

# GIS-Based Decision-Making Model for Road Maintenance with Vb.Net for Kabul City Roads

Fardeen Nodrat and Dongshik Kang  
University of the Ryukyus, Okinawa, Japan  
Email: {k168591, kang}@ie.u-ryukyu.ac.jp

**Abstract**—Afghanistan is facing monumental challenges in dealing with road maintenance. Based on a survey conducted in 2009 by Japan International Corporation Agency JICA, from the total of 183.2 km secondary/city roads, 16.8 km, 11.5 km and 154.9 km are in fair, poor and very poor conditions respectively. Currently, a technology based road maintenance model is an essential need of the government. Considering the problem, ArcGIS have the capabilities of analyzing, collecting, storing, manipulating, displaying editing vector and raster data and Vb.Net language programming beside having so many resources is a fast and easy way to produce .Net-based suitable applications. In order to show the effectiveness and better adoption with ArcGIS, the developed model will be coded as ArcGIS environment and merge with the GIS platform. The aim of this research is to develop a decision-making model with Vb.Net and using it in ArcGIS platform which we could produce road network and thematic maps and prioritize the road maintenance activities. For better using and planning of the budget a deterioration model will be consists of the model.

**Index Terms**—Kabul city, road maintenance, PCI, deterioration model, ArcGIS, Vb.Net

## I. INTRODUCTION

Afghanistan is lacking proper road maintenance which resulted in a huge amount of investment loss in the past 10 years. The emphasis of the government and donors was on development of new roads regardless of understanding and focusing over the maintenance capacity and budget. It is therefore over 4 billion USD investment in road assets is in the threat of loss. Recently the government and donors have recognized the issue and have focused to strengthen the capacity in the maintenance sector. The Ministry of Public Works is responsible for management and development of national and regional highways. The expert staff previously existed in mentioned ministry has drastically decreased due to three decades of war. The increasing length of national and regional highways day by day is another challenge for the Government to maintain. One of the main issues in the maintenance sector is that there is no technology and data based decision support tool for engineers to properly plan maintenance of roads and prepare long term strategic plans for maintenance.

Currently road maintenance prioritization is on ad-hoc basis without proper need assessment and technical evaluation. It is therefore an indispensable need for the government to have a technology based decision support tool to give planners and decision makers' objective based understanding for decisions in the maintenance programs development.

The present road maintenance framework in the Republic of Afghanistan incorporates the road works and maintenance, procedural rules and road maintenance, created amid the Soviet Union in 1978 and 1992. It ought to be noticed that at present, the framework can't completely address the issues of road maintenance. Since the rate of road traffic growth expands considerably speedier than the expansion in the length of paved roads, it prompts a generous increment of wear and harming impacts of cars on to the road bringing about an expanded interest for repair and restoration. Undesirably this pattern will raise in the close term [1].

Economy and the country's road administration effectively hunts for new types of management, including new ways to deal with orchestrating road maintenance administrations. If there should be an occurrence of an effective usage of this research, the road maintenance division of Afghanistan will completely change to the quality-based road maintenance strategy [2].

Road Maintenance is to preserve as closely as could reasonably be expected, the original designed condition of paved and unpaved roadways, and of traffic signs, signals and markings, in a manner most likely to minimize the total cost to society of vehicle operation and accident cost, in addition to the cost of giving the maintenance itself, under the requirements of serious asset confinements, in regard of skilled manpower, equipment and money, both local and foreign [3].

Pavement Management System (PMS) helps staff in assessing, tracing and grading pavement conditions in view of field examinations. The recurrence of roadway examination ranges from yearly to once like clockwork relying upon the kind of roadway. Comprehensive field assessments sort and evaluate pavement insufficiencies, for example, cracks, patches, and utility trench cuts. These inadequacies are entered into the PMS Program that figures a Pavement Condition Index (PCI) for every roadway. PCI values extend from zero (very poor) to 100 (excellent) [4].

The objective of this study are mainly focuses on overall status of road conditions and road maintenance system in Afghanistan mainly in Kabul city. In conclusion, the pavement condition index and deterioration model prediction methods for Kabul city roads will be provided.

The advantages of the model will be easy to design, use and extend for further activities. The model will allow the user to transfer the data into the database, analyze the information and produce different scenario applications for demonstrating the outcome into GIS Platform, which permits the planners to plan and develop a better strategic planning for future road maintenance activities.

## II. ROAD CONDITIONS IN KABUL CITY

### A. Road Network

#### 1) Administrative road classification

The Table I shows the road types and responsible organizations and basically the roads in Afghanistan are classified into five types by administrative bodies responsible by for them. Kabul Municipality is responsible for city roads located in its administrative area [5].

TABLE I. ROAD TYPE AND RESPONSIBLE ORGANIZATION

Road Type	Responsible Organization
Regional Highway	Ministry of Public Work (MPW)
National Highway	Ministry of Public Work (MPW)
Provincial Roads	Ministry of Public Work (MPW)
City Roads	In Kabul City, Kabul Municipality (KM)
Rural Roads	Ministry of Rural Road Development (MRRD)

#### 2) Functional road classification

Counting those falls in the classification of regional and national highways shown above, existing roads in Kabul City are characterized into the additional five classifications [5].

- Main arterial roads – three regional highways and one national highway emanating from the downtown area shape the fundamental edge of the city street framework also. The carriageways are made out of no under two lanes, and paved with asphalt concrete.
- Minor arterial roads – supplement the four fundamental routes to interconnect districts in the city. Most arterial roads have normal names of their own. The carriageways are composed of no less than two lanes and paved with asphalt concrete.
- Secondary roads – connect communities with the artery roads. They have width of no less than two lanes, and most of them are paved with asphalt concrete.
- Community roads – having no less than two lanes and form town blocks. Many of the community roads are not paved and without side drains.
- Other roads – are those forming town blocks in areas not designated for use by urban planning.

Most of them are narrow unpaved roads often with only one lane, and difficult to distinguish from private roads.

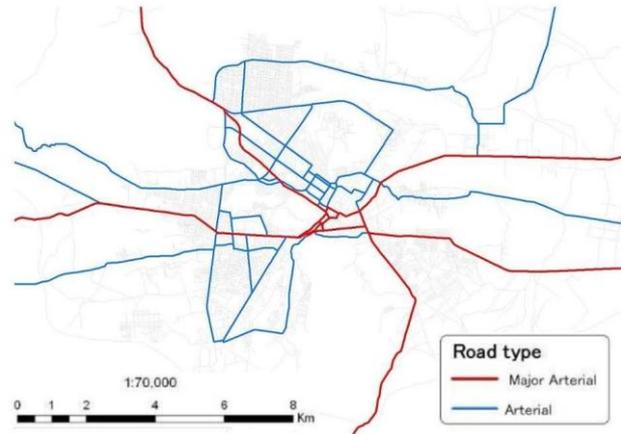
#### 3) Kabul urban road networks

The road network in the city spread out in an outspread shape from the center area toward the north, northwest, west, southwest, south and east directions, containing national and regional highways and provincial. Of these, all the national and regional highways are paved in two-lane roads [5].

The setup of existing Artery Road Network in Kabul City is appeared in Fig. 1. The Table II shows, the total length of the arterial road network and it is 330.7 km [5].

TABLE II. ARTERIAL ROAD LENGTHS IN KABUL CITY

Road Type	Length (km)
Major Arterial	137.4
Arterial	193.3
Total	330.7



Source: Kabul Metropolitan Area Urban Development Master Plan, JICA, 2009

Figure 1. Existing arterial road network configuration in Kabul City

### B. Road Conditions

Asphalt concrete is normally utilized for road pavement. Road surface conditions are for the most part harmed because of age, snow and ice, absence of legitimate drainage and deficient Maintenance. The Table III, shows the pavement conditions. The primary arterial and arterial roads have better surface conditions as they have been restored as of late with asphalt concrete pavement. In any case, because of inadequate maintenance works, many areas have deteriorated surface. Community roads and other roads are for the most part unpaved [5].

TABLE III. SURFACE CONDITION OF MAIN ARTERIAL, ARTERIAL AND SECONDARY ROADS

Road class	Good	Fair	Poor	Very Poor	Total (km)
Main arterial	96.7	6.5	5.6	5.3	114.1
Arterial	29.5	23.7	109.3	38.5	211.0
Secondary	-	16.8	11.5	154.9	183.2

### III. EXISTING ROAD MAINTENANCE SYSTEM IN KABUL CITY

Generally, in every country the road maintenance activities are categorized based on the organization and their staff expertise and mainly they are either routine or periodical. Because Afghanistan were one of Russians colonial government, so the Russian maintenance system has their impact on the current maintenance activities [6]. Currently, the road maintenance activities in Kabul City are as below [6]:

#### A. Routine Maintenance

Mainly the low-cost activities such as: restoration of the roads shoulder, roads surface, side drainage and cutting the grasses are take place in this phase. This activity is once or more than once in a year based on the organization work plan and are performed by skilled and non-skilled staff. The workload is calculated and sometimes they prepare proper work-plan.

#### B. Periodical Maintenance

The high loaded activities on roads cross section are performed in this phase. After three to seven years the traffic loads and road conditions are evaluating which needs for more skilled staff and higher budget, which the category and properties of roads will be change.

#### C. Emergency Maintenance

The emergency maintenance activities on road surface which happens unexpectedly due to the floods, traffic loads, earthquake, ... etc.

#### D. Seasonal Maintenance

Since Afghanistan is mountainous country with different weather, in this respect, the seasonal maintenance is different and categorized in the followings:

- Spring maintenance – in the spring after passing the winter the cleaning of side drainages from mud, stones and other things which blocks them. Surveying the culverts and maintaining them in case if blocked. Maintenance of road surface damages which occurred due to rain and snow followings and installation of damaged traffic sings.
- Summer maintenance – in the summer, mainly the road maintenance activities, graveling and surfacing activities take place in this phase.
- Fall maintenance – in the fall season, beside the checking of drainages, culverts and cutting the grass, the preparation for winter by installing the snow blocking nets and storing the sand & salt will take place.
- Winter maintenance – in the winter season, mainly the road maintenance activities are snow cleaning which will always be open to the public. Using of sand and salt on snow and ice for melting them. Also, constructing the structures for preventing avalanches (if needed).

### IV. CURRENT PROBLEMS OF ROAD MAINTENANCE IN KABUL CITY

Currently, the Kabul Municipality are dealing with so many problems. There is no proper and strategic maintenance plan, also due to las three decades of internal war in the country the technical staff drastically decreased. In the meantime, the Kabul City roads doesn't have conditions indexes such as pavement condition index, or international roughness index (IRI), ...etc. which they can prepare the maintenance plan and predict the future budget for maintenance and rehabilitation activities. Besides the above-mentioned problems one of the major challenge for responsible organizations are to eliminate the current system of paper works and archiving paper documents which rise following problems [2]:

- Perhaps some information buried among a large pile of documents that extracting data seems impossible.
- Any effort to extract information form loads of available data needs the painstaking work of several people.
- Work always starts from the beginning (In other words, there is always revise in activities).
- Handling documents always accompanied with loss of part of data.
- Updating the paper documents has always been a major problem.
- The above-mentioned problems also will be the consequences, including waste of money, time, task force as well as no better utilization of existing information.

### V. METHODOLOGY

Fig. 2, shows the flow chart of all the methodology process. A past literature review conducted regarding to road maintenance and asset management systems, use of GIS and Vb.Net for the same purpose in other countries. Also, the current practices and challenges in the road maintenance sector of the country have been identified. Since, the data which needed for this study are mostly paper documents so sample road inventory/information database will be prepared. On the other hand, for calculating the pavement condition index which will show the conditions of the roads, a model will be prepared using Vb.Net. This model will be consisting of road deterioration model and priority ranking for road maintenance activities. The deterioration model is dependent on the traffic load, environmental changes and any other correlated variables. Therefore, calculating the traffic load will be considered in the model. This model will be a simulation model which will show the deterioration rate of roads with respect to road maintenance sector budget condition over a period of time. These models will be incorporated into ArcGIS which will show the spatial location of the attribute data. At the end, using multi criteria analysis of the maintenance prioritization model will be prepared using the economic importance of the road, cost constraint,

traffic volume and condition of the road. Finally, the methods for using the GIS capabilities to prepare thematic maps for indicating the routine, periodical and emergency maintenance activities need will be explained. This platform will enhance the strategic decision-making process. It will be purely technical decision making and will protect the infrastructure asset on an objective basis.

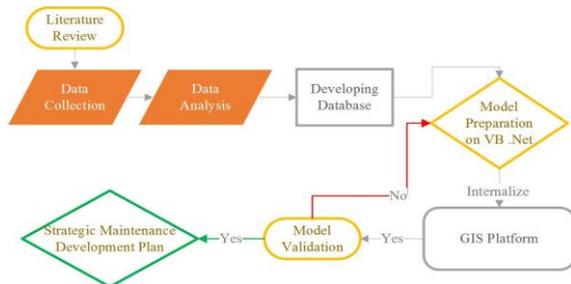


Figure 2. Research Methodology

### A. Literature Review

The pavement management system (PMS) was conceived in the mid of 1960s in the light of various unforeseen pavement distresses. Because of the developing requirements for highway rehabilitation and maintenance, in 1987 the PMS procedure was generally established [7].

Pavement management incorporates all exercises required in planning and programming, design, construction, maintenance and rehabilitation of a pavement segment bit of an open works program. A PMS is a set of tools or techniques that helps decision makers in finding the ideal procedures for giving and keeping up pavements serviceable conditions over a predetermined era. The purpose of a PMS is to enhance the productivity of decision making, give input on the outcomes of the verdicts, give coordination of exercises of an office and guarantee consistency of choices inside a similar organization at the diverse levels of administration [8].

The ArcGIS desktop 10.3 and Visual Studio 2015 will be the main software which we will use for this research. ArcGIS desktop 10.3 can combine the tabular information from database and geographic information to produce different scenario spatial maps. For developing the decision-making model (calculation of PCI and deteriorating prediction model) the Visual studio 2015 will be used, which have so many resources and allows us to easily produce the suitable applications.

### B. Data Collection

This research needs extensive data collection from governmental organizations regarding roads. For data collection, various survey forms and formats will be developed and there will be need for surveys for collection of those data which is not available in the government data bases. The data which will be collected for this study may include:

- Afghanistan road map
- Roads engineering information right of way, geometric design, structural design data, length, width etc.

- Roads historical information.
- Pavement condition data roughness, potholes, rutting, cracks, etc.
- Traffic volume data, axle load data, average daily/annual traffic, etc.

Most of the above information will be found at the Ministry of Public Works. Similarly, interviews will be conducted with higher officials and technical level professionals to understand the current practices and challenges in the road maintenance sector of the country.

### C. Data Analysis

After collection of all above information, the data will be evaluated and analyzed for its accuracy and readiness to use in GIS platform.

### D. Development Database

Since, this issue is very new thing in Afghanistan the existing data and information is not enough for developing the model. Therefore, after the collection and analyzing of the data a database will be developed and missing information will be added to be ready for using it in our model.

### E. Model Preparation

The three models of pavement evaluation model (which is a PCI calculation model), deterioration model and maintenance activities priority model will be prepared in visual studio platform. These models extract the data from database and evaluate the road conditions, predict the pavement life cycle and allows the planners to decide the important activities to take place.

### F. GIS Platform

The GIS platform will be consisting of below thematic maps, which allows the decision makers and planner to produce the different scenario and prepare the strategic development plan for road maintenance:

- Pavement distress maps
- Pavement performance evaluation map
- Maintenance activities priority maps
- Different deterioration scenario maps (budgetary maps)

### G. Validation

As the database and models will be prepared in different interfaces, therefore, it needs to be merged and validated with the ArcGIS to evaluate the accuracy of the final model.

## VI. CONCLUSION

This research is conducted to study the current road maintenance practices and challenges in Kabul City. The following conclusions are drawn based on literature review and current challenges:

- For archiving the road information documents, responsible organization should consider the computer based archiving system.
- For road surface, the responsible organization should collect roughness (IRI) and pavement

distress factors like rutting, cracking, corrugations, potholes etc. as the performance data to evaluate pavement condition.

- The key maintenance challenges are political, social, institutional and technical. In this regard, it is recommended to initiate the establishment of a Road Maintenance Unit and improve technical skills of local staffs to carry the developed system of programming, preparation and operations forward.
- A Vb.Net is good platform to prepare different type of model to calculate the PCI, develop deterioration model and activities priority ranking.
- A Geographic Information System is a good referencing method to represent attribute data as it can generate maps for the road network in terms of pavement condition and road classification.

For future works, I will confirm that our research is useful by comparing this model with other models in terms of advantages and disadvantages, pricing, and requirements of responsible organization for maintenance and rehabilitation activities.

#### ACKNOWLEDGMENT

The Authors would like to thank from the University of the Ryukyus, Japan International Cooperation Agency with Project for the Promotion and Enhancement of the Afghan Capacity for Effective Development (PEACE) for providing found and giving chance for improving of knowledge scales and the government of Afghanistan for its cooperation in this study.

#### REFERENCES

[1] Ministry of Public Work – MoPW. [Online]. Available: <https://www.mopw.gov.af/fa/> (23 March 2017).

[2] Kabul Municipality – KM. [Online]. Available: <https://km.gov.af/fa/> (23 March 2017).

[3] The World Road Association – PIARC. [Online]. Available: <https://www.piarc.org/en/> (23 March 2017).

[4] Sacramento County Department of Transportation – SACDOT. [Online]. Available: <https://www.sacdot.com/Pages/default.aspx> (23 March 2017).

[5] The Study for the Development of the Master Plan for the Kabul Metropolitan Area in the Islamic Republic of Afghanistan, Final Report – Sector Report 8: Transportation, JICA, RECS International Inc, 2009.

[6] M. Y. Shaghazy, *Technical Guideline for Road Maintenance of Rural Roads*, 1st ed., USOPS Press, 2010, pp. 7-8.

[7] R. Haas, W. R. Hudson, and L. C. Falls, *Pavement Asset Management*, Scrivener Publishing: Wiley, 2015, ch. 2, pp. 5.

[8] R. Haas, W. R. Hudson, and J. P. Zaniewski, *Modern Pavement Management*, Ontario. CA: Krieger Publishing Company, 1994, ch. 1, pp. 12-13.



**Fardeen Nodrat** was born in Kabul, Afghanistan in 1987. Nodrat has completed his high school education at Naderiah high school in 2003 in Kabul city. Nodrat got his bachelor degree in engineering geodesy from Kabul Polytechnic University in Kabul, Afghanistan in 2009. He previously worked as Survey Engineer, GIS Specialist, Infrastructure Engineer and Safety Engineering Specialist with Dehsabz City Development Authority from 2009 to 2015.

Currently, he is MSc Student in University of the Ryukyus in Okinawa, Japan.



**Dongshik Kang** is an Associate Professor at the Faculty of Information Engineering, University of the Ryukyus. His previous position was as an Assistant Professor at University of the Ryukyus (1999-2004). He received a Ph.D. in Engineering from the University of Osaka Prefecture. He is a member of the IEEJ, IEICE and GISA. His current research interests are neural networks, geographic information system, and intelligent systems.