Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2022, 9(12):73-83**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

On Studying the Prospective Road Construction Materials Demand for 50 Years

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Abstract Global road networks play a huge role in social development, economic growth, and easy access to natural resources. In today's world, road transportation carries more than 80% of passengers. The world's population is expected to grow to 9.8 billion by 2050, and half of the anticipated growth in the world population will be in Africa. In the development of economic activity, the demand for people and goods transportation is a prime indicator of changing demographics. As of 2021, there are 6,958,538 million people living in Libya. According to current estimates, the Libyan population will be more than 10.8 million by 2050. The road mesh was 83,200 km in 2010. By 2050, Libya's road network is expected to increase by at least double its current length, which is 95,180 km of paved roads. In this study, the potential future paved road network is estimated, as well as the expected amount of material to be used for road construction. On typical pavement construction layers in Libya, at least 249,847,500 m^3 of materials will be needed to construct new roads over the next 50 years. In addition, the country will require a significant amount of materials to cover the road maintenance and rehabilitation work required during t3hat same period.

Keywords Road, Construction, Materials, Libya, Evaluation, Google Earth Pro®

Introduction

There is no doubt that a well-developed road network plays an important role in facilitating the movement of people and goods. In fact, a road network that is in good condition can help to reduce congestion and improve the flow of traffic in a city or region. There is no doubt that a well-developed road network plays an important role in facilitating the movement of people and goods. In fact, a road network that is in good condition can help to reduce congestion and improve the flow of traffic in a city or region. However, there is currently a great deal of debate about whether population growth should be taken into consideration when planning new road projects. This is largely due to the fact that an increasing population tends to place additional strain on existing roads (among other things). A growing population places a significant burden on road networks. This is due to a number of reasons. For instance, more people require vehicles to get around, which puts more pressure on existing infrastructure such as roads and highways. As the world's population continues to grow rapidly, there are concerns about how efficiently roads are built to support increasing demand for transport services [1]. Population growth is, of course, linked to development, economic growth. Furthermore, it contributes to a high level of mobility in society, which in turn increases productivity and leads to greater economic prosperity [2]. The growth in vehicle ownership has meant that more people are using roads to travel and this has placed increasing pressure on existing infrastructure systems. This increased demand for road space is likely to continue in the future as more and more people move to towns and cities to live and work [3]. The relationship between a country's road network and its economic growth is undeniable. Studies have shown that countries with more developed road networks have higher levels of economic growth. A well-developed road network is essential to economic growth.

Furthermore, it is necessary for the efficient movement of goods and services, and it also provides access to markets and resources. In addition, good roads can increase the speed of communication, reduce travel costs, and improve the quality of services. All of these factors help to stimulate economic growth and development. Ultimately, it is clear that a well-developed road network is vital for economic growth, and investing in future road networks is a crucial step for any nation's economic development. There is therefore a growing need for comprehensive road planning and development strategies that take a population's impact and economic growth on infrastructure into account. In addition, construction materials constitute the top waste deposit in urban areas after water [4]. In most urban areas, consumption of these mostly non-renewable materials has increased significantly since the mid-20th century [4]. From extraction, transformation, transportation, to end-of-life management and storage, it generates many environmental impacts. Additionally, the expansion of a city severely limits the extraction of local mineral resources [5, 6].

Literature Review

The global road network, in its current state and with its predicted expansions, has a massive influence on social development, economic growth, and easy access to natural resources [7]. Worldwide, more than 80% of passengers travel by road [8], and road networks influence where and how we will live in the future [4]. The world population was an estimated 7.8 billion in 2021, having grown by almost one billion over the last twelve years [9]. Close to 1.3 billion people live in Africa, seventeen percent of the world's population. The number of people on earth is expected to increase by almost one billion to reach 8.6 billion by 2030 and will likely continue to increase to reach 9.8 billion in 2050. Between now and 2050, Africa will experience half of the total anticipated growth in the world population, so that Africa's percentage of the world population is expected to rise from seventeen percent to about twenty-six percent by 2050 [10, 11]. The areas with the largest population growth will be in North Africa, Sub-Saharan Africa, the Middle East, and India [12].

Population and economic growth have a huge influence on infrastructure demand. Changing demographics is a prime index of economic development as well as an indication of future transportation demands. A well-prepared road construction program is imperative to accommodate future population growth, including increasing numbers and types of vehicles, transport and other needs [13]. A high quality road network is an essential factor to assure economic development and meet the growing demands in terms of connectivity and accessibility [14]. Based on the primary expectations for 2050, the average road length will increase from 14.8 to 23%. On the other hand, some developing countries showed significant increases in road length, such as, Nigeria 52%, Congo 81%, New Guinea 50%, due to significant increasing in population density. That growth will add at least 25 million kilometers of new roads, roughly about fourteen million km of paved roads by 2030, and an additional eleven million km paved roads by 2050. Most of the additional paved roads will be in Africa [9, 15]. Currently, roughly 35% of the global road network is paved, with most of these roads in North America and Europe. Meanwhile, Africa and South America have most of the unpaved roads and less density. All countries will experience an increase in the length of their road network significantly by 2050. Which is expected to increase to four or five times its current level. [16]. Travel demand on highways is expected to increase, creating further challenges to the current highway networks. [16]. By 2050, world traffic movements are expected to more than double, to approximately the forty-three trillion annual vehicle kilometers [17, 18, 15].

In Libya, the population growth rate has been increasing, from 4,405,000 in 1995 to 6,958,538 in 2021, a growth rate of more than 2.27 % [19]. There has been substantial growth in urban populations in Libya over the last four decades, from 40% to 80% [20]. With this high rate, it is expected that the Libyan population will be more than 10.8 million with a growth rate increase of 2.4% by 2050 (Sub-Saharan). This trend of population growth will increase the demand for new paved road construction, to address the needs of the Libyan people over the next 50 years, as road transport is expected to remain the main mode for travel and transport between cities, even with a railway planned for the near future [21]. The road mesh expanded dramatically from roughly 10,000 km in 1980 to more than 83,200 km in 2010. While the percentage of paved roads of the total road network is 58%, Libya still has one of the lowest road network densities in Africa with 0.047% [22]. Libya clearly needs to enhance the national road network to meet the demands for long-distance travel and to facilitate transportation of merchandise and services across the country [23, 24].

Methodology

In this section, this research is focusing on studying the Prospective Road Construction Materials Demand for 50 Years. In addition, the methodology of this research has been divided into three main phases: 1) identify the studied area, 2) study the economic growth and GDP, 3) identify the used vehicles, 4) develop road network and 4) estimate the population. After studying the first step, the second step is taking place which is pavement design catalogue by studying the potential road network for 50 years. Finally, the prospective road construction materials demand for 50 years of the proposed roads.

To sum up, this research is focusing on the historical country vector data such as the population, road network, registered vehicles, Economic growth, per capita GDP, and land area combined with other different world data were used to predict the future road network, then used the result with the pavement design catalogue to estimate prospective construction materials needed to construct the roads for next 50 years. Figure 1 shows the flowchart to acquire prospective road construction materials demand.

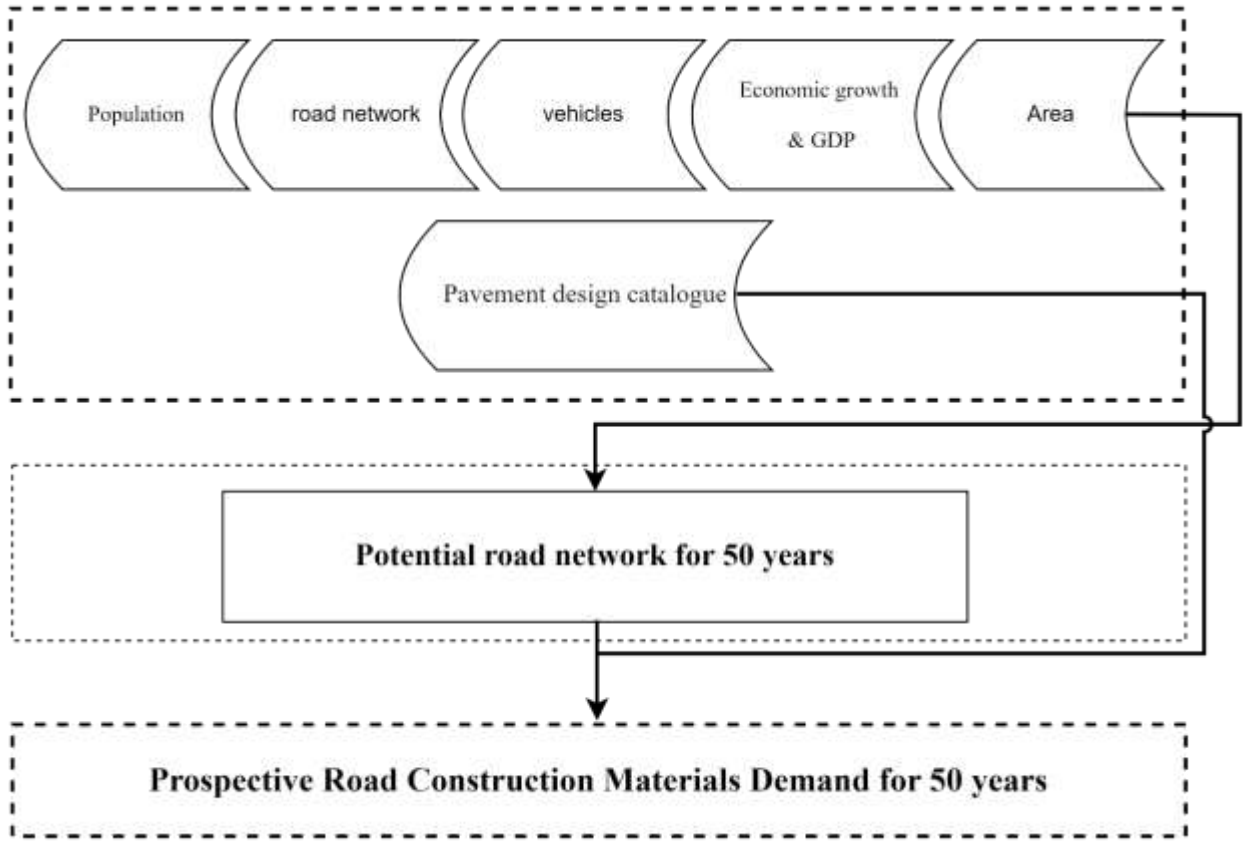

Figure 1: Flowchart to acquire prospective road construction materials demand.

Study area

Libya is in North Africa and covers a large part of the Sahara Desert, between Alt 20° and 33° N, and is situated between long 10° and 25° E, with a geographical area of1,759,540 square km. Figure 2 shows a location map of Libya. Both the Mediterranean and the desert climate exert a large influence. Libya has a variety of geological formations, which include igneous, metamorphic, and sedimentary rocks. The road mesh has expanded dramatically from roughly 10,000 km in 1980 to more than 83,200 km in 2010.

Figure 2: Map of Libya [25]

Demography and Population rate

The Libyan population in 2021 is 6,958,538 [26, 27]. This represents a considerable growth, as the 1995 census indicated 4,405,000, with a growth rate of 2.27% [27] (United Nations, 2021). In 1969, the population density was 1.2 people per sq-km, which began increasing to 3.8 people per sq-km in 2018, an average annual growth rate of 2.45%. In 2018, the population density was still comparatively very low, with 3.8 people living in one square kilometer, which was one of the lowest densities in the world [19]. In Libya, the urbanization rates show a steady growth, from 49% in 1970 to 79% in 2016. There has been substantial growth in urban populations in Libya over the last four decades, from 40% to 80% [20]. Figure 3 shows the Annual Percentage of Population Residing in Urban Areas, 1950-2020.

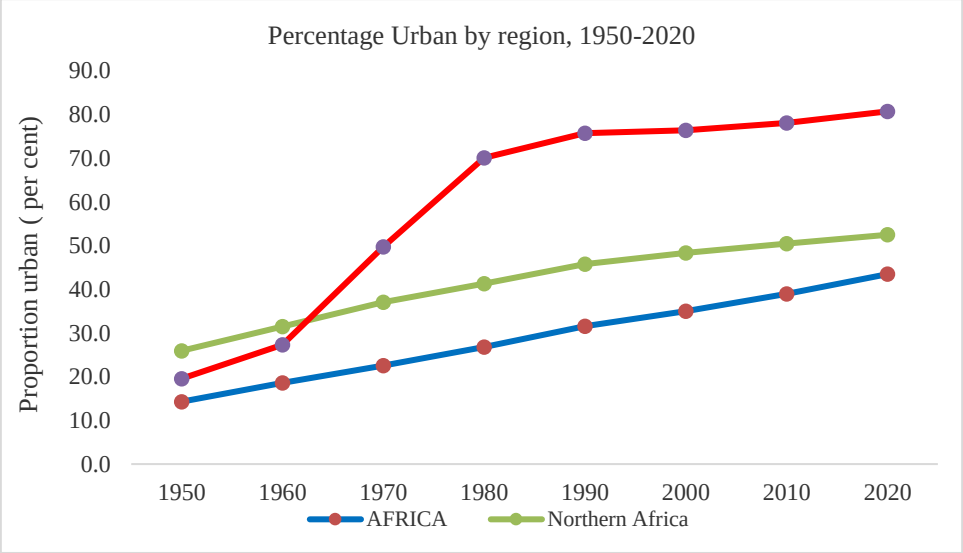

Figure 3: Annual Percentage of Population Residing in Urban Areas, 1950-2020 [20].

Approximately 85% of the total population lives in the coastal area, particularly in the major cities such as Zawia, Gherian, El-Khoms, Misrata, Sirte, Benghazi, El-Baida Derna, Tobruk, and the capitol Tripoli. The remaining 15% live in the southern part of Libya in the desert cities and towns, such as Sebha et al., [28]. The capital Tripoli in the west is the largest city in Libya with a population of approximately 1.800.000 million people. Benghazi in the east is the second-biggest city with a population of roughly 812,000 people [29, 30, 28]. Figure 4 shows the population distribution of the main cities in Libya.

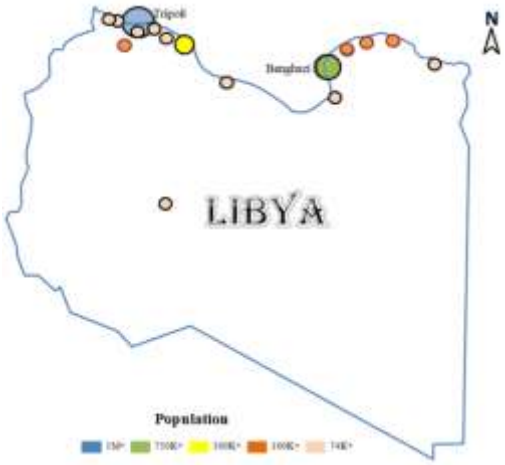

Figure 4: The population distribution of the main cities in Libya [29]

Roads Network

Road transport is the main mode for travel and transport between cities, although a railway has been planned for the near future [21]. There has been a significant expansion in the road network in Libya during the last decades; from about 8,800 kilometres of roads, half unpaved in 1978, to 25,000 kilometres of paved roads in 1985. By 2010, the total road network was estimated at 83,200 kilometers, with 47,590 kilometers of paved roads [31]. The percentage of paved roads of the total road network is 58%, the paved road per thousand people is 7.06 km. However, Libya still has one of the lowest road network densities in Africa with 0.047% [22]. Figure 5 shows Libya's current road network. The two major axes of the road network are the main one along the coastal to connect cities where the population and activity is concentrated, and the other one is a north-south route to help connect the isolated remote areas in the South to the main cities in the North. Specifically, the agricultural projects in the desert oases in the South have benefited from easier transportation of their products to the consumer areas in the North.

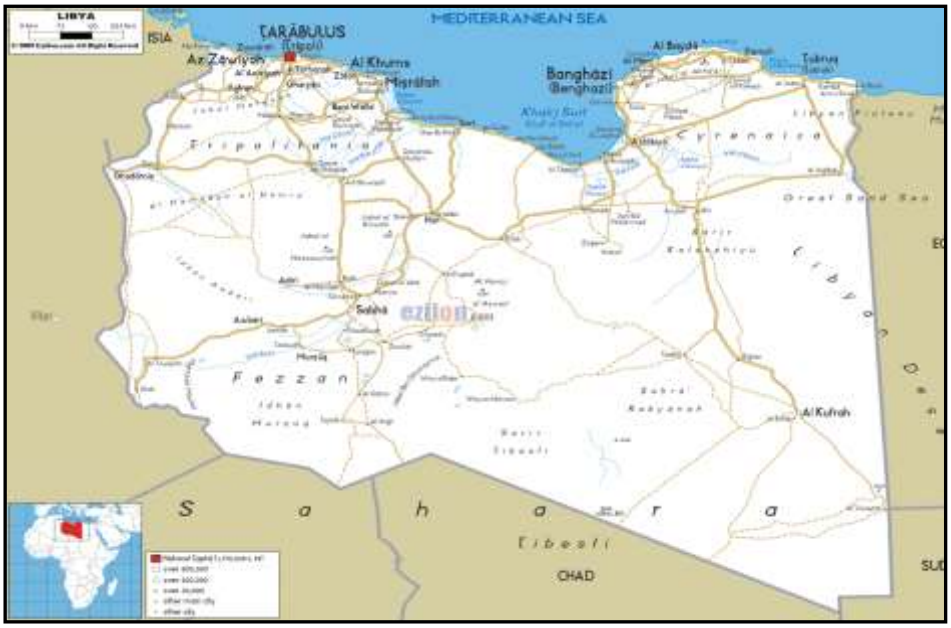

Figure 5: Road network in Libya (maps, 2015) [32].

There are current plans to link the country with sub-Saharan countries Chad and Niger by constructing approximately 1,400 km of paved roads. Other plans include linking Tunisia in the West to Egypt in the East by the trans-Libyan motorway. This will provide Libya with a transportation network hub for North Africa. Products and travellers could thus be brought along the coast, south to Chad and Nigeria, and north to the Mediterranean

region [21, 33]. However, in terms of the road quality, most of the existing road network in Libya shows a low level of geometric characteristics, with poor service and maintenance. Libyan road quality ranked 142 of 144 countries in 2016 [34, 35].

Economic and population growth

The total road density is significantly affected by population concentration, and increases in population require more accessible infrastructure [37, 38]. There is a clear relationship between the evolution of road networks, economic growth, and national wealth. Moreover, road networks are closely linked to resource exploitation, economic growth, and market accessibility [39, 40]. Economic development stages and population density also have a significant influence on road construction. The expansion of road networks reflects the economic and population growth of a country and its demand for new road construction [41]. Changing demographics is a prime index of economic development as well as an indication of future transportation demands. An imperative infrastructure program to accommodate future population growth includes planning for more vehicles and increasing traffic [13].

Libya has a large geographical area 1,759,540 square km, and the distances between cities are very long, combined with inappropriate transportation systems. This situation means the existing road network must be rebuilt by adding additional good quality paved roads to meet the needs for transportation of people and goods between cities [41]. The Libyan population in 2020 was 6,890,535 [26], which represents a considerable growth since the previous census of 1995 (4,405,000), and indicates a population growth rate of 1.94%. The population density is very low, with 3.8 people living in one square kilometer, one of the lowest densities in the world [2]. Libya's GDP growth rate averaged 2.89% from 2000 to 2015, reaching its highest point in 2012 with 104.37 percent. However, during the war and invasion, GDP went down by 17.3% in 2017, and dropped another 5.5%in 2019. GDP growth is expected to decrease to minus 0.6 % in 2020, and to be steady around 1.4% over 2021-22 [42].

Registered Vehicles

There is a parallel relation between economic growth and the increase in the number of vehicles on the roads in Libya [21, 40]. The gradual increase in population during the past 10 years and the lack of public transportation systems in Libya has led to an increase of private vehicle ownership. There is also a direct relation between population growth and the number of road trips. There was an enormous increase in the number of private vehicles from 1,826,533 in 2007 to 3,553,497 in 2013. Figure 6 shows the relation between vehicles and population in Libya (2001-2013). Libya has the highest rate of private vehicle ownership in Africa, with 310 vehicles per 1000 people. By 2030, the number of privately registered vehicles is predicted to be 393 vehicles per thousand people. With this enormous growth in the number of vehicles, the expansion and maintenance of the highways and roads has been struggling to keep up. [30, 39, 40, 41].

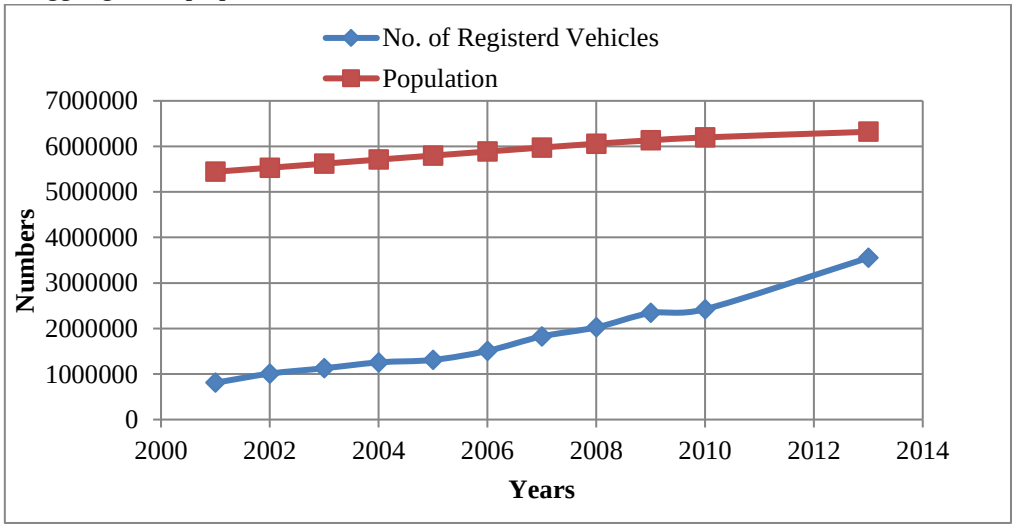

Figure 6: Relation between vehicles and population in Libya (Yahia & Ismail, 2013) [41].

Results & Discussion

In this research, the authors have been studied the prospective road construction materials demand for 50 Years. In addition the results of this study is focused on three main elements as the following:

Pavement design method in Libya

Asphalt pavement roads are the primary and generally the only pathway of the Libyan overland transportation system. The pavement design was based on the AASHTO Interim Guide for the Design of Pavement Structures. A majority of the primary roads in Libya are flexible pavements, with an expected design life of 20 years [43, 44, 45]. The estimated number of equivalent standard axle load (8.2 tons), with a traffic level reaching or exceeding 2 500 000 EAL in the areas with medium to heavy traffic [46] semi-solid asphalt (AC 60/70) is the current asphalt cement (bitumen) binder used in roads in Libya, manufactured by the Azzawia Oil Refining Company in Libya, as suggested by Libya's general road department [45, 46, 47]. Based on the regulations of AASHTO Guide for Design of Pavement Structures-1993, the necessary assumptions for all of the above-mentioned variables have been considered for specific locations, with the road pavement designed accordingly.

Libyan population projections and the potential road network

Population growth and economic development create a demand for expanding the road network system. A high quality road network is an essential factor to improve economic development and meet growing population demands in terms of connectivity and accessibility [14]. Based on the primary expectations for 2050, the average road length will increase from 14.8 to 23%, representing an additional 3 to 4.7 million km of paved roads worldwide. Most of the additional paved roads are expected to be in Africa. Currently, 35% of the road surfaces worldwide are paved; with most of these roads located in North America and Europe. Africa and South America have most of the world's unpaved roads, and much lower density of roads [15]. The growth rate of the population in Libya has been increasing steadily, going from 4,405,000 in 1995 to 6,958,538 in 2021, for a growth rate of more than 2.27%. Therefore, the population rate trend will experience a considerable rise over the next 50 years. Current expectations are that the Libyan population will be more than 10.8 million with a growth rate increase of 2.4% by 2050 (Sub-Saharan). and the population growth over the past few years have increased the need to expand the highways and roads [15, 21]. This trend will only place more pressure on the nation to upgrade the national road network to meet the needs of the growing population for the next 50 years. A good quality road network is needed to meet the demands for long-distance travel and to transport merchandise across the country [24].

The Libyan government plans to invest approximately 40 billion USD to develop the national transportation infrastructure, including renewing existing roads in the national network as well as adding more good quality paved roads to encourage transport between cities and to link Libya with neighboring countries [34]. To estimate the optimal potential road network, the population growth can be used as an indicator, as predicting the economic growth in Libya in the near future is a difficult challenge. Based on expectations for 2050 the world population will be 9.8 billion and the road length will increase dramatically by four to five times the current level. And the expectation of the population of Libya will reach 10.8 million, representing almost twice the current population by 2050. Population growth will increase accompanied by the enormous increase in the number of vehicles, all of which leads to the necessity to expand and new build the current road networks. Moreover, there is a strong and positive relationship between road length and population growth in a country, assuming that the future population size and the length of the road network continue to increase. According to all that, the length of the road network in Libya will increase by at least doubled the current road length, which will be roughly 95,180 km of paved roads by 2050. Additionally, given that most of the existing road network in Libya shows a low level of geometric characteristics with poor service and maintenance, maintenance of these road networks is urgently required, as well as rehabilitation works, so that some of the main roads could become double carriageways. The entire unpaved road network will need to be paved. These measures will enhance the national road network and allow it to meet the needs of the growing population.

The Prospective Construction Materials Demand

Being able to estimate the amounts of aggregates needed for road construction in different areas is crucial to provide a plan of the existing road networks in the country and their maintenance combined with the potential road construction projects. Part of this planning requires knowledge of the geotechnical aspects of the areas where the roads will be built in order to estimate the amounts of potential materials available locally. Based on our prediction, the potential paved road network will be roughly 95,180 km of paved roads to meet the demands for the growing population for the next years, maintenance and rehabilitation of most of the existing road network will be needed, as well as the paving of the entire network of unpaved road.

Based on the regulations of AASHTO Guide for Design of Pavement Structures, the local variables, assumptions and aspects such as those relevant to climate, soil geotechnical characteristics, construction materials, and anticipated local traffic, road pavement design can be performed accordingly. The authors could also estimate how much material is needed for every layer per kilometer by determining the thickness and dimensions of the roads. The amount of material per kilometer can then be multiplied by the lengths of the roads to be constructed per year, based on estimated demand. The projected amount of material required for the next 50 years can thus be reasonably approximated. The authors have used a design catalogue as an example with which to calculate the materials needed to construct road surfaces comprised of two traffic lanes, each 7.5 m wide and with 2 x 1.5 m of paved shoulders. The pavement construction layers usually selected are: sub-base 200 mm, 150 mm base, and 100 mm asphaltic concrete binder and wearing course [43, 48, 49, 50 ,51, 52], as illustrated in Figure 7.

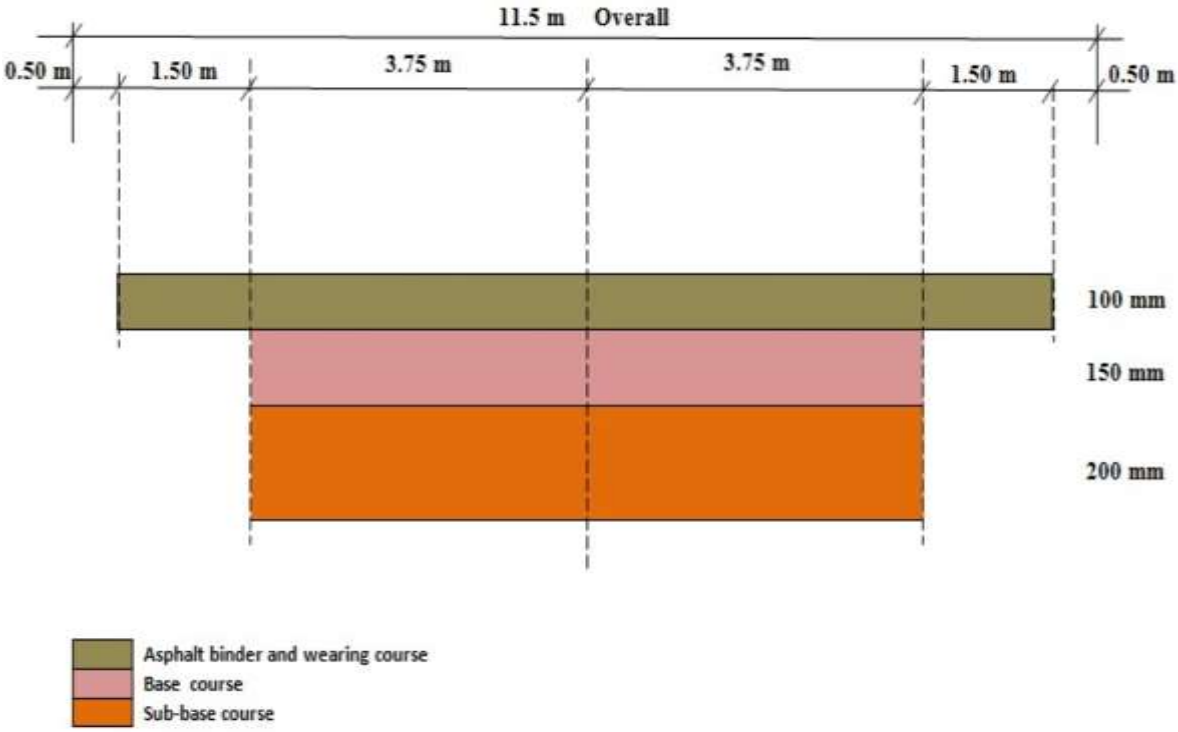

Figure 7: Typical pavement construction layers in Libya (Hunt, 1979) [43].

The width of the road is 10.5 with a thickness of 0.5 m for 1 km, which represents 10.5 x 0.5 x 1000 m = 5250 m^3 of material per km. For future demand, the authors have multiplied 5250 by 951.8 (the total estimated km of road surfaces (from Section 3), to obtain 49,96,950 m^3 for one year. The authors have then multiplied 49,96,950 m^3 by 50 years, for 249,847,500 m^3, representing the amount of materials required over the next 50 years. This number only represents the materials that will be used for the construction of new roads. Another very large amount of materials will be required for maintenance and rehabilitation of the existing road network over the next 50 years. With new road construction depleting the inventory of Libya's natural materials, it is essential to develop and implement a policy to manage the materials used to cover current and future needs, and to conserve an inventory of natural materials for the future.

Conclusion

This article has studied he prospective road construction materials demand for 50 Years of state of Libya. In addition, population and economic growth have a high influence on infrastructure demand. Changing demographics is a prime index of the development of economic as well as prospective transportation demands. The Libyan population in 2021 comprises 6,958,538 people, with a very low density of 3.8 people living in one square kilometer. The road mesh was 83,200 km in 2010, with the percentage of paved roads of the total road network at 58%. Still, Libya has one of the lowest road network densities in Africa 0.047%. Current expectations are that the Libyan population will almost double by 2050, when it will be more than 10.8 million people, dramatically increasing the demands on the road network. The potential paved road network will have almost twice the number of paved roads as today to meet the demands of the growing population for the next 50 years. Based on typical pavement construction layers, at least 249,847,500 m^3 of materials will be needed to construct new roads over the next 50 years. In addition, the country will need a significant amount of materials to cover the road maintenance and rehabilitation works required during that same period. Therefore, developing and promoting a policy to manage and control the materials required for current and future needs is crucial to conserve the inventory of natural materials.

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