BIM AND GIS ENABLED CARRIAGE COST ANALYSIS

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Abstract

In the recent time, increasing the global competition in the construction field, many researchers start focusing on the Information Technology (IT) for real time monitoring and material cost calculation. In the construction management day by day increases the challenge for better controlling and monitoring because the construction supply chain management required real time visual representation. In this time, we are using the photography, videography and manual drawing for the controlling, monitoring, visualizing and calculation of carriage cost. But its fail to fulfil the demand for real time monitoring and time taking. For the fulfilment of the objective the using BIM (Building Information and Modeling) and GIS (Geographic Information System) in one system is the better tool to visualize the real time situation and also to calculate material carriage cost. First, the proposed methodology is implemented by BIM to find detailed material take off for first phase documentation and with the help of GIS to deduct the transportation distance between project site and material suppliers with a map. In QGIS with the help of graphical modular to find out the transportation cost of material and select the effective supplier. In this paper presented the integration of BIM and GIS, 3D site visualization, location by map, better visual monitoring of CSCM (Construction Supply Chain Management), transportation cost and optimum material source. Model is developed in QGIS 3.0 platform. A case study is presented to show the applicability of the developed model for carriage cost calculation. The Model to help the contractors and clients both. For the contractors to select form which material suppliers to be procured by following shortest route and carriage cost and for clients to compare the carriage cost from available material sources.

Keywords: BIM, GIS, Carriage Cost Analysis, CSCM, 3D Visualization, Map

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2. Introduction

In India, construction industry is one of the major sectors. It gives a lot of jobs and the growth of this sector is directly affect the economy of the country. Construction industry have lot of risk because construction project is unique in nature and project depend on the different sources. This risk can be reduced with the help of proper management tools and techniques.

A resource is an item that contributes to the successful fulfilment of project activities such as manpower, money, material, equipment, time or space. But inappropriate planning could cause unnecessary time spent due to traffic congestion, repositioning materials and even labour inefficiency or temporary facilities. But use of BIM-GIS is the better tool in order to minimize the transportation cost and improve efficiency. In a client's viewpoint, to assess more suitable bidder, they need to prepare the detail report to accommodate the carriage cost. So, there is a need to develop a tool to decide material carriage cost. From the contractor's viewpoint, it's challenging task to find optimum material source. So that the required materials can be brought from source to the site with right time and with minimum carriage cost. The purpose of materials management is to get the right materials in the right quantity to be supplied at the right time. In the construction sector, the contractor plays a major role in material supply. So, it is very difficult to find right vender at right time. So, observing both client and contractor point of view to decide develop a tool for carriage cost calculation. To fulfil these needs, a model is created using GIS software QGIS 3.0. To find out carriage cost of material. And with the help of BIM software Revit 2018 to find quantity take-off of project. This quantity will use in model (develop by QGIS 3.0) for the calculation of total carriage cost. In this model you can find out the shortest path along with carriage cost per unit or total carriage cost also.

The aim of research to develop a model in GIS platform to find the best material supplier by using the shortest path analysis and estimating the carriage cost of materials. And will be used BIM platform to develop 3D model of project and calculate required quantity of Material that helps in decision making of material procurement. The objectives to achieve the defined aim are listed below.

- To develop the 3D model for visualization and calculating the quantity of material required with in BIM platform.
- To understand the factor affecting the carriage cost of material through literature.
- To create special and attribute database for the road network and study area.
- To solve network analysis to find the shortest/fastest path around the project site.
- To create a model for calculating the carriage cost.

3. Literature review

Some previous studies about use of BIM and GIS in carriage cost analysis as GIS is one kind of geographic information super map computer software. GIS can be used to identify the optimal location for distribution center, trading posts and fabrication plant etc.

Susanty et al., (2016) used to identify optimal location for distribution center, trading posts and fabrication plant etc. Route analysis and service scheduling is one of the most common examples of GIS applications in supply chain management. Su et al., (2012) said the newly developed MLEM (Material Layout Evaluation Model) was based on the MAG(Material Accessibility Grade), a quantitative measure of the material accessibility that was redefined in this study as the collaboration of material pick-up convenience, delivery convenience, and delivery distance.

Bansal et al., (2007) estimated building cost using GIS platform and also suggested that it can be used in the carriage cost calculation. Wang et al., (2017) prepared the location map of available material suppliers and used, to provide the optimum suggestion by assessment of service distance and transport network analysis. But after that Jha (2011) mentioned the significance of estimation in construction. He demonstrated the importance of estimation from both contractor and client's point of view. In the carriage cost calculation depends on the various factors as per CPWD manual like distance, vehicle speed, fuel charges, hire charges of crew and machinery is considered in preparing the DAR-2016. CPWD (DAR) is more reliable than state SoR for the calculation of carriage cost.

Based on the above studies, Model development is proposed in GIS platform (QGIS) to calculate

the carriage cost. And to identify the optimum material source location applying shortest path analysis. It helps in decision making of material procurement.

4. Methodology

Our Methodology is divide in three stages. Which shown in fig1. First is data collection, second is 3D model development on BIM (Revit 2018) and third is processing of all data in GIS (QGIS 3.0). With the help of all three stages to analysis the optimum material source location associated with carriage cost in the shortest route. In the first stage, two types of data required one non-spatial data and other spatial data. In non-spatial data like detail drawing of project, material source addresses, road network & allowable speed on the road. Spatial data should save like material source location in point shape file, road network dataset in line shape file & study area in polygon shape file in QGIS. All the road not having same allowable speed so speed limit adds in attribute table of road network. In the second stage, the development of 3D model using Revit Architecture.

For the model development some input data required like 2D drawing in .dwg format & also the cross-sectional detail of all component required to develop the 3D model with architectural & structural view. After completing model, to export quantity take-off file in excel sheet and convert unit of material as you required. In the third or final stage, use QGIS 3.0 to save all the data collect from above two stages. All the data set required in Network Analysis and find out shortest route between construction site and material sources. For network analysis for shortest route with carriage cost, facilities and incident locations should be given. Model will take study area shape file, material sources shape file, road network shape file with speed limit, capacity of truck/crew & total material quantity required. Then click to run and get result shape file along with carriage cost. For carriage cost calculation, DSR 2016 formula are taken.

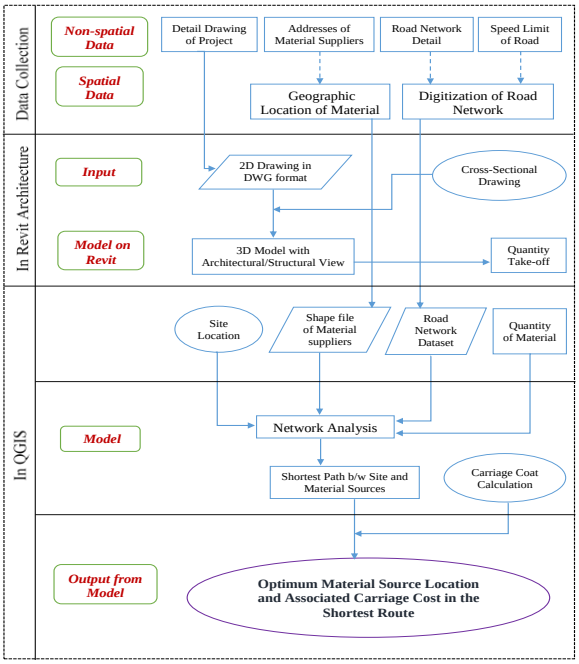

Figure1: Flowchart showing the research methodology

4.1. Data Collection

The area that has been chosen for the study is Greater Warangal of Telangana State which is a cluster of three major town's i.e Kazipet, Hanamkonda and Warangal. Greater Warangal Municipal Corporation is common administration for the mentioned cluster.

After the planning of project to prepare 2D CAD drawing in .dwg format. It .dwg file helps in model building on BIM (Revit Architecture). Because this drawing provides detail of construction like area, size of component, and cross-sectional view etc.

Greater Warangal connected with major towns and cities by means of Railway and roads. Some national highway passes through the city are, like NH 163 and NH 563 etc. Details of all road network have been taken from GWMC and digitized in QGIS 3.0. This digitized road network is shown in table 1.

Table 1. Name of road with in study area

Name of Road	Name of Road
Hyderabad-Hanamkonda road (NH 202)	Jaya Prakash Narayana road
Inner Ring road (Bye-pass)	Narsampet road
Desaipet road	Mahatma Gandhi road
Karimnagar road	Khammam road
University City road	Under Bridge road
Mulugu road	Mogilicherla road
Hunter road	Warangal Station road
Swami Vivekananda road	

With the help of google map geographic coordination of all the material supplier's location has been collected.

4.2. Creation of Geospatial Database

Data is dynamically liked to map and stored in database, which display graphical representation of object when database change the graphical representation (map) will be change. In this study, Non-spatial and Spatial data used. Spatial data is associated with attributes and related with real world in the form of points, lines and polygons (area). In order to prepare spatial database, firstly to collect geo-referenced line shapefile of road network and then collect coordinate of all the material supplier location form google map and convert in point shapefile and also define the study area in the form of polygon shapefile. All the data put in QGIS and save in shapefile format with the help of QGIS catalog and set the coordinated system in which study will be projected. In digitize process the x and y coordinate will be created and automatically stored in attribute table as spatial data. The digitize road network and material supplier's location shown in fig 2 & 3.

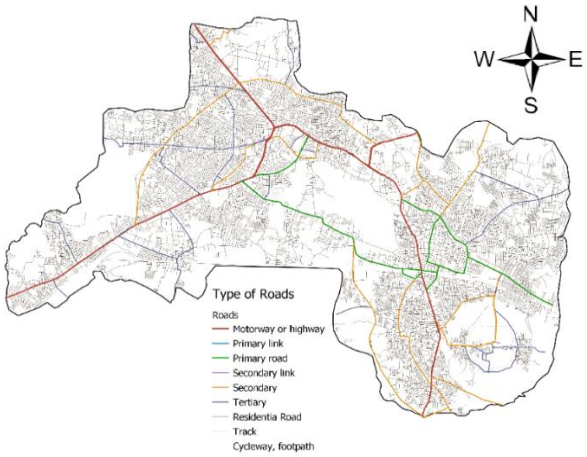

Figure 2: Digitize road network of greater Warangal

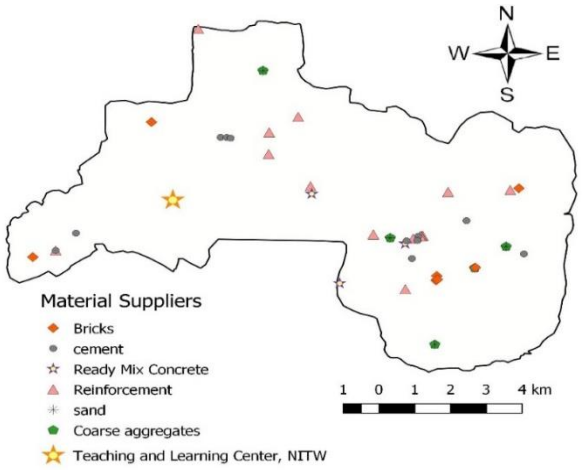

Figure 3: Digitize material source locations

Non-spatial data have no specific location in space. It's present in textual or tabular form to describing the geographic location. These types of data have no specific location in space. But it linked with geographic location like allowable road speed is related with road network. Allowable Road speed collect with the help of field survey in tabular form and it helps in network analysis.

4.3. Model development

This models for spatial analysis and data management processes. One can create and modify geo-processing models in Processing Modeler, where a model is represented in two steps one input and another algorithm. Using above steps this model resembles a chain with a series of activities, using the output of one activity as input to another activity.

Final Model is created in the form of toolbox with name "CarriageCostAnalysis" using QGIS model development plugin. In the QGIS catalog work

package where all the Non-spatial and Spatial data is stored and used in processing of model.
In model development some assumption is taken as given below

- Traffic density or road traffic is changing every hour but it's very difficult to collect the data of every hour so it was assumed road density is constant every hour.
- In some roads the U-turn is restricted but this study U-turn is allowed on all roads.
- In this study to assume the road connectivity to all habitats and material source location.
- Even though the carriage cost of material was depended on various factor but some factor was depended on nature it cannot control. With the help of literature to identify the independent factor is mainly lead distance and Allowable speed of vehicle. For calculating total carriage cost per unit is depend on independent factor mainly. So, in this study, the network analysis on the basis of travel time which accommodate both lead distance and allowable speed of vehicle.

Model is nothing but a network in which various tools are arranged in a logical sequence to perform certain functions and gives desired output. Model processes the input given by user and provides desired output. Model is developed to the find the best possible nearest material supplier to the project site based on Minimum travelled time and shortest distance. Carriage cost through that route can also be calculated by adding some simple fields. Developing the model for the study is divided into three stages. The model is developed in QGIS platform. The procedure followed for performing the analysis is described below.

Various tools which were used in developing the model is Geographic modular tool as main tool. Within geographical modular, tool for input are vector layer, vector field &vector value and tool for algorithm are clip, shortest path analysis and field Calculator etc. First select input layer within geographical modular for study area, road network, material sources, capacity of crew and total quantity of material. Then algorithm tab was opened and, in this tab, clip was selected for the clipping of road network within the study area. After that shortest path (point to layer) was added for network analysis. Then using field calculator all the value of attribute table was calculated with optimum material source location and associated carriage cost in the shortest route. This model is present in the form of one tool which name *"Carriage Cost Analysis".* This Graphical model and tool shown in fig 4 & 6 respectively.

5. Results and Discussion

A case study was undertaken in calibrating the effectiveness of this Model. Construction of Teaching and Learning Centre at Nit Warangal was considered for case study. The geographic location of the building was 17°59'12.2" North and 79°31'58.0" East. The construction work was started on 2016 and it was estimated to be completed by 2018. To this building, the nearest material source locations, shortest routes to acquire the materials and the carriage cost were identified using the *"Carriage Cost Analysis"* tool.

In the first stage to develop 3D model of project site to find out the material take-off (quantity of material required in project) as well as the better visualization of the project. 3D model shows in fig 5. And also detail of material quantity shows in table 2.

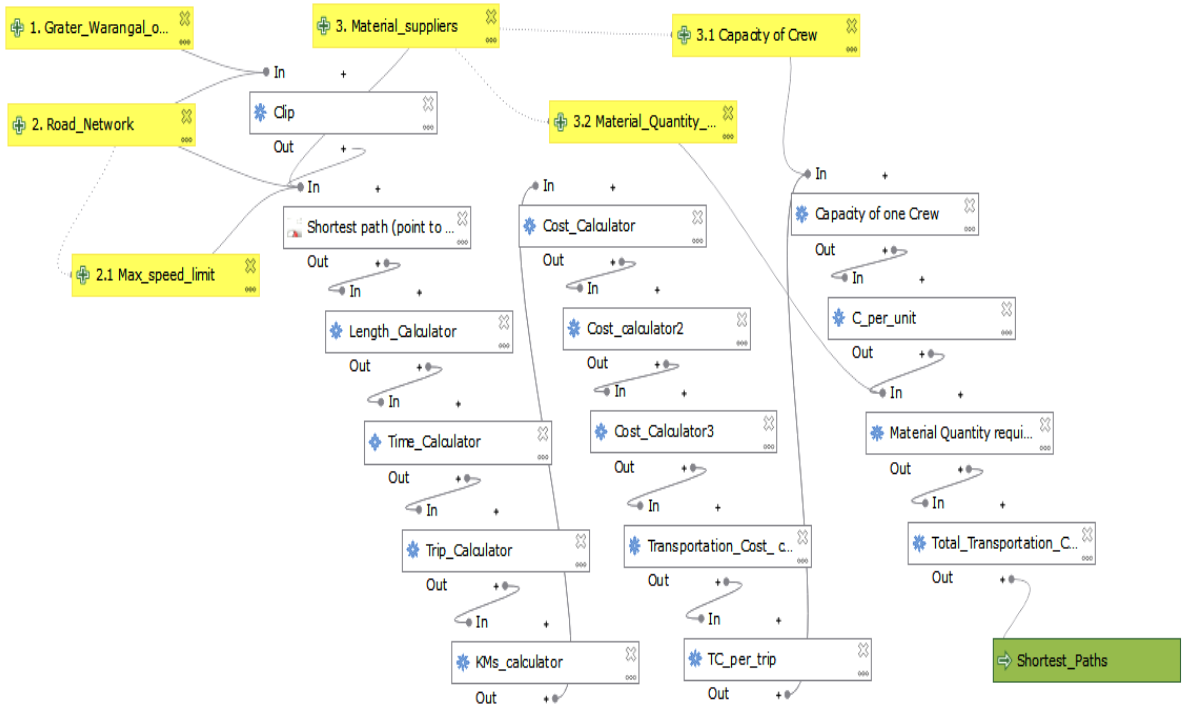

Figure 4: Geographical Model of Carriage cost Analysis

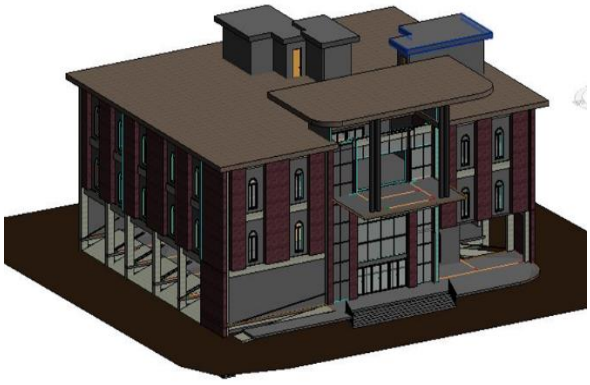

Figure 5: 3D Model of Teaching and Learning centre Warangal (project site)

This above 3D model developed by using Revit Architecture. With the help of Revit architecture software to find the material take-off or quantity of material as shown in table 2.

The model was opened in QGIS 3.0 and the inputs – Study area shapefile, Road network dataset, Material suppliers' location shapefile, capacity of crew/truck and quantity of material was added to the model then run, once the model was run it gives the carriage cost of one material and shortest path of material source locations. If one wants to find for another material, model should be rerun.

Table 2. Quantity of Material

Materials Name		Material Quantity (in cum)	Total Quantity (in cum)	Quantity as per Requirement
Bricks		23.76		
		83.06	**106.82**	***53410 No.***
Concrete (RMC)		1.66		
		264.61		
		115.09		
		408.33		
		762.11	**1551.8**	***1551.8 cum***
Concrete (1551.8 cum) for M20	**Cement**	423.22		609434.18 kg = ***609.43 ton***
	Sand	634.83		***634.83 cum***
	Aggregate	1269.65		***1269.65 cum***
Reinforcement or steel		1.2738		***10 ton***

5.1. Coarse Aggregates

To get the details of coarse aggregate suppliers, model was run after study area, road network, coarse aggregate suppliers' shapefile, capacity of crew and material quantity was selected. The details were shown in Fig 6. The output from the model was shown in Fig 7. The details of the route length, carriage cost per unit and total carriage cost would be saved in the attribute table of the output shapefile. The attribute table was shown in Table 3.

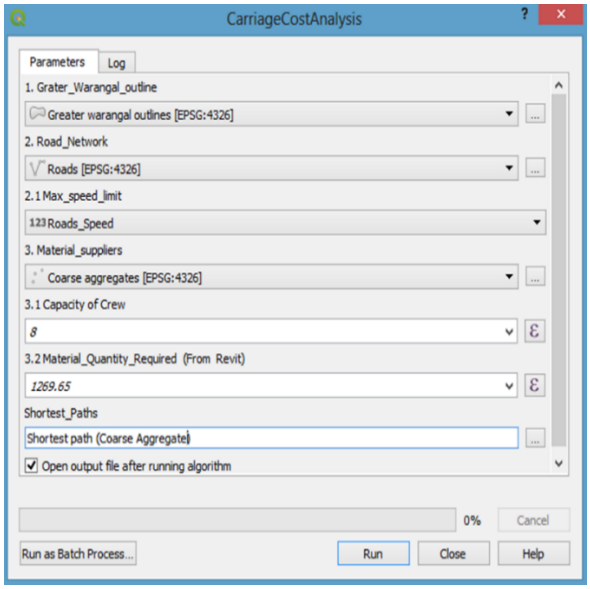

Figure 6: Model to identify nearest coarse aggregate locations to the project site with carriage cost

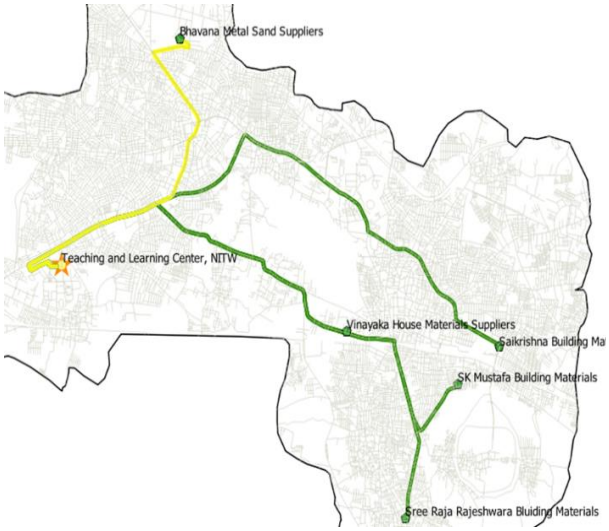

Figure 7: Locations of nearest coarse aggregate suppliers to the project site (output from model)

The attribute table of the output file from the model has the non-spatial data of the output file like the names and addresses of the nearest suppliers' in ascending order, distance from the project site to the suppliers' location in kilometers (length_km), Total travel time in minutes (Time_min), no. of trips (Trips) possible in a 8 hour working day from site to supplier's location, no. of kilometers can be one in a day(KMs), cost of diesel (C_diesel), cost of mobil oil (C_mobil), cost of crew and truck hire charges (C_Crew), Transportation cost per day (T_Cost), Transportation cost per trip (TC_trip), Net quantity payable per truck or capacity of truck (Capacity) based on unit of measurements of materials, the lead rate per trip per unit(C_pre_trip), material quantity required (MQ_by_revit) and Total transportation cost or carriage cost (Total_TC).

Similarly, model was run for all material and find the lead distance with carriage cost per unit and include 15% overhead charges as per CPWD norms. In given table 4 carriage cost including 15% overhead charges comparing with DSR (Delhi schedule of rates) for proving the validation of tool.

Table 3. Details of nearest coarse aggregate suppliers to the project site (Attribute table from model

	Name	Length_km	Time_min	Trip	KMs	C_diesel	C_Mobil	C_Crew	T_Cost	TC_per_trip	Capacity	C_per_unit	MQ_by_Revit	Total_TC
1	Bhavana Metal Sand Suppliers	8.22586...	14.101...	5.44...	95.530...	889.386...	167.17...	3668	4724.56...	868.1679...	8	108.5209...	1269.65	137783.67...
2	Vinayaka House Materials Suppliers	8.69981...	14.913...	5.34...	98.975...	921.464...	173.20...	3668	4762.67...	891.2940...	8	111.4117...	1269.65	141453.93...
3	SK Mustafa Building Materials	12.6297...	21.650...	4.64...	123.36...	1148.57...	215.89...	3668	5032.47...	1083.050...	8	135.3812...	1269.65	171886.85...
4	Sree Raja Rajeshwara Bluiding Materials	13.0857...	22.432...	4.57...	125.79...	1171.14...	220.14...	3668	5059.29...	1105.301...	8	138.1627...	1269.65	175418.31...
5	Saikrishna Building Materials	13.1417...	22.528...	4.56...	126.08...	1173.87...	220.65...	3668	5062.52...	1108.034...	8	138.5043...	1269.65	175852.05...

Table 4: Comparison of carriage costs obtained from interface and DAR

S. No.	Material	Name of Supplier	Lead distance in Km	Carriage cost (CC) (Rs per unit)	CC including overhead of 15%	From DSR (Rs)
1	Sand	Bhavana Metal Sand Suppliers	8.225	₹ 108.52 (per cum)	**124.79**	164.15
2	Cement	KCP cement	3.181	₹ 69.11 (per ton)	**79.47**	92.24
3	Reinforcement	Uma Maheshwara Iron and Cement	3.825	₹ 72.59 (per ton)	**83.47**	92.24
4.	Coarse Aggregates	Bhavana Metal Sand Suppliers	8.225	₹ 108.52 (per cum)	**124.79**	164.15
5	Bricks	Srinivasa Traders	4.544	₹ 229.51 (per 1000 no.)	**263.93**	276.72

6. Conclusions

The GIS based system used in this model stores all the information related to Study area, Location of Material sources and Road network. This information is further utilized in identifying the shortest possible route for finding the Optimum Material source and in Carriage Cost Analysis. Identification of Optimal Sites is done using a GIS approach in integration with certain Mathematical Equations.

- All the information and details related to available Building Material Suppliers were collected and digitalized with the help of QGIS.
- A case study was used to validate and verify the model.
- The analysis of Carriage cost is done by comparing the results with the values in DAR-2016 and the results were satisfactory. All the outputs received through the model elucidates that the developed model can serve the purpose for which it has been formulated.

Limitations

The limitations of this work are as follows-

- The traffic studies on roads were not performed. So, the hourly traffic data was not included to the model. The network dataset was prepared by considering there was uniform traffic in a day.
- In developing the network dataset, assumption was made that U turn and two-way traffic was allowed on all roads. Therefore the model will solve the problem accordingly. So there might be a chance of getting a wrong route as output because all the roads are considered to be having two way traffic.
- The carriage cost of materials for only mechanical transport was considered. Carriage of materials manually was not considered.
- The developed model runs only in the QGIS environment.

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Short Author/s Biography