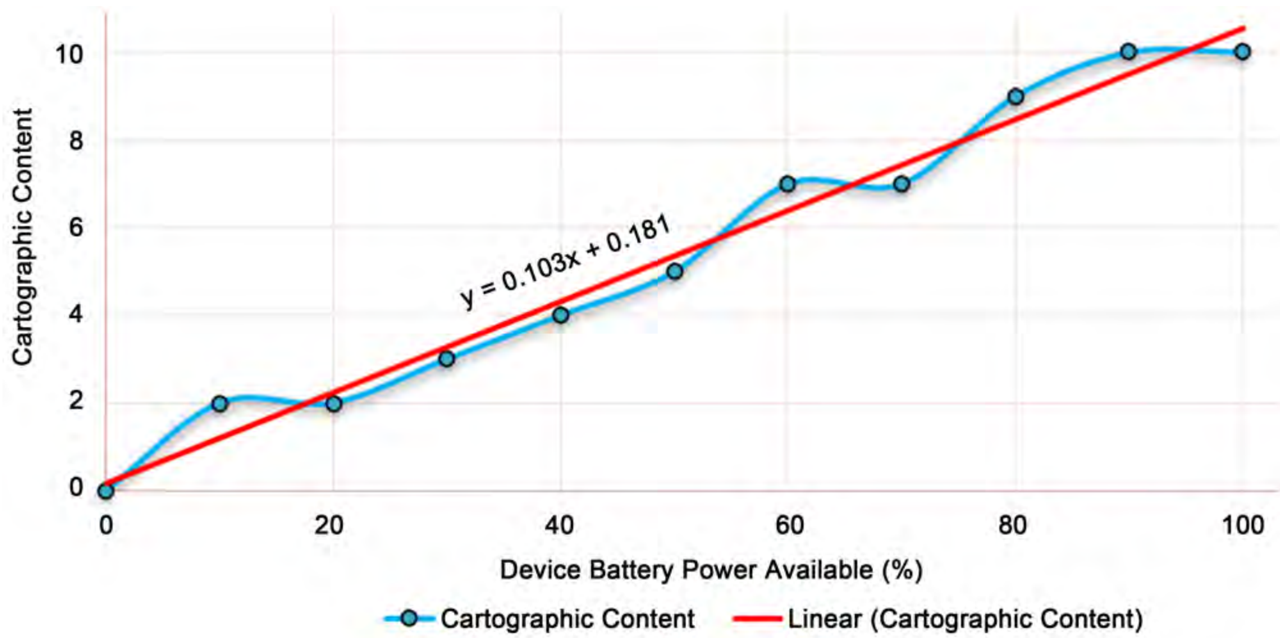

Figure 14. Linear relationship between cartographic content against mobile device battery power.

both the independent and dependent variables varying directly proportional to each other.

4.3.3. Random Access Memory (RAM) Data Volume

Simulation model on RAM data volume in use, implies on percentage of Random-Access Memory (RAM) in use by mobile device operating system and other applications running. This signifying an amount of information space available for processing request and response transmissions, through mobile device to user interface. **Table 6** indicates RAM data volume variation as at 0% capacity in

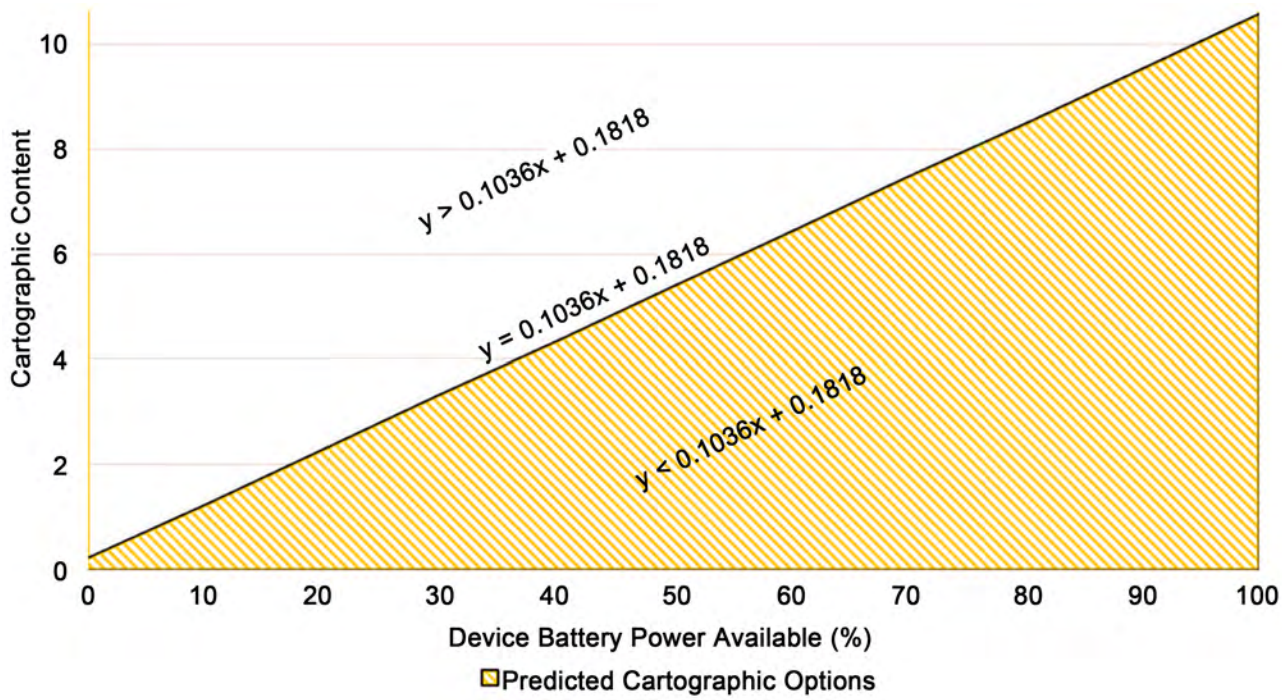

Figure 15. Predicted region for cartographic content as influence by mobile device battery power.

Table 6. Cartographic content as influenced by RAM data volume in use.

Cartographic Content	Assigned Rank											
Non	1	1	1	1	1	1	1	1	1	1	1	0
Line map	2	1	1	1	1	1	1	1	1	1	1	0
Terrain	3	1	1	1	1	1	1	1	1	1	0	0
Satellite Imagery	4	1	1	1	1	1	1	1	1	1	0	0
Google maps	5	1	1	1	1	1	1	1	1	1	0	0
Pictorial	6	1	1	1	1	1	1	1	1	0	0	0
Motion pictures	7	1	1	1	1	1	1	1	0	0	0	0
Live camera feeds	8	1	1	1	1	1	1	0	0	0	0	0
3D models	9	1	1	1	1	1	0	0	0	0	0	0
Virtual reality models	10	1	1	1	1	0	0	0	0	0	0	0
		0	10	20	30	40	50	60	70	80	90	100
		Data Volume in Use by Other Applications (%)										

use by mobile device application, capable of receiving any cartographic content that is inferior varying through to superior content. Whereas at 100% capacity usage by device applications, means there being no space available for any data transmission by any other application, hence no cartographic content is able to be presented. The simulation model indicates 0 for not displaying and 1 for showing cartographic content, where critical pairing for this is as given; (0, 10), (10, 10), (20, 10), (30, 10), (40, 9), (50, 8), (60, 7), (70, 6), (80, 5), (90, 2), (100, 0), being the optimal content presented for data volume of RAM in use.

In **Figure 16** is a linear relationship which is inversely proportional between RAM data volume capacity in use and cartographic content, it portrays a negative gradient of 0.0973 with an intercept of 11.864.

The shaded region in **Figure 17** represents cartographic content that can be displayed with varying RAM data volume in use in the device. This is an inversely proportional linear relationship between the variants.

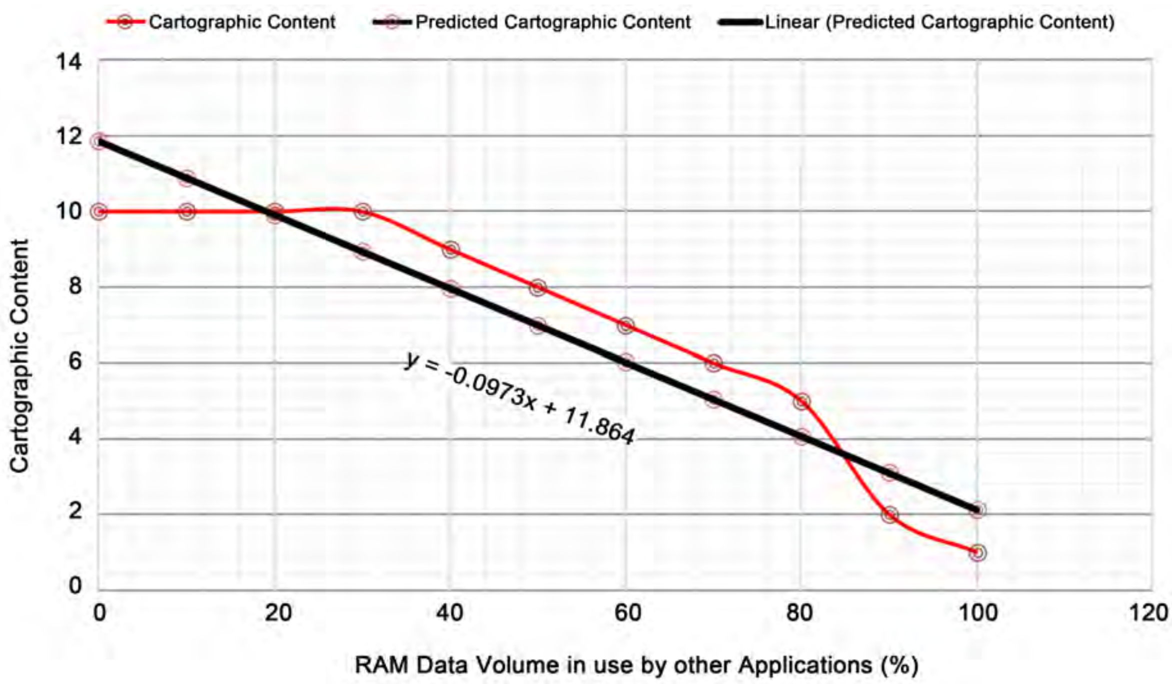

Figure 16. Relationship between cartographic content against RAM data volume capacity in use.

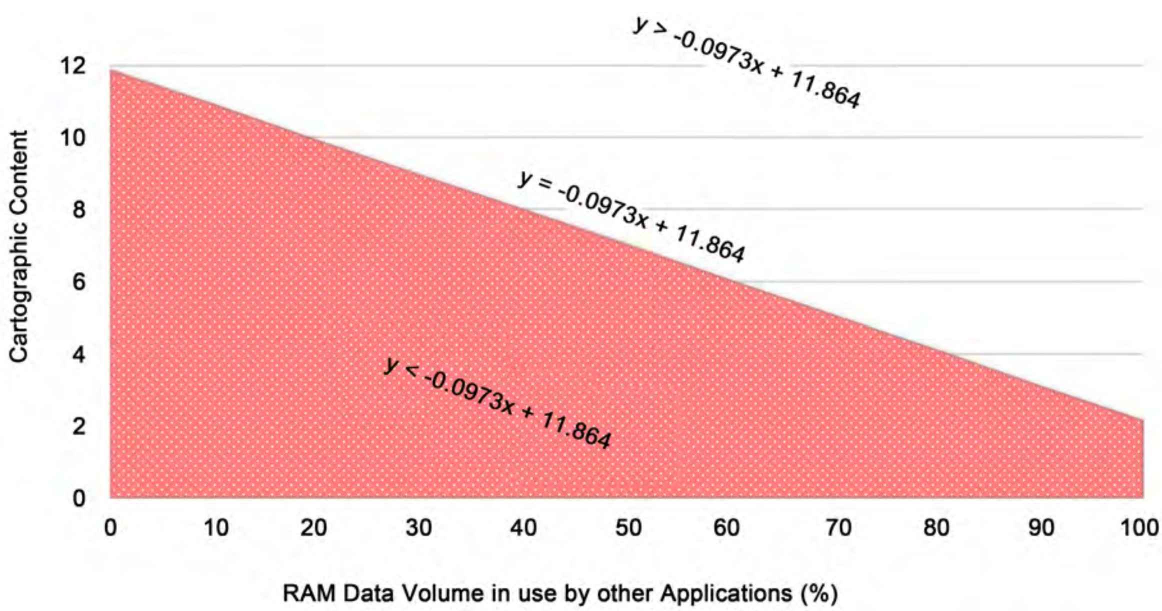

Figure 17. Predicted region for cartographic content as influence by RAM data volume in use.

4.3.4. Signal Strength

Table 7 shows signal strength measured in decibels (dB), which is transmission power output as received by mobile device from a transmitting service provider, influencing cartographic content. Signal strength, transmission signals vary from −110 dB being the lowest signal strength value representing 0%, while −30 dB being the highest signal strength value representing 100%. At 0% signal strength, cartographic content with less data volume or size inferred to be inferior in quality are presented. At 100% signal strength all and any content is possible implying that from inferior varying through to superior cartographic content can be presented. The simulation model 0 indicate not showing and 1 indicate showing or display of content, with the following obtained as critical pairing values; (0, 1), (10, 2), (20, 3), (30, 5), (40, 5), (50, 7), (60, 7), (70, 10), (80, 10), (90, 10), (100, 10) being optimal content for signal strength variation.

Figure 18 indicates a simulation model that gives a linear relationship with cartographic content directly proportional to signal strength, portraying a positive gradient of 0.1 with an intercept at 1.3636.

The shaded region in Figure 19 represents cartographic content, that can be obtainable with varying signal strength from a service provider to mobile device. This is a directly proportional linear relationship between the variants within the area defined by $y \le 0.1x + 1.3636$.

4.3.5. Time Limit Error

Table 8 demonstrates Time limit error, which is associated with runtime error of an application, it determines the time available for response to be executed and varies from 0%,where there is no time registered as running out. Time limit error at 100% is full time limit error registered, application processing should terminate, and hence no response delivered therefore no cartographic content

Table 7. Influence of signal strength on cartographic content.

Cartographic Content	Assigned value											
Non	1	1	1	1	1	1	1	1	1	1	1	1
Line map	2	0	1	1	1	1	1	1	1	1	1	1
Terrain	3	0	0	1	1	1	1	1	1	1	1	1
Satellite Imagery	4	0	0	0	1	1	1	1	1	1	1	1
Google maps	5	0	0	0	1	1	1	1	1	1	1	1
Pictorial	6	0	0	0	0	0	1	1	1	1	1	1
Motion pictures	7	0	0	0	0	0	1	1	1	1	1	1
Live camera feeds	8	0	0	0	0	0	0	0	1	1	1	1
3D models	9	0	0	0	0	0	0	0	1	1	1	1
Virtual reality models	10	0	0	0	0	0	0	0	1	1	1	1
		0	10	20	30	40	50	60	70	80	90	100
							Signal Strength (%)					

Table 8. Influence of time limit error over cartographic content.

Cartographic Content	Assigned Rank	Possibilities										
Non	1	1	1	1	1	1	1	1	1	1	1	1
Line map	2	1	1	1	1	1	1	1	1	1	0	0
Terrain	3	1	1	1	1	1	1	1	1	0	0	0
Satellite Imagery	4	1	1	1	1	1	1	1	0	0	0	0
Google maps	5	1	1	1	1	1	1	0	0	0	0	0
Pictorial	6	1	1	1	1	1	1	0	0	0	0	0
Motion pictures	7	1	1	1	1	1	1	0	0	0	0	0
Live camera feeds	8	1	1	1	1	1	1	0	0	0	0	0
3D models	9	1	1	1	1	1	1	0	0	0	0	0
Virtual reality models	10	1	1	1	1	1	1	0	0	0	0	0
		0	10	20	30	40	50	60	70	80	90	100
		Time Limit Error (%)										

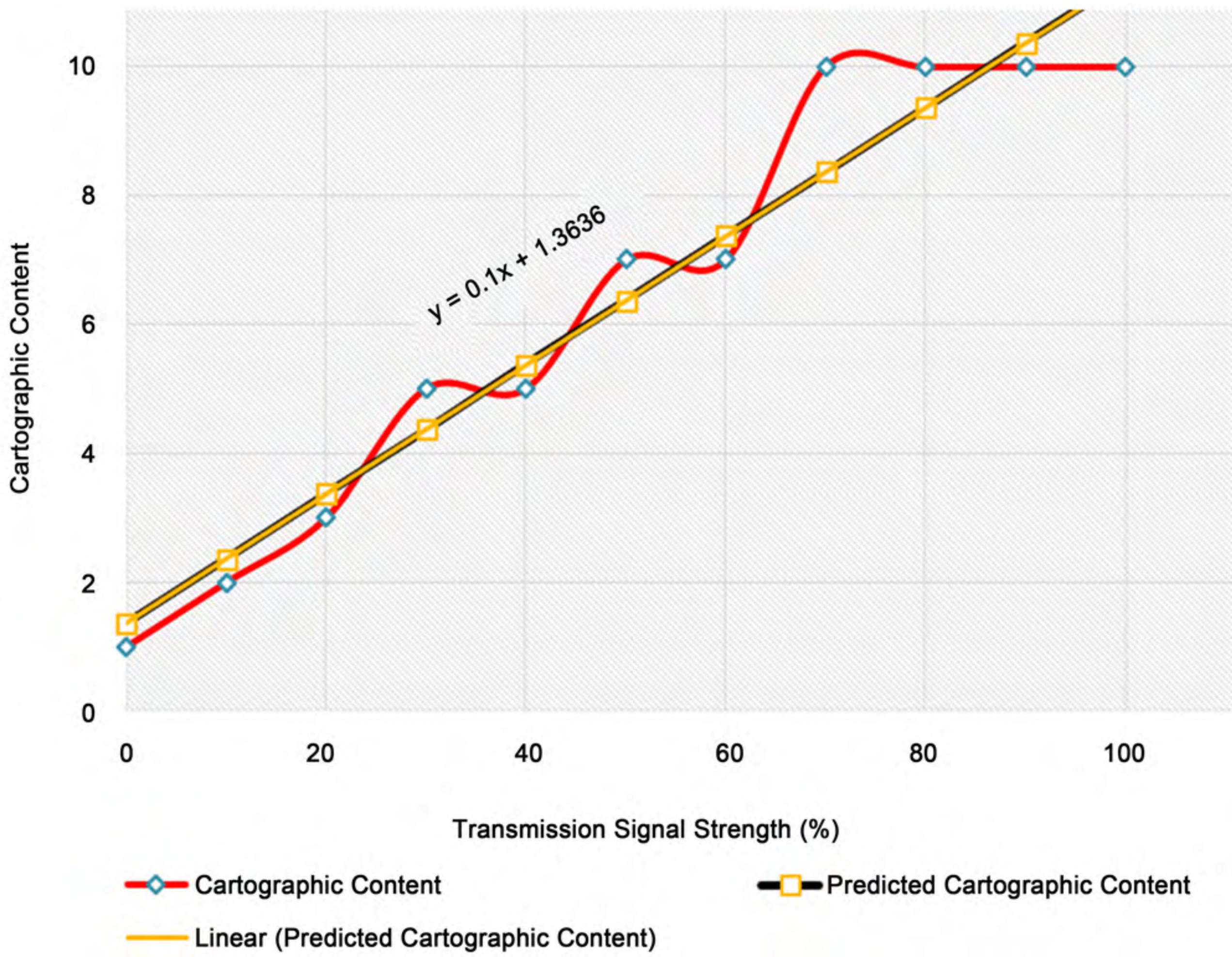

Figure 18. Relationship between cartographic content against signal strength.

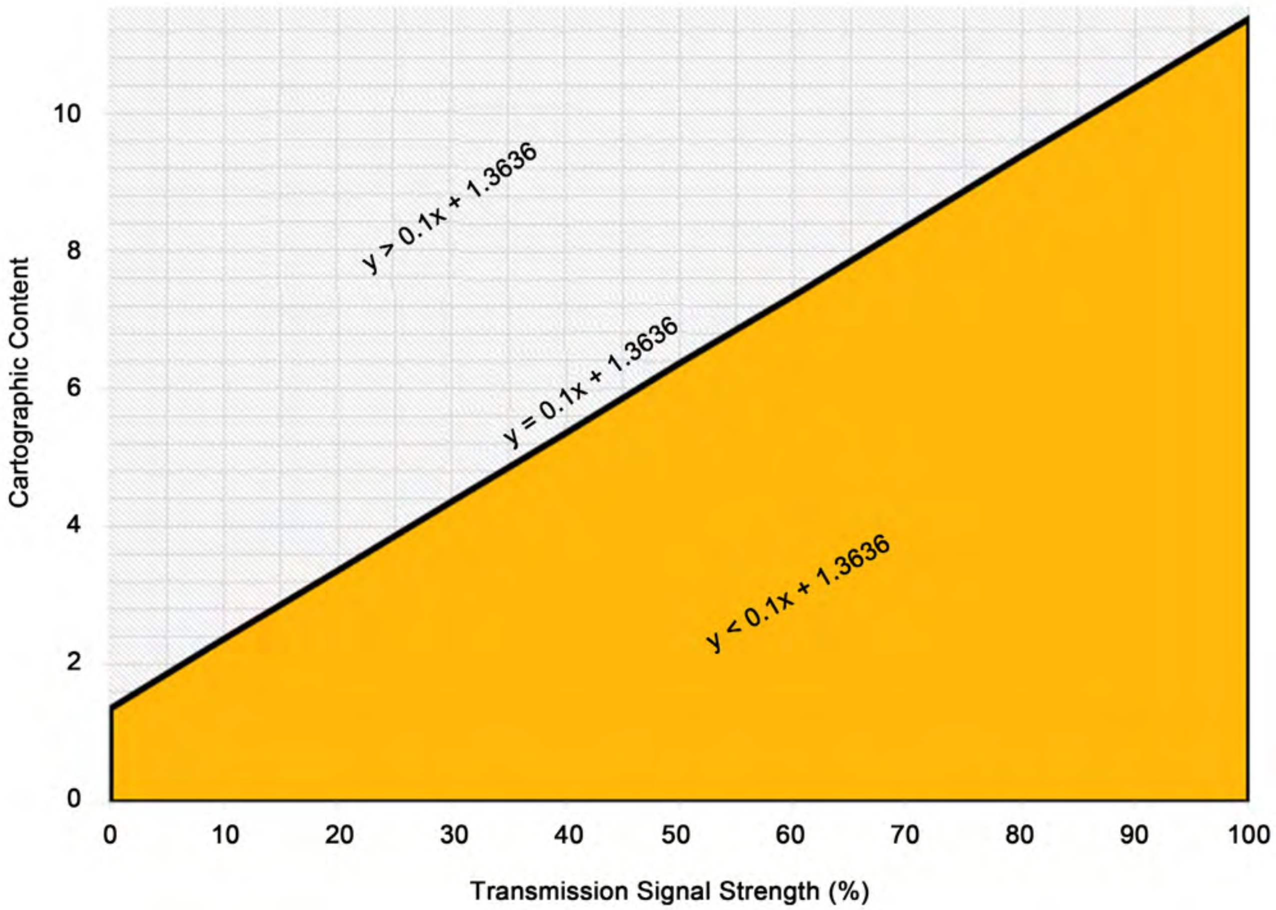

Figure 19. Predicted region for cartographic content as influence by signal strength.

should be displayed giving a runtime error. This implies that the less time limit error registered the more the time available and conversely. Less time registered offers possibility of superior cartographic content being presented, more time registered means less superior cartographic content presentation expected, hence at 0% any cartographic content should be allowed, while at 100% no content should be expected. The modeling can be summarized as follows; (0, 10), (10, 10), (20, 10), (30, 10), (40, 7), (50, 7), (60, 5), (70, 5), (80, 3), (90, 2), (100, 1), being content that can be delivered within time limit error of the application.

Figure 20 indicates a simulation model that gives a linear relationship that is inversely proportional between cartographic content to time limit error. It shows a negative gradient of 0.1 with an intercept at 11.364.

The shaded region in **Figure 21** represents cartographic content that can be presented with varying time limit error for LBNS application, this is the area $y \le -0.1x + 11.364$.

4.3.6. Distance to Destination

Table 9 illustrates distance to destination as obtained by mobile device GPS functionality, varying from 0% to 100% based on remaining distance to destination. With calculated real time distances from GPS/GNSS system, cartographic

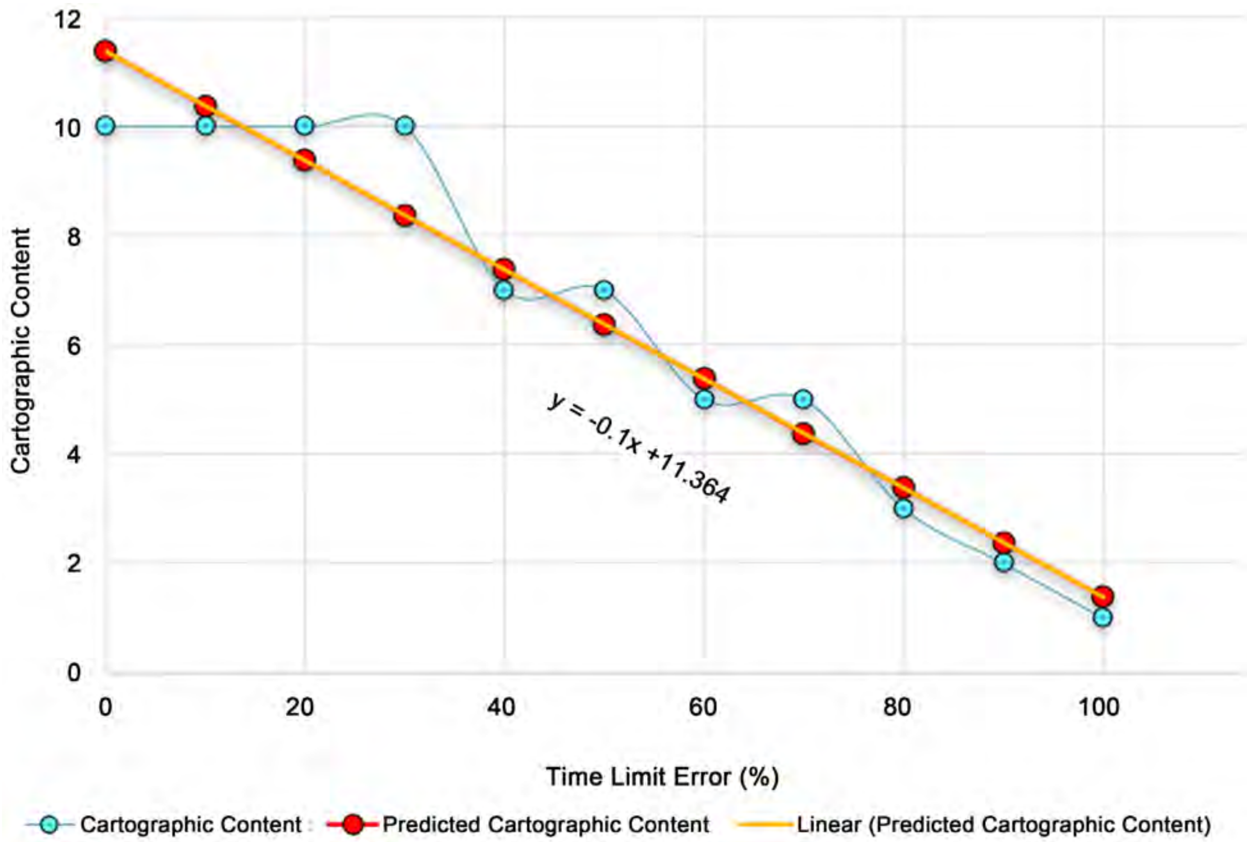

Figure 20. Relationship between cartographic content against time limit error.

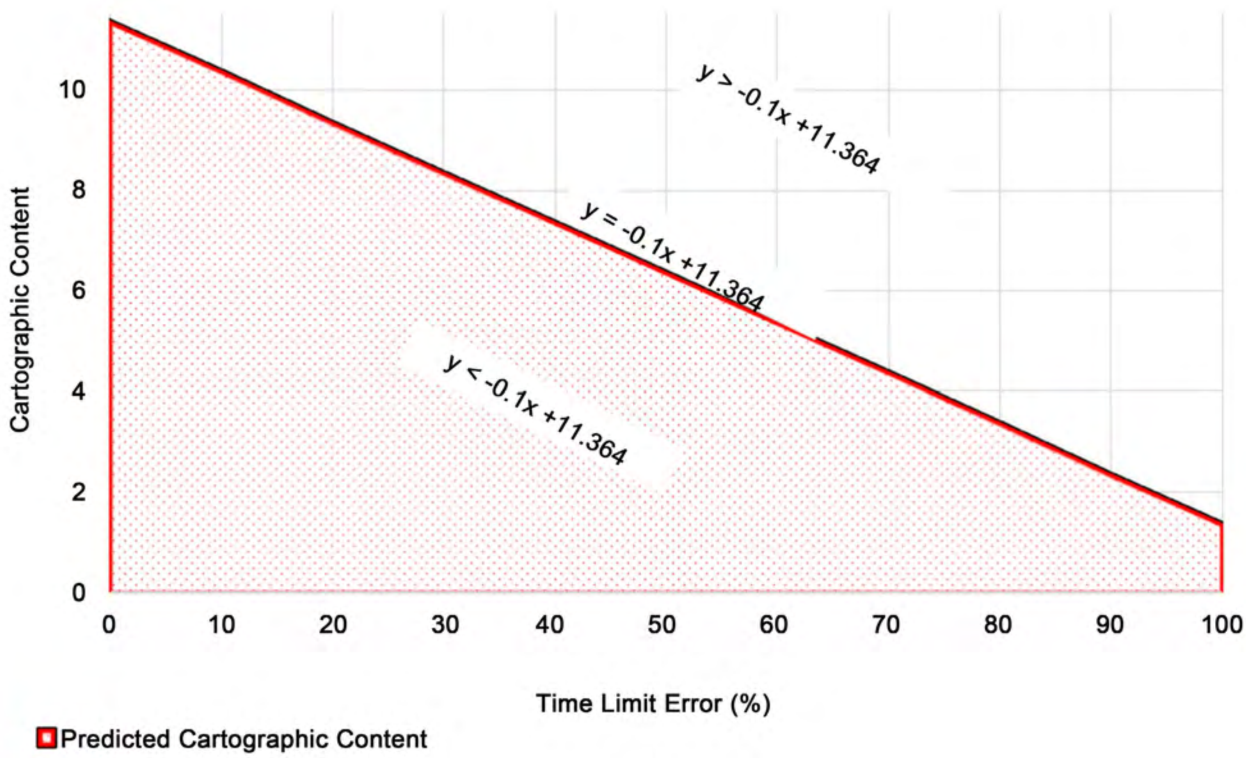

Figure 21. Predicted region for cartographic content as influence by time limit error.

Table 9. Influence of distance to destination over cartographic content.

Cartographic Content	Assigned	Possibilities										
Non	1	0	0	0	0	0	0	0	0	0	0	0
Line map	2	0	0	0	0	0	0	0	0	0	1	1
Terrain	3	0	0	0	0	0	0	0	0	1	1	1
Satellite Imagery	4	0	0	0	0	0	1	1	1	1	1	1
Google maps	5	0	0	0	1	1	1	1	1	1	1	1
Pictorial	6	1	1	1	1	1	1	1	1	1	1	1
Motion pictures	7	1	1	1	1	1	1	1	1	1	1	1
Live camera feeds	8	1	1	1	1	1	1	1	1	1	1	1
3D models	9	1	1	1	1	1	1	1	1	1	1	1
Virtual reality models	10	1	1	1	1	1	1	1	1	1	1	1
		0	10	20	30	40	50	60	70	80	90	100
		Distance to Destination (%)										

content vary based on remaining distance to destination as estimated in a mobile device. At 0% remaining distance mean more superior cartographic content to be presented and vice versa, therefore at 100% distance to destination less superior content can be presented. Summarized simulated critical pairing is as outlined; (0, 6), (10, 6), (20, 6), (30, 5), (40, 5), (50, 4), (60, 4), (70, 4), (80, 3), (90, 2), (100, 2), providing optimal content for distance to destination.

Figure 22 indicates a simulation model that gives a linear relationship of cartographic content that is inversely proportional to distance to destination. It shows a negative gradient of 0.4364 with an intercept at 6.8909.

Figure 23 shows the shaded region that represents cartographic content that can be obtainable with varying distance to destination. This is the region on and above the best fit line in the region of $y \le -0.0436x + 6.4545$.

4.4. Function Modelling

For optimal cartographic content, the resultant function is as below:

$$f(x) = \sum_{i=0}^{100} ax_{1i} + bx_{2i} + cx_{3i} + dx_{4i} + ex_{5i} + fx_{6i} + C$$

where,

a, b, c, d, e, f are coefficients;

$x_1, x_2, x_3, x_4, x_5, x_6$ are variables within the hardware and user status;

$C(K_1, K_2, K_3, K_4, K_5, K_6)$ is a constant for individual variables.

Substituting for the coefficients in the function,

$$f(x) = \sum_{i=0}^{100} ax_{1i} + bx_{2i} + cx_{3i} + dx_{4i} + ex_{5i} + fx_{6i} + C$$

We have,

$$f(x) = \sum_{i=1}^{100} -0.05x_{i1} + 0.1036x_{i2} - 0.0973x_{i3} + 0.1x_{i4} - 0.1x_{i5} - 0.0436x_{i6}$$
$$+ 6.7727 + 0.1818 + 11.8636 + 1.3636 + 11.3636 + 6.4545$$

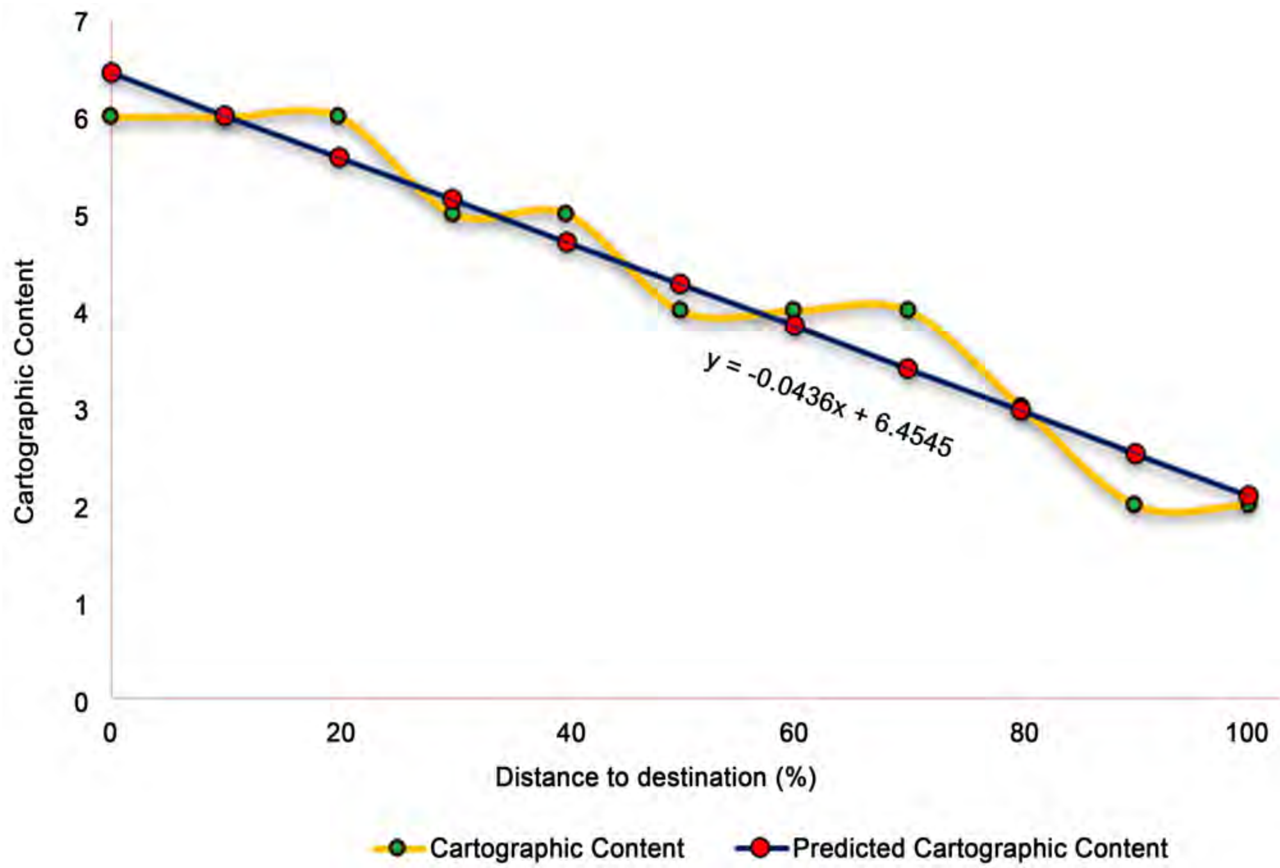

Figure 22. Relationship between cartographic content against distance to destination.

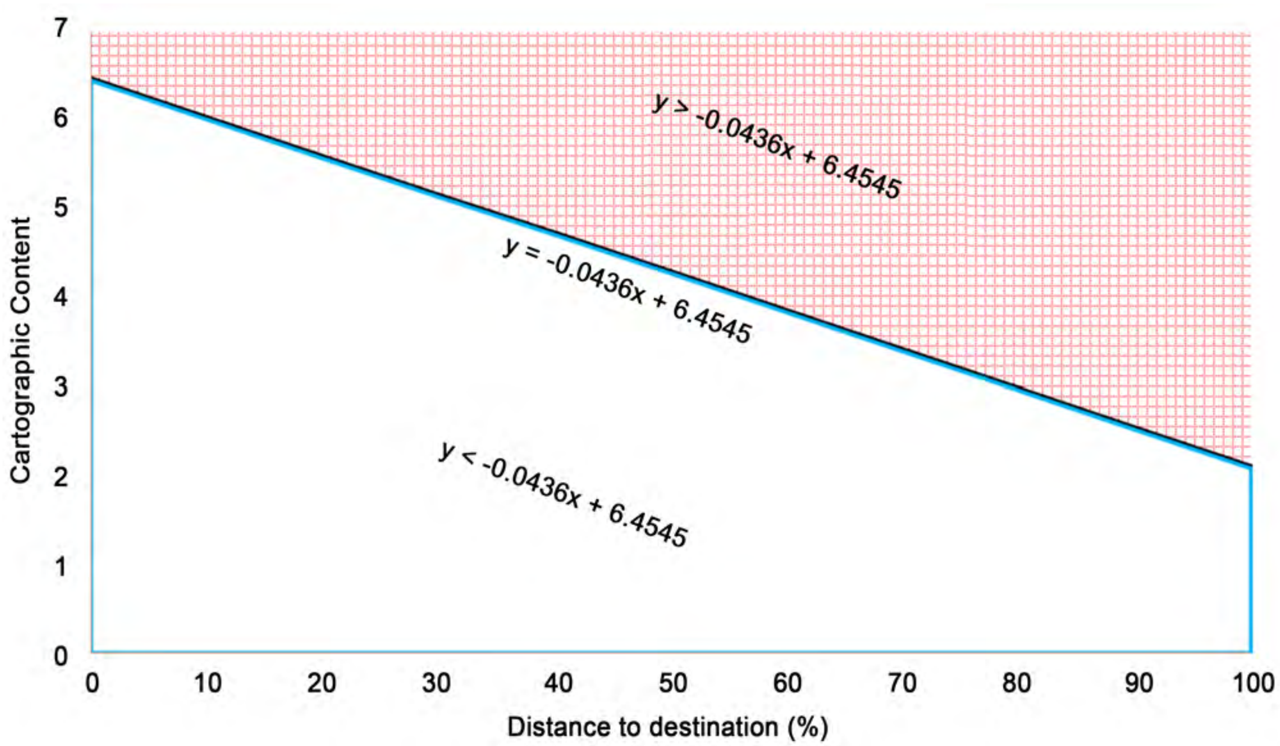

Figure 23. Predicted region for cartographic content as influence by distance to destination.

Weighted Mean Score

In order to choose an optimal cartographic visualization content based on user status and fickle variables of mobile device, a weighted mean score was obtained. Using a Likert scale ranking criteria from most important, important, average, less important, not important varying from 5, 4, 3, 2, 1 respectively as indicated in Table 10. An aggregated score of the weighted cartographic content at any given instance of request is obtained and a weighted mean score obtained.

Computed to find the optimum content for presentation.

$$\overline{x} = \frac{\sum w_i x_i}{\sum w_i}$$

With an assumption that the most important variable be user status, followed by battery power and distance to destination as important, time limit error being taken as average while signal strength and data volume were considered as less important and not important respectively as indicated in Table 11.

The resultant function is

$$f(x) = \sum_{i=1}^{100} W_1 a x_1 + W_2 b x_2 + W_3 c x_3 + W_4 d x_4 + W_5 e x_5 + W_6 f x_6 + W_1 K_1 + W_2 K_2 + W_3 K_3 + W_4 K_4 + W_5 K_5 + W_6 K_6$$

where W is the weight matrix.

Table 10. Likert scale preference ranking.

Rankings	Value
Most Important	5
Important	4
Average	3
Less Important	2
Not Important	1

Table 11. Ranking of independent variables on mobile device.

Variables	Weight
User Status	5
Battery Power	4
Data volume	1
Signal strength	2
Time of Delivery	3
Distance to Destination	4
Total Sum	19

$$f(x)=\sum_{i=1}^{100}\frac{5}{19}(-0.05)x_{i1}+\frac{4}{19}(0.1036)x_{i2}+\frac{1}{19}(-0.0973)x_{i3}+\frac{2}{19}(0.1)x_{i4}$$
$$+\frac{3}{19}(-0.1)x_{i5}+\frac{4}{19}(-0.0436)x_{i6}+\frac{5}{19}(6.7727)+\frac{4}{19}(0.1818)$$
$$+\frac{1}{19}(11.8636)+\frac{2}{19}(1.3636)+\frac{3}{19}(11.3636)+\frac{4}{19}(6.4545)$$

For varying values of x that are independent variables, the solution is given by the above mathematical equation, which represents the cartographic content to be delivered.

5. Prototype LBNS

A prototype LBNS was developed using Android Studio 2.2.2 as the Integrated Development Environment (IDE), Android Software Development Kit (SDK) version 24.4.1 which is loaded with Google's material design concept, Google maps for android, Volley library version 1.0.19 and Picasso library version 2.5.2. Incorporated with the optimization algorithm as an added module, it is able to provide a user with a personalized cartographic visualization content, to enable user's orientation, recognition of geographic space, providing swift decision making and response, hence improved outcome.

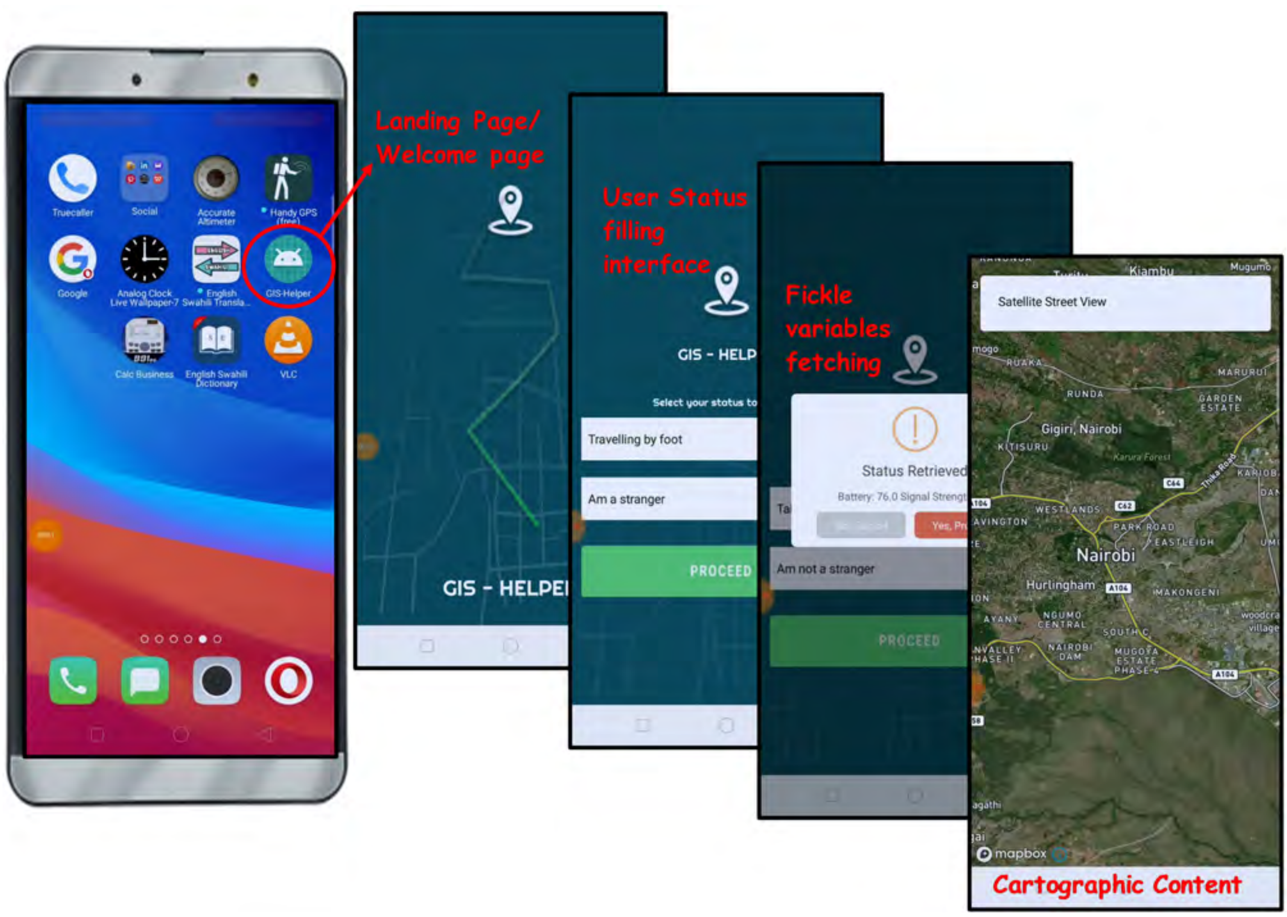

Figure 24. Prototype LBNS; GIS HELPER application.

GIS Helper application is a LBNS with optimization module for cartographic content, aimed at improving on relevance and effectiveness of cartographic visualization content delivery to mobile device user, to improve on decision making leading to appropriate reaction or response hence outcome. This is a simple to interact application that has a landing page or welcome page, leading to a user interface where a user is to choose on their status as indicated in **Figure 24**. This includes travelling mode and familiarity to destination, further leading to the application fishing out status of mobile device fickle variables as registered in the system. Optimization is done in the application where suitable cartographic content is delivered to a user through a user interface.

6. Conclusion and Recommendation

- LBNS technology can be developed based on existing technical challenges, to suit user needs, aspirations and satisfaction, considered as a social being which is non-technical challenge, to warrant acceptance and adoption.
- Personalized LBNS can be achieved through optimization of cartographic content, in relationship to user status and mobile device variables. Optimized solution in contextual cartographic content in geographic Information retrieval, can be achieved through multiple data sourcing, if applied to the application.
- Optimization in LBNS provides room for improvement on cartographic content presentation variables, for user satisfaction and consumption resulting to appropriate and relevant content that steers decision making for user's response, on situation as per prevailing circumstances of mobile device.
- For any users at same location, same destination, it is not necessarily true that cartographic content delivery is exactly the same, as it is dependent on individual familiarity to destination and fickle variables of their individual mobile devices, which may not necessarily have similar variable at any given instance, thereby personalizing individual user needs.

Recommendations

- In optimization of cartographic content in LBNS, suitable cartographic variable need to be developed for the application to offer satisfaction to user, in which recognition and orientation of user should be achieved within a limited time. More investigations can be performed to determine cartographic content preference, based on varied user need as they form the base to optimization solution.
- LBNS is a user decision-making tool, in that it should be able to immediately change on what information to retrieve based on instantaneous changing circumstances of user and mobile device. The content should also provide general orientation of user within some geographic environment.
- An automated system can be developed to link to the optimization structure which can automatically alter how cartographic content can be presented to a

user, through continued monitoring, testing and evaluation of the application. This will improve on efficiency in tailor making of application to conform to needs of specific users.

- Apart from user status given priority in the system, more variant either technical or non-technical need to be tested as well to determine their viability in the effort of improving LBNS and its service performance.

Acknowledgements

I wish to extend my special thanks to my supervisors Prof. E. H. Waithaka, Prof. M. K. Gachari and Prof. D. N. Kuria for their guidance, support and patience. I equally give a lot of gratitude to my beloved Wife Everlyne Nangila Nyongesa for her encouragement, moral and material support. I also express my sincere appreciation to Jomo Kenyatta University of Agriculture and Technology for sponsoring my research work.

Conflicts of Interest

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

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Appendix

Appendix I. Function Modelling

For optimal cartographic content, the resultant function is as below:

$$f(x) = \sum_{i=1}^{100} W_1 a x_1 + W_2 b x_2 + W_3 c x_3 + W_4 d x_4 + W_5 e x_5 + W_6 f x_6 + W_1 K_1 + W_2 K_2 + W_3 K_3 + W_4 K_4 + W_5 K_5 + W_6 K_6 \quad \text{(A.1)}$$

where,

a, b, c, d, e, f are coefficients;

$x_1, x_2, x_3, x_4, x_5, x_6$ are variables within the hardware and user status;

$C(K_1, K_2, K_3, K_4, K_5, K_6)$ is a constant for individual variables.

Appendix II. Matrix Algebra

For the function, x can be obtained from A and y through a regression analysis in Equation (A.1), using matrix algebra as indicated Figure 25:

$$Ax = y \quad \text{(A.2)}$$

Appendix III. Function Input for Element *A* and *y*

The elements of A and y shown below, populate the A and y matrices resulting in matrices shown in Figure 26.

$$A_{1i}, y_{1i} : (0,6),(10,6),(20,6),(30,6),(40,5),(50,4),(60,4),(70,4),(80,3),(90,2),(100,1)$$

$$A_{2i}, y_{2i} : (0,0),(10,2),(20,2),(30,3),(40,4),(50,5),(60,7),(70,7),(80,9),(90,10),(100,10)$$

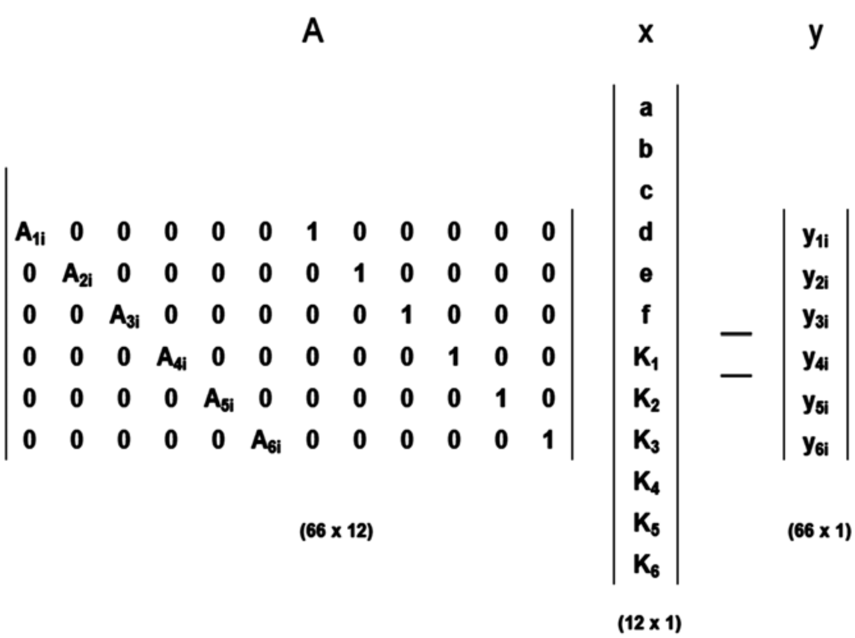

Figure 25. Matrix multiplication for A, x and y matrices.

A												x	y
0	0	0	0	0	0	1	0	0	0	0	0		6
10	0	0	0	0	0	1	0	0	0	0	0		6
20	0	0	0	0	0	1	0	0	0	0	0		6
30	0	0	0	0	0	1	0	0	0	0	0		6
40	0	0	0	0	0	1	0	0	0	0	0		5
50	0	0	0	0	0	1	0	0	0	0	0		4
60	0	0	0	0	0	1	0	0	0	0	0		4
70	0	0	0	0	0	1	0	0	0	0	0		4
80	0	0	0	0	0	1	0	0	0	0	0		3
90	0	0	0	0	0	1	0	0	0	0	0		2
100	0	0	0	0	0	1	0	0	0	0	0		1
0	0	0	0	0	0	0	1	0	0	0	0		0
0	10	0	0	0	0	0	1	0	0	0	0		2
0	20	0	0	0	0	0	1	0	0	0	0		2
0	30	0	0	0	0	0	1	0	0	0	0		3
0	40	0	0	0	0	0	1	0	0	0	0		4
0	50	0	0	0	0	0	1	0	0	0	0		5
0	60	0	0	0	0	0	1	0	0	0	0		7
0	70	0	0	0	0	0	1	0	0	0	0		7
0	80	0	0	0	0	0	1	0	0	0	0		9
0	90	0	0	0	0	0	1	0	0	0	0		10
0	100	0	0	0	0	0	1	0	0	0	0		10
0	0	0	0	0	0	0	0	1	0	0	0		10
0	0	10	0	0	0	0	0	1	0	0	0		10
0	0	20	0	0	0	0	0	1	0	0	0		10
0	0	30	0	0	0	0	0	1	0	0	0		10
0	0	40	0	0	0	0	0	1	0	0	0	a	9
0	0	50	0	0	0	0	0	1	0	0	0	b	8
0	0	60	0	0	0	0	0	1	0	0	0	c	7
0	0	70	0	0	0	0	0	1	0	0	0	d	6
0	0	80	0	0	0	0	0	1	0	0	0	e	5
0	0	90	0	0	0	0	0	1	0	0	0	f	2
0	0	100	0	0	0	0	0	1	0	0	0	K1	0
0	0	0	0	0	0	0	0	0	1	0	0	K2	1
0	0	0	10	0	0	0	0	0	1	0	0	K3	2
0	0	0	20	0	0	0	0	0	1	0	0	K4	3
0	0	0	30	0	0	0	0	0	1	0	0	K5	5
0	0	0	40	0	0	0	0	0	1	0	0	K6	5
0	0	0	50	0	0	0	0	0	1	0	0		7
0	0	0	60	0	0	0	0	0	1	0	0	(12 x 1)	7
0	0	0	70	0	0	0	0	0	1	0	0		10
0	0	0	80	0	0	0	0	0	1	0	0		10
0	0	0	90	0	0	0	0	0	1	0	0		10
0	0	0	100	0	0	0	0	0	1	0	0		10
0	0	0	0	0	0	0	0	0	0	1	0		10
0	0	0	0	10	0	0	0	0	0	1	0		10
0	0	0	0	20	0	0	0	0	0	1	0		10
0	0	0	0	30	0	0	0	0	0	1	0		10
0	0	0	0	40	0	0	0	0	0	1	0		7
0	0	0	0	50	0	0	0	0	0	1	0		7
0	0	0	0	60	0	0	0	0	0	1	0		5
0	0	0	0	70	0	0	0	0	0	1	0		5
0	0	0	0	80	0	0	0	0	0	1	0		3
0	0	0	0	90	0	0	0	0	0	1	0		2
0	0	0	0	100	0	0	0	0	0	1	0		1
0	0	0	0	0	0	0	0	0	0	0	1		6
0	0	0	0	0	10	0	0	0	0	0	1		6
0	0	0	0	0	20	0	0	0	0	0	1		6
0	0	0	0	0	30	0	0	0	0	0	1		5
0	0	0	0	0	40	0	0	0	0	0	1		5
0	0	0	0	0	50	0	0	0	0	0	1		4
0	0	0	0	0	60	0	0	0	0	0	1		4
0	0	0	0	0	70	0	0	0	0	0	1		4
0	0	0	0	0	80	0	0	0	0	0	1		3
0	0	0	0	0	90	0	0	0	0	0	1		2
0	0	0	0	0	100	0	0	0	0	0	1		2
(66 x 12)													(66 x 1)

Figure 26. Matrices A and y elements inputs.

$$A_{3i}, y_{3i} : (0,10),(10,10),(20,10),(30,10),(40,9),(50,8),$$
$$(60,7),(70,6),(80,5),(90,2),(100,0)$$

$$A_{4i}, y_{4i}: (0,1),(10,2),(20,3),(30,5),(40,5),(50,7),$$
$$(60,7),(70,10),(80,10),(90,10),(100,10)$$

$$A_{5i}, y_{5i}: (0,10),(10,10),(20,10),(30,10),(40,7),(50,7),$$
$$(60,5),(70,5),(80,3),(90,2),(100,1)$$

$$A_{6i}, y_{6i}: (0,6),(10,6),(20,6),(30,5),(40,5),(50,4),$$
$$(60,4),(70,4),(80,3),(90,2),(100,2)$$

Therefore:

$A^T A$

38500	0	0	0	0	0	550	0	0	0	0	0
0	38500	0	0	0	0	0	550	0	0	0	0
0	0	38500	0	0	0	0	0	550	0	0	0
0	0	0	38500	0	0	0	0	0	550	0	0
0	0	0	0	38500	0	0	0	0	0	550	0
0	0	0	0	0	38500	0	0	0	0	0	550
550	0	0	0	0	0	11	0	0	0	0	0
0	550	0	0	0	0	0	11	0	0	0	0
0	0	550	0	0	0	0	0	11	0	0	0
0	0	0	550	0	0	0	0	0	11	0	0
0	0	0	0	550	0	0	0	0	0	11	0
0	0	0	0	0	550	0	0	0	0	0	11

(12 x 12)

$(A^T A)^{-1}$

9.091E-05	0	0	0	0	0	-4.545E-03	0	0	0	0	0
0	9.091E-05	0	0	0	0	0	-4.545E-03	0	0	0	0
0	0	9.091E-05	0	0	0	0	0	-4.545E-03	0	0	0
0	0	0	9.091E-05	0	0	0	0	0	-4.545E-03	0	0
0	0	0	0	9.091E-05	0	0	0	0	0	-4.545E-03	0
0	0	0	0	0	9.091E-05	0	0	0	0	0	-4.545E-03
-4.545E-03	0	0	0	0	0	3.182E-01	0	0	0	0	0
0	-4.545E-03	0	0	0	0	0	3.182E-01	0	0	0	0
0	0	-4.545E-03	0	0	0	0	0	3.182E-01	0	0	0
0	0	0	-4.545E-03	0	0	0	0	0	3.182E-01	0	0
0	0	0	0	-4.545E-03	0	0	0	0	0	3.182E-01	0
0	0	0	0	0	-4.545E-03	0	0	0	0	0	3.182E-01

(12 x 12)

$A^T y$

1800
4090
2780
4600
2400
1870
47
59
77
70
70
47

(12 x 1)

x		$(A^TA)^{-1}A^Ty$
a		-0.0500
b		0.1036
c		-0.0973
d		0.1000
e		-0.1000
f	=	-0.0436
K1		6.7727
K2		0.1818
K3		11.8636
K4		1.3636
K5		11.3636
K6		6.4545
(12 x 1)		(12 x 1)

Substituting for the coefficients in the function (A.1),

hence,

$$f(x)=\sum_{i=1}^{100}-0.05x_{i1}+0.1036x_{i2}-0.0973x_{i3}+0.1x_{i4}-0.1x_{i5}-0.0436x_{i6} \quad \text{(A.3)}$$
$$+6.7727+0.1818+11.8636+1.3636+11.3636+6.4545$$

Appendix IV. Weighted Mean Score

In order to choose an optimal cartographic visualization content, based on user status and fickle variables of mobile device, a weighted mean score was obtained. Using a Likert scale ranking criteria, from most important, important, average, less important, not important, varying from 5, 4, 3, 2, 1 respectively as in Table 12. An aggregated score of the weighted cartographic content at any given instance of request, is obtained and a weighted mean score computed as in expression A.4 to find the optimum content for presentation.

$$\bar{x}=\frac{\sum w_i x_i}{\sum w_i} \quad \text{(A.4)}$$

With an assumption that the most important variable be user status, followed by battery power and distance to destination as important, time limit error being taken as average, while signal strength and data volume were considered as less important and not important respectively as indicated in Table 13.

Table 12. Likert scale preference ranking.

Rankings	Value
Most Important	5
Important	4
Average	3
Less Important	2
Not Important	1

Table 13. Assignment of weights to variables of mobile device.

Variables	Weight
User Status	5
Battery Power	4
Data volume	1
Signal strength	2
Time of Delivery	3
Distance to Destination	4
Total Sum	19

Thus a (12 × 1) weight matrix multiplied to the function obtains a resultant cartographic content. This is demonstrated in equation below.

$$x = (I \cdot W)^{\mathrm{T}} \cdot (A^{\mathrm{T}} A)^{-1} A^{\mathrm{T}} y \tag{A.5}$$

where

I is identity matrix;

W is weight matrix.

Hence through matrix multiplication of identity matrix shown in Figure 27, with assigned weights to produce a weight matrix indicated in Figure 28, resulting to determinant for the optimization function which is cartographic content option to be presented.

$$x = (I \cdot W)^{\mathrm{T}} \cdot (A^{\mathrm{T}} A)^{-1} A^{\mathrm{T}} y \tag{A.6}$$

where

I is identity matrix;

W is weight matrix.

The resultant function is

1	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	1

Figure 27. A (12 × 12) identity matrix.

5/19
4/19
1/19
2/19
3/19
4/19
5/19
4/19
1/19
2/19
3/19
4/19

Figure 28. *A* (12 × 1) weight matrix.

$$f(x)=\sum_{i=1}^{100} W_1 a x_1 + W_2 b x_2 + W_3 c x_3 + W_4 d x_4 + W_5 e x_5 + W_6 f x_6 + W_1 K_1 + W_2 K_2 + W_3 K_3 + W_4 K_4 + W_5 K_5 + W_6 K_6 \quad (A.7)$$

where W is the weight matrix.

Hence final optimization algorithm,

$$f(x)=\sum_{i=1}^{100} \frac{5}{19}(-0.05)x_{i1} + \frac{4}{19}(0.1036)x_{i2} + \frac{1}{19}(-0.0973)x_{i3} + \frac{2}{19}(0.1)x_{i4} + \frac{3}{19}(-0.1)x_{i5} + \frac{4}{19}(-0.0436)x_{i6} + \frac{5}{19}(6.7727) + \frac{4}{19}(0.1818) + \frac{1}{19}(11.8636) + \frac{2}{19}(1.3636) + \frac{3}{19}(11.3636) + \frac{4}{19}(6.4545) \quad (A.8)$$

For varying values of x that are independent variables, the solution is given by the above mathematical equation, which represents the cartographic content to be delivered.