

**LIFE CYCLE COST ANALYSIS WITH CONSTRAINED AND UNCONSTRAINED BUDGET
FOR CITY ROAD NETWORK**

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in partial fulfillment of the requirements for
the award of the degree of
MASTERS OF ENGINEERING
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Submitted by
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DECLARATION

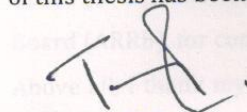
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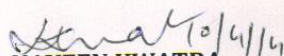
CERTIFICATE

This is to certify that the thesis "**Life Cycle Cost Analysis with Constrained and Unconstrained Budget for the City Road Network**" being submitted by **Mr. Amritpal Singh, Roll No 821123008** in partial fulfillment for the award of degree of **Masters of Engineering in Civil Infrastructure Engineering at Thapar University, Patiala** is a bonafide work carried out by him under our guidance and supervision and that no part of this thesis has been submitted for the award of any other degree

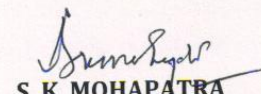

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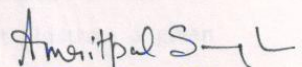
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(AMRITPAL SINGH)

ABSTRACT

The objective of this study is to develop a powerful system for the analysis of pavement management and investment strategies for the maintenance of the huge urban road network. The Highway Development and Management-4 (HDM-4) software has been used for strategy and program analysis of 10 road sections of Noida City. The HDM-4 tool provides the deterministic approach in data input and processing also utilizes data on existing road condition, traffic volume and composition to predict road deterioration as per the urban road conditions in terms of IRI value. HDM-4 simulates total life cycle conditions and costs for an analysis period under a user specified scenario of circumstances. A network economic evaluation is the most challenging use of the model, but the effort is well justified due to the potential savings on transportation costs achieved by comparing various alternatives and performing a budget constraint optimization. This study presents guidelines of HDM-4 analysis, reviews the applied methodology, input requirements and also shows future directions in order to apply HDM-4 effectively according to available urban conditions especially the mix traffic and the drainage conditions of the Noida city.

The methodology described here attempts to take advantage of all the capabilities of HDM-4, deal with the limitations of HDM-4, and produce usable results. The examples presented are actual HDM-4 inputs and results obtained from applying the model in many road stretches in the Noida city. The examples, which were selected from different evaluations performed on different roads to best illustrate a given evaluation step, do not otherwise reflect a particular pattern or relationship. The methodology used by the author calls for HDM-4 analysts to first identify the possible road works and then determine which road works to evaluate for each road class as a function of the traffic and other characteristics of the road class. For example, the works selected could be: (i) preventive treatment or surface treatment works for roads in good condition, (ii) surface treatment or asphalt concrete resurfacing works for roads in fair condition, and (iii) strengthening or reconstruction works for road in poor condition. It is important that the selected road works per road class be feasible from a purely technical point of view to produce realistic results.

HDM-4 allows for the definition of condition-responsive and scheduled project alternatives, for example, the maintenance schedule can be set up to execute an overlay when roughness reaches 4.0 IRI or execute an overlay every 15 years. However, under the proposed methodology, project alternatives are defined so that a given road work is scheduled in a given calendar year followed by a condition-responsive maintenance policy that keeps the road in good condition after the road work is executed. By defining the project alternatives this way, all possible combinations of road works and timing of road works are considered in the evaluation, making it easier to explore the corresponding results. Purely condition-responsive or scheduled project alternatives (for example, executing overlay at 4.0 IRI or every 15 years) are not recommended because: (i) the interval between roads works should change over time due to the traffic growth; (ii) over an evaluation period, the same road works typically should not be repeated (for example, if one defines an alternative as 100 mm overlay when roughness reaches 4.0 IRI, the first overlay of 100 mm may be reasonable, but another overlay of 100 mm as a second capital work may be unreasonable); and (iii) the management of HDM-4 outputs is easier if one schedules the first road work in a given calendar year because the timing of the first road work can be coded on the project alternative code and name, making it easier to identify the solution of each road class.

The Pavement Management System methodology, developed in this study would be useful for the highway agencies in planning pavement maintenance strategies in a scientific manner and ensuring rational utilization of limited maintenance funds. Graphical presentations of PMS results will also be useful for gaining better support from decision-makers, for adequate and timely fund allocations for preservation of the highway network. This methodology may be used for preparing the maintenance management programme for the National Highways covered under the prestigious National Highway Development Programme (NHDP) of India. Once this PMS methodology for National Highway network is implemented and made operational for a few years; this would serve as a window to State Governments, particularly for State Highways and Major District Roads. Thereafter, similar kind of PMS may be developed for other categories of roads such as State Highways and Major District Roads, using the inputs of PMS methodology presented in this study.

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1.1 INDIAN ROAD NETWORK

A well developed road network provides savings in vehicle operating costs as well as faster, comfortable journeys. The fuel consumption is also reduced along with the safer travel. There are benefits to trade especially in movement of perishable materials. Hence the maintenance costs are also reduced. A better all round development of areas also takes place. Thus, India relies heavily on roads to move freight in the most cost-efficient and effective manner.

Road transport has been acknowledged as the primary requirement for the development of basic infrastructure such as agriculture, industries, and power sector leading to overall economic growth of the country. Roads are an enormous national investment and require maintenance to keep them in satisfactory condition and ensure safe passage at an appropriate speed and with low road user costs. Without timely maintenance, roads deteriorate considerably, leading to higher vehicle operating costs (VOC), increased number of accidents and reduced reliability of transport services. When the maintenance work can no longer be delayed, it will often involve extensive rehabilitation, and even reconstruction, costing many times more than timely maintenance treatment carried out earlier. Late or inadequate maintenance will increase the ultimate repair costs, road user costs and inconvenience to road users, and reduce safety. Road maintenance is therefore an essential function and should be carried out on a timely basis.

The importance of preserving an adequate condition of the road network is widely recognized. Although, developing and maintaining a good road network is not an easy task. It requires meticulous planning, enormous funds, challenging construction techniques, strict quality control and other related aspects. In today's economic environment of constrained budgets, as the existing road infrastructure has aged, a more systematic approach towards determining maintenance and rehabilitation needs is necessary. Road networks need to be managed now and not just maintained.

The wide ranges of climate and different physical characteristics have given the continental character to India. Climatically, the country extends through some of the World's most difficult terrains from the North-Western scorching deserts of Rajasthan to the Eastern rainforests of Assam and the icy bitterness of the Northern Himalayan borders. The road subgrade, and foundation soil encountered within India are generally classified into four major groups, namely Alluvial soil, Aeolian desert sands, Black Cotton soil, and Red & Yellow lateritic soils. Alluvial soil forms the largest single soil group and occurs commonly in the Indo-Gangetic plains over an area of 1.5 million sq. km.

India owns the second largest network of roads in the world, next only to USA. For a vast country like India, having an area of 3.3 million sq. km., with population density of over 300-persons/sq km, the importance of an adequate road transportation system is quite obvious. Table 1.1 gives the category wise road length in the present road network of the country [NHAI@2013].

Table 1.1 Present Road Network of India (2013)

Sr. No.	Classification	Length (km)	Percentage
1.	Expressways	200	0.01
2.	National Highways	79243	2.38
3.	State Highways	131899	3.96
4.	Major District Roads	467763	14.05
5.	Rural and Other Roads	2650000	79.60
	Total Road Length	3329105	100.00

Source: NHAI@2013

1.1.1 National Highways

National Highways (NH) constitutes the primary system of road transportation in the country. These are the major carriers of road traffic across the length and breadth of the country. These highways play a vital role in the national transport endeavor. The National Highways constitute less than 2 percent of the total road length and carry about 40 percent of total road traffic [MORT&H 2001c]. The Third Road Development Plan (1981–2001) had proposed a total NH network of 66,000 km, and the NH network

as on today stands at in excess of 79,243 km [NHAI@2013]. In view of the importance of the National Highways in the overall road network of the country, Government of India took a historical decision to widen and strengthen the existing NH's under the National Highway Development Project (NHDP). In the Fourth Twenty Year Road Development Plan for the period 2001-2021, it has been decided that the high density traffic corridors of National Highways are converted to Expressways.

1.1.2 National Highway Development Project (NHDP) - The NHDP is a project to upgrade, rehabilitate and widen major highways in India to a higher standard. National Highways account for only about 2% of the total length of roads, but carry about 40% of the total traffic across the length and breadth of the country. This project is managed by the National Highways Authority of India (NHAI) under the Ministry of Road, Transport and Highways. The Government of India recognizes that the poor performance of the National Highway system has been a major drag on the growth of national economy. Thus, in order to give a boost to the economic development of the country, a massive programme for 4/6 laning of about 13000 kms of National Highways has been taken up since 1999, under the NHDP. The primary objective of NHDP is to ease congestion and improve the riding quality of the country's major National Highway corridors. NHDP consists of a Golden Quadrilateral, which is the key portion of the road network linking Delhi, Mumbai, Calcutta and Chennai with the addition of a North-South corridor connecting Kashmir to Kanyakumari, and an East-West corridor linking Silchar to Saurashtra. The entire NHDP project map is shown in Figure 1.1 [NHAI@2013]. The NHDP project is targeted to be completed by the end of year 2013, at an estimated cost of Rs. 2,20,000 Crores.

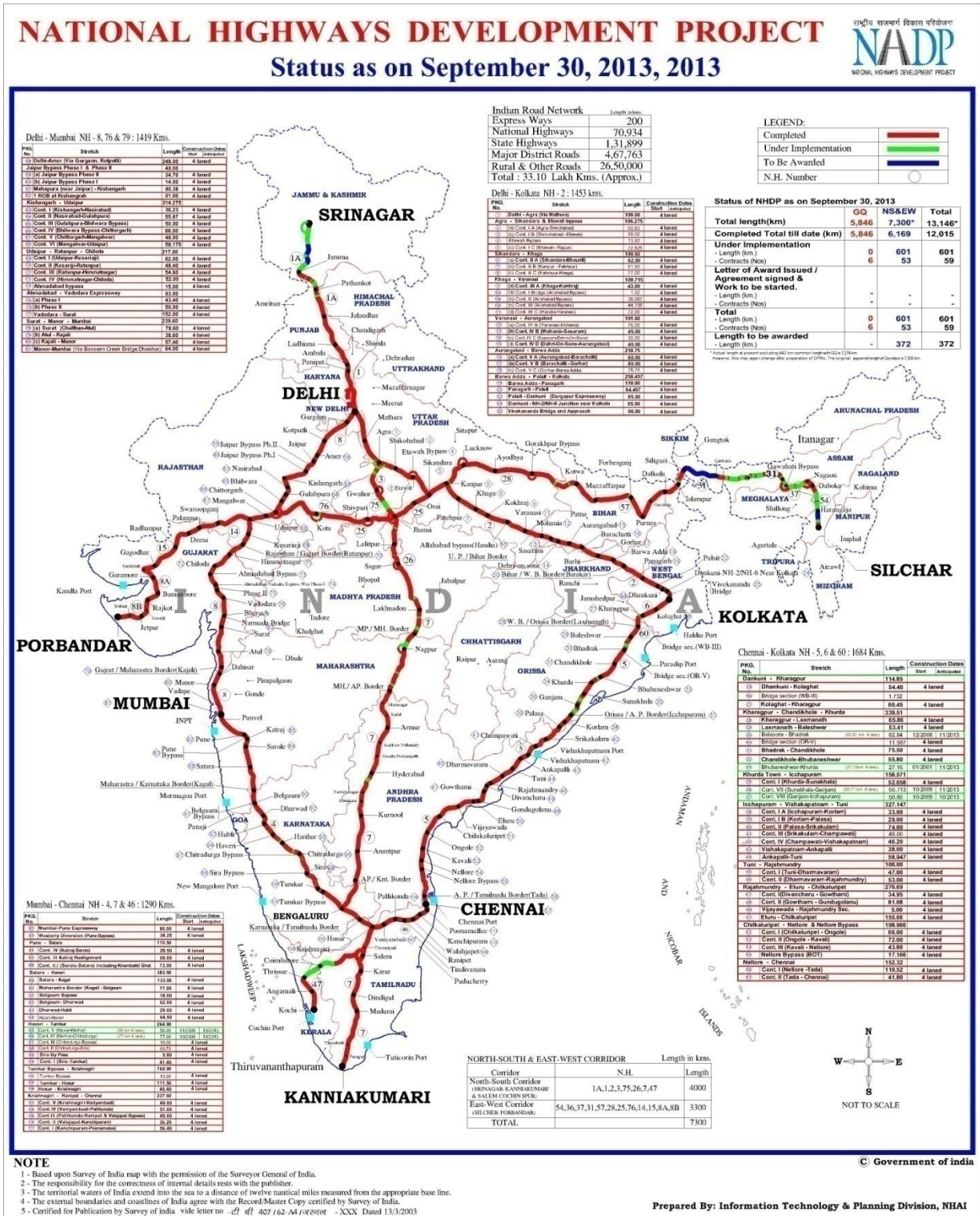
1.1.3 Expressways - An expressway is a controlled-access highway; it is a highway that controls entrances to it and exits from it by incorporating the design of the slip roads for entry and exit into the design of the highway itself. Access-control should not be confused with collection of toll. An expressway may be free to use and may not collect toll at all. Expressways are the highest class of roads in the Indian Road Network. These are six- or eight-lane highways with controlled-access. For providing rapid, unhindered and safe movement of high-speed traffic, it would be necessary to go in for Expressways type facilities. Many of the National Highway corridors where four-laning is being done now

will again get saturated in 5 to 10 years time. Moreover, there are several sections, which are riddled with encroachments and ribbon development, and thus simple solution of widening existing roads may not be cost effective due to non-availability of land around existing 4-lane National Highways. The Ministry of Road Transport & Highways (MORT&H), Government of India has recommended the construction of about 16,000 km of Expressways, over a period of next 20 years, at an estimated cost of Rs. 1,00,000 Crores [MORT&H 2001c]. The proposed Expressway network in India to be completed by the year 2021 is shown in Figure 1.2. The construction programme would be implemented jointly by the Central and State Governments with the participation of the private sector. A few States are already progressing with the construction of Expressways on their own e.g. Mumbai-Pune Expressway in Maharashtra State and Bangalore-Mysore Expressway in the Karnataka State of India. Another, very prestigious Taj Expressway Project has been taken up by the Government of State of Uttar Pradesh, which proposes to provide a high-speed road link between New Delhi and Agra – the city of world famous monument of Tajmahal.

1.1.4 State Highways and Major District Roads

The main roads of a state connecting up with the National highway or highways of adjacent states and linking the district head quarters and important cities within the state are called State highways. These provide the main arteries of traffic within a state. State highway refers to the numbered highways which are laid and maintained by the state government. State Highways (SH) and Major District Roads (MDR) constitute the secondary system of road transportation in the country. The State Highways provide linkages with the National Highways, district headquarters of the State, important towns and tourist centers. These are major carriers of traffic within the State and a reasonable level of inter-state traffic. Their total length stands at 137,000 km at present. It is assessed that although these roads are only 4% of the total highway network but still carry about 40% of the total road traffic [MORT&H 2001c]. Major District Roads run within the districts connecting areas of production with markets, connecting rural areas to the district headquarters and subsequently to State Highways and National Highways. The State Highways and Major District Roads act as the linkages between the rural and urban areas. These roads contribute significantly not only to the rural economy, but to the industrial development of the country as well by enabling

movement of industrial raw materials and products from and to the interiors of the country.



Delhi - Kolkata NH - 2 : 1453 kms.

PKD No.	Stretch	Length	Construction Status
1	Delhi - Agra via Mathura	189.20	4 tared
2	Agra		

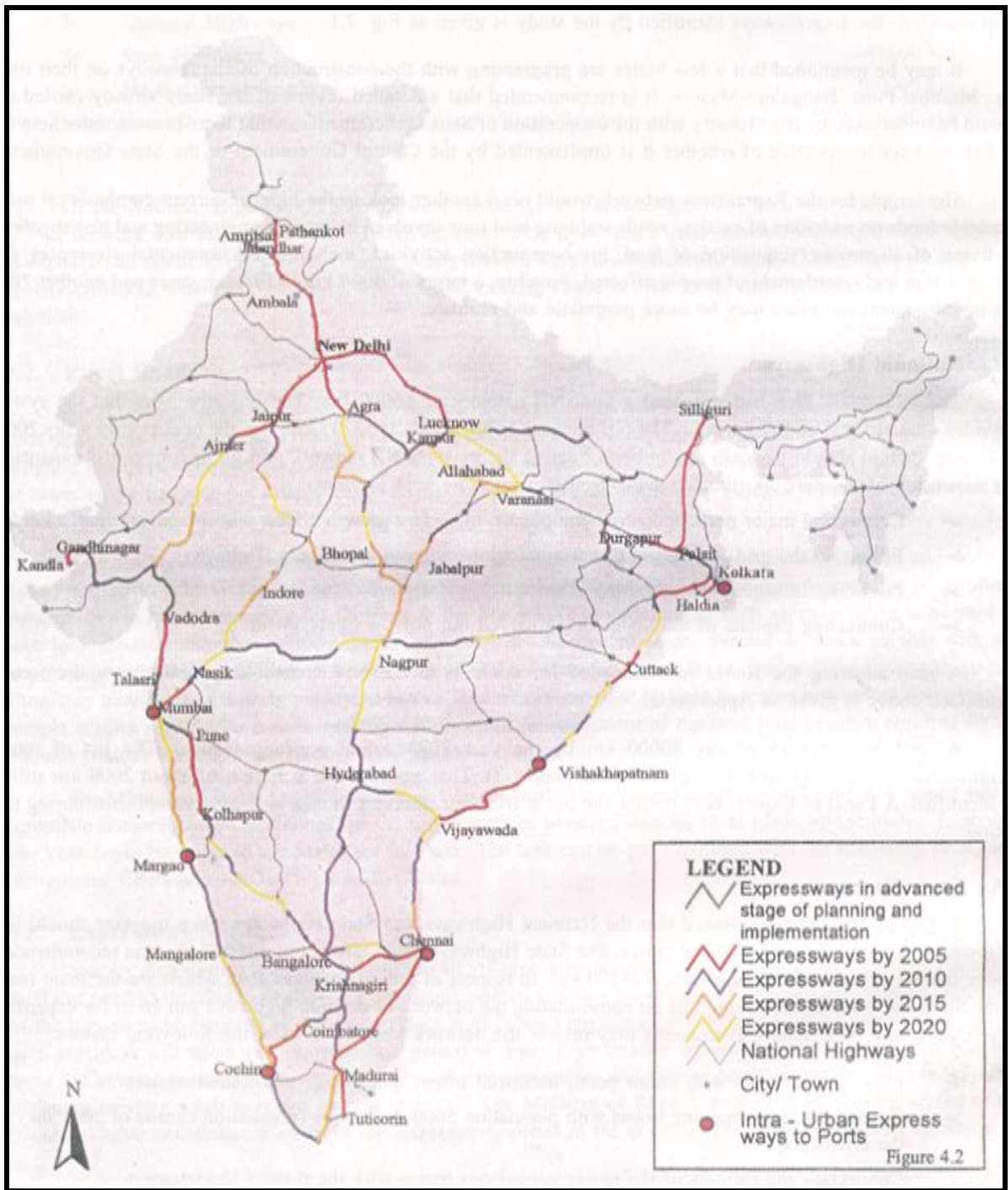


Figure 1.2 Proposed Expressways Network in India to be Completed by 2021 [MORT&H 2001c]

1.1.5 Rural Roads

The rural roads in India form a substantial portion of the Indian road network. These roads are in poor shape, affecting the rural population's quality of life and Indian farmer's ability to transfer produce to market post-harvest. Over 30 percent of Indian farmer's harvest spoils post-harvest because of the poor infrastructure. Many rural roads are of poor quality, potholed, and unable to withstand the loads of heavy farm equipment. These roads are also far from all season, good quality 2-lane or 4-lane highways, making economic resource flow slow, and logistical costs between different parts of India one of the highest in the world. Rural Roads, which comprise of Other District Roads (ODR) and the Village Roads (VR) serve as one of the key infrastructure for integrated rural development, which has become a matter of growing urgency for considerations of social justice, national integration and economic uplift of the rural masses. They help the rural poor by increasing their accessibility to schools, health centers and to more employment opportunities. In yet another indirect way, roads influence the process of growth through changes in socio-economic attitudes of people by facilitating the dispersal of knowledge and reduction of inequalities leading to demand for more goods and services.

1.1.6 Pradhan Mantri Gram Sadak Yozna (PMGSY) - Recently, an extensive road development programme called Pradhan Mantri Gram Sadak Yozna (PMGSY) has been envisaged for the country involving colossal amount of money, manpower and materials. PMGSY was launched on 25th December 2000 as a fully funded Centrally Sponsored Scheme to provide all weather road connectivity in rural areas of the country. The programme envisages connecting all habitations with a population of 500 persons and above in the plain areas and 250 persons and above in hill States, the tribal and the desert areas. According to latest figures made available by the State Governments under a survey to identify Core Network as part of the PMGSY programme, about 1.67 lakh Unconnected Habitations are eligible for coverage under the programme. This involves construction of about 3.71 lakh km. of roads for New Connectivity and 3.68 lakh km. under upgradation. It is proposed to connect about 1-lakh villages in the next seven years. This scheme aims to connect within the next three

years, every village that has a population of more than one thousand, through good all-weather roads.

1.1.7 Urban roads: Urban roads are about 2.5 lac Kilometer which is around 10.18 % as on 31st March, 2002. The urban roads carry large traffic volume and the economic loss due to poor condition of road amounts to a huge sum in spite of their small mileage [MORT&H Website]. Urban roads fall within the jurisdiction of Municipal Corporation, Municipal Boards, Cantonment Boards and Port Trusts which are statutory bodies in urban areas. The urban roads are further classified as:-

1.1.7.1 Arterial roads- An arterial road is a high-capacity urban road. The primary function of an arterial road is to deliver traffic from collector roads to freeways, and between urban centres at the highest level of service possible. As such, many arteries are limited-access roads, or feature restrictions on private access. Though the design of arterial roads varies from country to country, city to city, and even within cities, they share a number of common design characteristics. For example, in many cities, arteries are arranged in concentric circles (commonly referred to as ring roads) or in a grid. Many jurisdictions also classify arterial roads as either principal (major) or minor.

1.1.7.2 Sub-arterial roads- The city roads which provide lower level of travel mobility than arterial streets are called Sub-arterial streets. Their spacing may vary from 0.5 km in central business districts to 3 to 5 km in Sub-urban areas. Loading and unloading are usually restricted. Pedestrians are allowed to cross these highways at intersections.

1.1.7.3 Collector Streets- The city roads which are constructed for collecting and distributing the traffic to and from local streets, and also to provide an access to arterial and sub-arterial streets, are also called Collector streets. These are located in residential, business and industrial areas. These roads are accessible from the buildings along them. Parking restrictions are few and that too during peak hours.

1.1.7.4 Local Streets- The city roads which provide an access to residence, business and other buildings are called local streets. The traffic carried either originates or terminates along the local streets. Depending upon the

important of the adjoining areas, a local street may be residential, commercial or industrial. Along local streets pedestrians may move freely and parking may be permitted without any restriction.

The Design speeds and space standards for various category of urban road recommended by IRC are given in Table 1.2 [IRC: 86 1983].

Table 1.2 Design Speed and Space Standards for Roads in Urban Areas

Road Classification	Design Speed (kmph)	Recommended RoW (meters)
Arterial	80	56-60
Semi-Arterial	60	30-40
Collector Streets	50	20-30
Local Streets	30	10-20

1.2 Deficiencies of Present Road Network

The growth of road network, both in terms of capacity and quality has not kept pace with the tremendous growth in demand for road transport in India. That is why the current road network of India has to content with serious deficient as outlined below:

1.2.1 Growing Road Transport Demand

The growth of road traffic in India in the post independence era has been quite unprecedented. While the vehicle population has grown from just 3 lakh in 1951 to about 450 lakh now, the quantum of goods being carried by road transport has undergone an incredible increase from 600 lakh tonnes to 40,000 lakh tonnes at present. Table 1.3 gives the growth in number of vehicles over the last 60 years.

Also, the share of road transport in passenger movement and freight movement has increased by 20% to 85% and 20% to 70% respectively, during the last 60 years. When one observes the shares of the two principal modes, i.e. railways and road transport,

there has been a considerable shift in passenger and freight traffic carried by road transport in comparison to rail transport over the last 60 years, as given in Table 1.4.

Table 1.3 Growth of Vehicles during Last 60 Years

Year	Total No. of Vehicles (in thousands)	Commercial Vehicles (in thousands)
1951	306	116
1961	665	225
1971	1865	437
1981	5391	716
1991	21374	1687
1995	30295	2217
1997	37231	2748
2000	48393	3240
2015	110000*	7500*

* Estimated figures

Source: MORT&H [2001c], and NHAI@2013

Table 1.4 Modal Shifts in Traffic Categories

Traffic Category	Year 1951		Year 2013	
	Road	Rail	Road	Rail
Passenger	20%	80%	85%	15%
Freight	20%	80%	70%	30%

Source: MORT&H [2001c] and NHAI@2013

1.2.2 Volume Constraints

The entire road network is facing serious capacity constraints. National Highways comprise only 2% of the total road length in the country, but carry 40% of total road based traffic. Nearly 15% of the National Highway length is still single lane. The position is still worse with respect to State Highways, which comprise 6% of the total road length but about 75% of the length is still single lane [MORT&H 2001c]. For smooth, efficient and safe movement of traffic, the minimum pavement required is a two-lane pavement, one lane for each direction of traffic. Thus, frequent deceleration and

acceleration become necessary. Such speed changes result in increased fuel consumption and increased wear and tear of vehicles, leading to high vehicle operating costs (VOC).

1.2.3. Lower Quality of Roads

In spite of having such a vast network of roads, the quality of roads largely remains poor, so much so that more than half of the roads are still devoid of any kind of paving. The existing road network has aged, leading to appearance of numerous kinds of distresses viz. cracking, ravelling and potholing on road surface. These distresses, under the combined action of moving traffic and environmental factors have been continuously growing in extent and severity, in the absence of timely upkeep and maintenance. Over 50 percent of the National and State Highways and a higher percentage of other categories of roads are in very bad condition. About 85% of the National and State Highways are not structurally adequate to carry the permissible standard axle load of 10.2 tonnes [MORT&H 2001c].

1.2.4. Increased Traffic and Axle Loads

Traffic on the Indian roads, in terms of volume and axle loads, is increasing at an alarming rate, with the annual growth rate estimated to be of the order of about 10% [MORT&H 2001c]. This phenomenal growth in vehicle population and road usage has put a tremendous strain on the existing road network. There has been considerable increase in the axle loads carried by freight vehicles, but the regulations governing the axle weight limitations have not been changed significantly for last many years, with consequent negative effect on pavements in terms of fatigue and accelerated deterioration. The present spectrum of axle loads plying on the Indian roads shows that as against a prescribed legal limit of 10.2 tonnes axle load, commercial vehicles with much higher axle loads, even to the extent of 18-22 tonnes are plying on these roads. According to 'Road Damage Formula', pavement that can last for 10 years without overloading will last only for 6.5 years, if there is 10 percent overloading on an average. With 30 percent overloading, the same pavement will last only for 3.5 years [CRRRI 1994]. This situation has led to a much faster rate of pavement deterioration, which calls for timely additional maintenance inputs, not planned otherwise, for preserving and keeping up the roads to the minimum acceptable level of service.

1.2.5 Insufficient Road Length

The country at present has only about one and a half million kms of motorable roads for as many as 45 million vehicles. Table 1.5 gives the growth in total road length, surfaced road length and National Highways road length during the last 60 years. With the continuing all round industrial and agricultural development and a clear shift in favour of road transport, the demand has been rapidly increasing for additional road lengths, which are also structurally and functionally adequate. About 30% of India's 5,76,000 villages are still without a road link. There are a large number of missing links in the National Highway Grid, required to be plugged as a matter of highest priority for the smooth flow of traffic.

Table 1.5 Total Road Length, Surfaced Road Length and National Highways Road Length (in thousand km)

Year	Total Road Length	Surfaced Road Length	National Highways Length
1951	397	156	198.11
1986	1736	824	320.88
1991	2327	1090	336.50
1992	2462	1136	336.86
1993	2678	1263	339.16
1994	2955	1338	342.49
1995	3057	1379	342.62
1996	3123	1409	345.08
1999	3259	1517	520.10
2002	3315	1558	581.12

Source: MORT&H [2001c]

1.2.6 Inadequate Allocation of Funds

Present allocation of funds for construction and maintenance of roads is far short of requirements. Allocation of funds for maintenance does not exceed 60% of the normal requirements of roads [MORT&H 2001b]. Consequently, the gap between the allocation and requirements has been accumulating over the years and thus, now poses a threat to the road network. This is all the more serious as traffic is growing rapidly both in

volume and weight. Maintenance being a non-plan activity, there is also tendency by the decision-makers to apply ad-hoc cuts in the face of resource constraints. Table 1.6 gives the shortfall in fund allocations for maintenance and rehabilitation (M&R) in respect of National Highways.

Table 1.6 M&R Fund Requirements and Allocations in Respect of National Highways

Year	Requirements (Rs. Crores)	Allocations (Rs. Crores)	Shortfall (Rs. Crores)	% Shortfall
1981-82	55.55	47.00	8.55	15.39
1982-83	60.00	51.00	9.00	15.00
1983-84	71.90	61.00	10.00	15.16
1984-85	108.30	75.00	33.30	30.75
1985-86	116.82	90.00	26.82	22.96
1986-87	176.78	94.25	82.53	46.69
1987-88	177.24	99.03	78.21	44.13
1988-89	198.00	142.36	55.64	28.10
1989-90	194.50	143.55	50.95	26.20
1990-91	257.91	153.12	104.79	40.63
1991-92	291.29	166.76	124.53	42.75
1992-93	330.00	168.67	161.33	48.89
1993-94	415.00	214.50	200.50	48.31
1994-95	475.00	246.90	228.10	48.00
1995-96	535.00	288.43	246.57	46.09

1996-97	570.00	372.00	198.00	34.74
1997-98	600.00	497.50	102.50	17.08
1998-99	1050.00	549.80	500.20	47.63
1999-2000	1250.00	703.00	547.00	43.76

Source: MORT&H [2001b]

1.2.7 Deficiencies in Design Standards

The majority of roads in the country are deficient with regard to design standards, geometrics, safety aspects and road user comfort conditions. Because of limited resources availability at a given point of time, the practice of stage construction is adopted. The pavements are designed for an initial service life of about 15 years [IRC:37-2012] and then strengthening is provided as the traffic demand increases. The present poor condition of the road network is mainly because of the reason that the emphasis in the past had been on the construction of new roads and maintenance has always got the back seat because of financial constraints. This implies that both the construction and maintenance activities of roads are equally important for the development of the road network and thus must be treated in an integrated manner.

1.2.8 Deficiencies in Maintenance Management Practices

The current engineering practice in India is to design pavements and select maintenance and rehabilitation alternatives based on subjective judgement and engineering experience of the road engineers only. Even, if the engineer responsible for making decisions has a significant experience base to draw up the maintenance strategies, there are inadequate analytical tools available for use by the highway agencies to assist the practicing highway engineers in selecting the best strategy based upon economics of 'life cycle cost'. Implementation of rational methodologies is constrained by many factors, including relatively low level of human resources and the lack of institutional and technical capacity to adopt existing comprehensive decision-making models.

1.2.9 Other Factors

Apart from funds, there are other factors too. These are the outdated system of gang labour, lack of planning, scheduling and monitoring of maintenance operations, inherent deficiencies in structural thickness, lack of attention to drainage, and poor enforcement of legal axle load limits etc. These factors have also contributed much towards accelerated deterioration of road networks and hastened the process of network decay [MORT&H 2001c].

DISTRESSES IN FLEXIBLE PAVEMENTS

2.1. General

The quality of roads dictates the economy of a country and hence the quality of our life's. Roads are vital for the transport of the goods and passengers. In India, road transport carries approximately 85% of passenger traffic and 70% of freight transport. But the construction of highways involves huge amount of the investment and mainly sixty percent of the highway project cost is associated with the pavement construction. Pavement is a durable surfacing of a road, airstrip, or similar area and the primary function is to transmit loads to the sub-base and underlying soil subgrade. Around ninety percent of the Indian Highways have a covered surface with bituminous layers which are constructed and maintained by using naturally available road aggregates and bitumen, a petroleum product, which being mixed at high temperatures to produce hot mix asphalt. Mix design for the different layers of the pavement can have a major impact on the performance, cost and sustainability of the bituminous surfaces.

2.2. Flexible Pavement

Flexible Pavements are those pavements which reflect the deformation of subgrade and the subsequent layers to the surface. Flexible, usually asphalt, is laid with no reinforcement or with a specialized fabric reinforcement that permits limited flow or repositioning of the roadbed underground changes.

→The design of flexible pavement is based on load distributing characteristic of the component layers. The black top pavement including water & gravel bound macadam fall in this category.

→Flexible pavement on the whole has low or negligible flexible strength flexible in their structural action). The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain transfer through contact points of granular structure.

→The vertical compressive stress is higher on the pavement surface directly under the wheel load and is equal to contact pressure under the wheels. Due to the ability to distribute the stress to large area in the shape of truncated cone the stresses get decreased in the lower layer.

→As such the flexible pavement may be constructed in a number of layers and the top layer has to be strongest as the highest compressive stresses.

→To be sustained by this layer, in addition to wear and tear, the lower layer have to take up only lesser magnitude of stress as there is no direct wearing action due to traffic loads, therefore inferior material with lower cost can be used in the lower layers.

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out and then passes these loads to the next layer below. Typical flexible pavement structure shown in plate 1.1 consisting of:-

a. Surface course: Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete (AC). The functions and requirements of this layer are:

- It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,
- It must be tough to resist the distortion under traffic and provide a smooth and skid-resistant riding surface,
- It must be water proof to protect the entire base and sub-grade from the weakening effect of water.

- b. Binder course:** This layer provides the bulk of the asphalt concrete structure. Its chief purpose is to distribute load to the base course. The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design.
- c. Base course:** The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage. It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.
- d. Sub-Base course:** The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure. If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course. A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, sub-base course may not be provided.
- e. Sub-grade:** The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content.

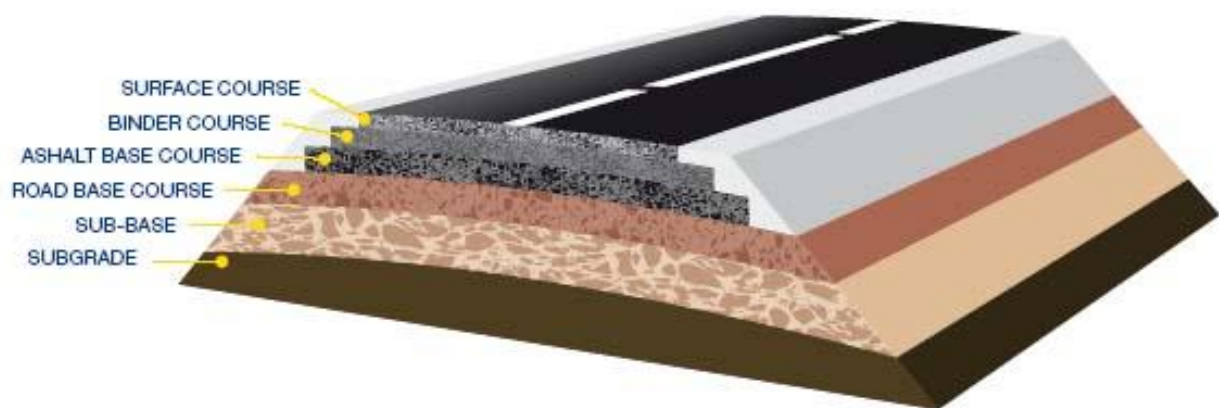


Figure no 2.1: Different layers of the Flexible Pavement Section

A flexible pavement structure is typically composed of several layers (as shown in Figure no 2.1) of material with better quality materials on top where the intensity of stress from traffic loads is high and lower quality materials at the bottom where the stress intensity is low. Flexible pavements can be analyzed as a multilayer system under loading and are constructed by using different layers such as Bituminous concrete (BC), Dense Bituminous Macadam (DBM), Bituminous Macadam (BM), Wet Mix Macadam (WMM) and Granular Subbase (GSB) as per the MORTH specifications with the designed thickness as per the IRC: 37-2012 have shown in Figure no 2.2.

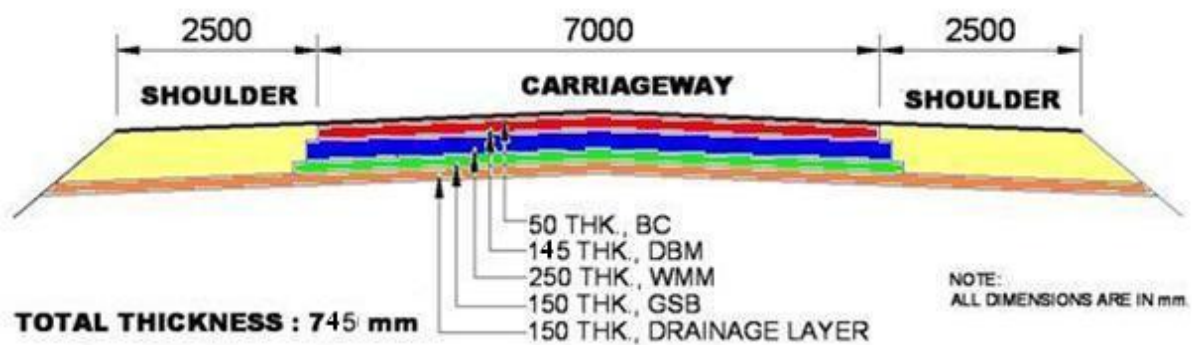


Figure no 2.2: - Section of Flexible Pavement designed as per IRC: 37-2012

2.3. Pavement deterioration

The rate of pavement deterioration is directly affected by the standards of maintenance applied to repair defects on the pavement surface such as cracking, raveling, potholes, etc., or to preserve the structural integrity of the pavement (for example, surface treatments, overlays, overall long-term condition of the road pavement directly depends on the maintenance or the improvement standards applied to the road.

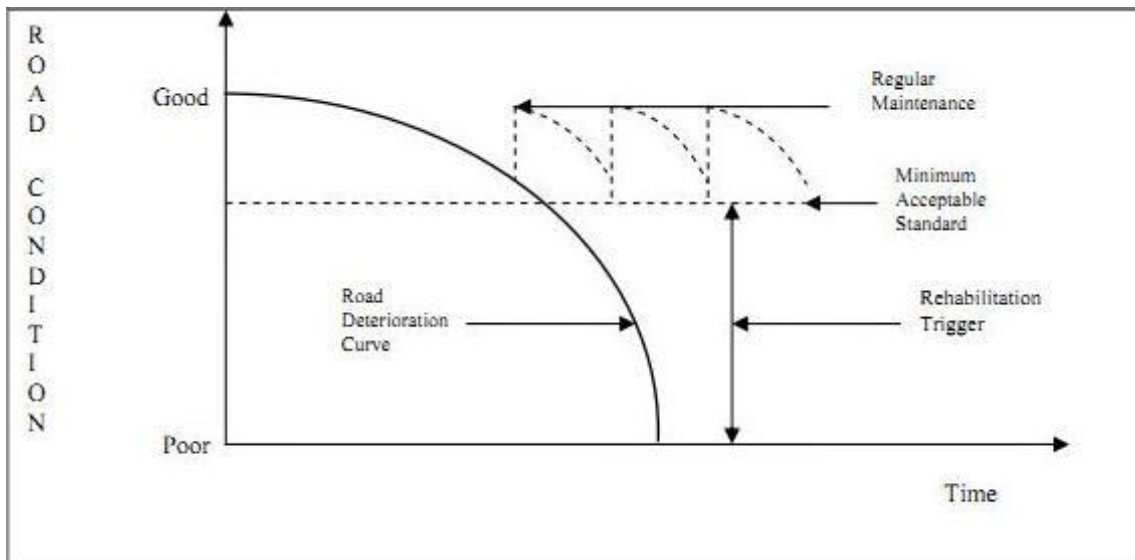


Figure 2.3: Pavement Deterioration Curve [Hass & Hudson, 1978]

2.4. Distresses in the pavements

Fatigue cracking (Alligator cracking)

Fatigue cracking is commonly called alligator cracking. This is a series of interconnected cracks creating small, irregular shaped pieces of pavement. The cracking pattern gives the appearance of alligator skin or chicken wire. It is caused by failure of the surface layer or base due to repeated traffic loading (fatigue). Eventually the cracks lead to disintegration of the surface. The final result is potholes. Alligator cracking is usually associated with base or drainage problems. Small Areas may be fixed with a patch or area repair. Larger areas require reclamation or reconstruction. Drainage must be carefully examined in all cases.

Longitudinal cracking

Longitudinal cracks are long cracks that run parallel to the centre line of the roadway. These may be caused by frost heaving or joint failures or they may be load induced. Understanding the cause is critical to selecting the proper repair. Multiple parallel cracks may eventually form from the initial crack. This phenomenon, known as deterioration, is usually a sign that crack repairs are not the proper solution. Filling or sealing longitudinal cracks can work if the cracks are narrow and not deteriorated too much. Figure 5 shows sealed longitudinal cracks.

Transverse cracks

Transverse cracks form at approximately right angles to the centre line of the roadway. They are regularly spaced and have some of the same causes as longitudinal cracks. Transverse cracks will initially be widely spaced (over 20 feet apart). They usually begin as hairline or very narrow cracks and widen with age. If not properly sealed and maintained, secondary or multiple cracks develop, parallel to the initial crack. The reasons for transverse cracking, and the repairs, are similar to those for longitudinal cracking. In addition, thermal issues can lead to low-temperature cracking if the asphalt cement is too hard.

Roughness

Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle (and thus the user). Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption and maintenance costs. Pavement Roughness can be measured subjectively or objectively.

Surface Distress

Surface distress is any indication of poor or unfavourable pavement performance or signs of impending failure. The general surface distresses can be grouped under the following three broad groups. The distresses under each of the groups are also mentioned along with the unit of measurement in parentheses.

Surface deformation

Pavement deformation is the result of weakness in one or more layers of the pavement that has experienced movement after construction. The deformation may be accompanied by cracking. Surface distortions can be a traffic hazard.

Rutting

Rutting is the displacement of pavement material that creates channels in the wheel path. Very severe rutting will actually hold water in the rut. Rutting is usually a failure in one or more layers in the pavement. The width of the rut is a sign of which layer has failed. A very narrow rut is usually a surface failure, while a wide one is indicative of a subgrade failure. Inadequate compaction can lead to rutting. Minor surface rutting can

be filled with micro paving or paver placed surface treatments. Deeper ruts may be shimmed with a truing and levelling course, with an overlay placed over the shim. If the surface asphalt is unstable, recycling of the surface may be the best option. If the problem is in the subgrade layer, reclamation or reconstruction may be needed.

Corrugation

Corrugation is referred to as wash boarding because the pavement surface has become distorted like a washboard. The instability of the asphalt concrete surface course may be caused by too much asphalt cement, too much fine aggregate, or rounded or smooth textured coarse aggregate. Corrugations usually occur at places where vehicles accelerate or decelerate. Minor corrugations can be repaired with an overlay or surface milling. Severe corrugations require a deeper milling before resurfacing.

Shoving

Shoving is also a form of plastic movement in the asphalt concrete surface layer that creates a localized bulging of the pavement. Locations and causes of shoving are similar to those for corrugations. Repair minor shoving by removing and replacing. For large areas, milling the surface may be required, followed by an overlay.

Depressions

Depressions are small, localized bowl-shaped areas that may include cracking. Depressions cause roughness, are a hazard to motorists, and allow water to collect. Depressions are typically caused by localized consolidation or movement of the supporting layers beneath the surface course due to instability. Repair by excavating and rebuilding the localized depressions. Reconstruction is required for extensive depressions.

Swell

A swell is a localized upward bulge on the pavement surface. Swells are caused by an expansion of the supporting layers beneath the surface course or the subgrade. The expansion is typically caused by frost heaving or by moisture. Subgrade with highly plastic clays can swell in a manner similar to frost heaves (but usually in warmer months). Repair swells by excavating the inferior subgrade material and rebuilding the removed area. Reconstruction may be required for extensive swelling.

Disintegration

The progressive breaking up of the pavement into small, loose pieces is called disintegration. If the disintegration is not repaired in its early stages, complete reconstruction of the pavement may be needed.

Potholes

Potholes are bowl-shaped holes similar to depressions. They are a progressive failure. First, small fragments of the top layer are dislodged. Over time, the distress will progress downward into the lower layers of the pavement. Potholes are often located in areas of poor drainage. Potholes are formed when the pavement disintegrates under traffic loading, due to inadequate strength in one or more layers of the pavement, usually accompanied by the presence of water. Most potholes would not occur if the root cause was repaired before development of the pothole. Repair by excavating and rebuilding. Area repairs or reconstruction may be required for extensive potholes.

Patches

A patch is defined as a portion of the pavement that has been removed and replaced. Patches are usually used to repair defects in a pavement or to cover a utility trench. Patch failure can lead to a more widespread failure of the surrounding pavement. Some people do not consider patches as pavement defect. While this should be true for high quality patches as is done in a semi-permanent patch, the throw and roll patch is just a cover. The underlying cause is still under the pothole. To repair a patch, a semi-permanent patch should be placed. Extensive potholes may lead to area repairs or reclamation. Reconstruction is only needed if base problems are the root source of the potholes.

Bleeding

Bleeding is defined as the presence of excess asphalt on the road surface which creates patches of asphalt cement. Excessive asphalt cement reduces the skid-resistance of a pavement, and it can become very slippery when wet, creating a safety hazard. This is caused by an excessively high asphalt cement content in the mix, using an asphalt cement with too low a viscosity (too flowable), too heavy a prime or tack coat, or an improperly applied seal coat. Bleeding occurs more often in hot weather when the asphalt cement is less viscous (more flowable) and the traffic forces the asphalt to the

surface. In some cases, a repair can be made by applying hot sand or slag to blot up the excess asphalt. This is a very difficult problem to solve. It sometimes requires removing the bleeding pavement and placing a new surface. A thin wearing course will only solve the problem temporarily. The bleeding asphalt will eventually work its way upward.

Polishing

Polishing is the wearing of aggregate on the pavement surface due to traffic. It can result in a dangerous low friction surface. A thin wearing course will repair the surface.

Delamination

Delamination is a failure of an overlay due to a loss of bond between the overlay and the older pavement. Common causes of delamination include: wet or dirty surface during paving of the overlay, failure to use a tack coat, or poor compaction of the overlay. Proper paving techniques, including cleaning the surface and use of tack coat, will reduce the chances of delamination. Surface distress is related to roughness (the more cracks, distortion and disintegration - the rougher the pavement will be) as well as structural integrity (surface distress can be a sign of impending or current structural problems). Current methods of recording pavement surface distresses are using video imaging using a specially equipped van that is fitted with high-resolution cameras. The van can travel at the usual highway speeds. Evaluation is either done manually by playing the video back on specially designed workstations while trained crews rate the recorded road surface or automatically by computer image processing software. In more advanced Integrated Pavement Analysis Units, in addition to high resolution video cameras, other instruments such as non-contact (laser) profilometers for mapping longitudinal as well as transverse pavement profile, distance measuring instrument and computer workstations for processing the data are fitted. Automatic Road analyser and Laser Road Surface Tester fall in this category.

Skid Resistance

Skid resistance is the force developed when a tyre that is prevented from rotating slides along the pavement surface (Highway Research Board, 1972). Skid resistance is an important pavement evaluation parameter because inadequate skid resistance will lead to higher incidences of skid related accidents. Skid resistance depends on pavement surface texture. Skid resistance changes over time. Typically it increases in the first two

years following construction as the roadway is worn away by traffic and rough aggregate surfaces become exposed, and then decreases over the remaining pavement life as aggregates become more polished.

Deflection

Pavement surface deflection measurements are the primary means of evaluating a flexible pavement structure. Although other measurements can be made that reflect (to some degree) a pavement's structural condition, surface deflection is an important pavement evaluation method because the magnitude and shape of pavement deflection is a function of traffic (type and volume), pavement structural section, temperature affecting the pavement structure and moisture affecting the pavement structure. Deflection measurements can be used in back calculation methods to determine pavement structural layer stiffness and the subgrade resilient modulus. Furthermore, pavement deflection measurements are non-destructive destructive in nature which adds on to the overall viability of usage.

3.1 Pavement Management System Studies in India

Kerali et.al (1998) has represented the role of Highway Development and Management-4 (HDM-4) in road management. The HDM-4 is the successor to the World Bank Highway Design and Maintenance Standards Model (HDM-III). The scope of the new HDM-4 tools has been broadened considerably beyond traditional project appraisals, to provide a powerful system for the analysis of road management and investment alternatives. The HDM-4 incorporates three dedicated applications tools for project level analysis, road work programming under constrained budgets, and for strategic planning of long term network performance and expenditure needs. It is designed to be used as a decision support tool within a road management system. Standard data import and export facilities are provided for linking HDM-4 to various database management systems. Local adaptation and calibration of HDM-4 models can be achieved by specifying default data sets that represent pavement performance and vehicle resource consumption in the country where the model is being used. The highway management process as a whole can, therefore, be considered as a cycle of activities that are undertaken within each of the management functions of planning, programming, preparation and operations. The HDM-4 analytical framework is based on the concept of pavement life cycle analysis. This is applied to predict the following over the life cycle of a road pavement, i.e. road deterioration, road work effects, road user effects and socio-economic and environmental effects. Once constructed, road pavements deteriorate as a consequence of several factors, i.e. Traffic loading, Environmental weathering, Effect of inadequate drainage systems.

Pienaar et. al [2000] carried out a study on a comparison of the HDM-4 with the HDM-III on a case study in Swaziland. He reported on three case studies in Swaziland, consisting of the upgrading of gravel road to paved road standard, where both the HDM-III and HDM-4 program packages were used. One case study was addressed in detail to illustrate the main differences / improvements, while for the other two case

studies only a brief project overview and the final results were provided. Certain work has been done in South Africa on pavement deterioration factors (10). For the HDM- III analysis a factor of 0.9 has been used for the roughness-age term, 0.8 for structural cracking progression, and 1.0 for the other deterioration factors. HDM-4 makes provision for a number of calibration factors related to surface distress, structural defects, roughness and drainage. Compared to HDM-III, HDM-4 does not use the roughness-age term as such, and a distinction is made between “all structural cracking” and “wide structural cracking”. In the absence of guidelines for HDM-4 calibrations factors, a value of 1.0 was assumed for all calibration factors for purposes of the analysis.

Tiwari (1997) represents that the concept of “serviceability” of roads and its evolution through time is widely accepted by pavement engineers and professionals as a way to evaluate road quality and conditions. Both the Present Serviceability Index (PSI) and International Roughness Index (IRI) can be used as indicators of road riding quality and serviceability. The objective of the study was to develop realistic models for estimating PSI for asphalt pavement sections located in the urban city of Noida, near Delhi, the capital of India. The PSI model was developed as a function of the pavement age. An attempt was made to calibrate the American Association of State Highway & Transportation Officials (AASHTO) equation for PSI and determine the suitability of this equation in Indian pavement conditions for selected urban roads. The developed models were also validated. Based on the developed PSI model, the maintenance alternatives have been suggested for the urban road sections in the study area.

Medina et al. (1999) cited a portion of the Pavement Policy for Highways that defines pavement management as, “a set of tools or methods that can aid decision-makers in finding cost-effective strategies for providing and maintaining pavements in a serviceable condition” The pavement management system must address methods, schedules, and budgets associated with achieving the goals. The three main components of a pavement management system are data collection, data analysis, and implementation. One approach to pavement management is shown schematically. The data collection component is summarized in a database which includes the inventory, condition evaluation, and maintenance strategies. The analysis portion of the Pavement Management Structure requires the synthesis of the pavement condition

assessment, which is determined from the condition evaluation and the maintenance strategies, along with global concerns related to the network. Based on the results of the network need, one can prioritize the work and develop a work plan, which is, of course, constrained by budgets. Once projects have been selected that are high on the priority list and feasible within the budget, they are implemented.

Naidu et al. (2004) represents the study of an attempt to select optimum maintenance strategies and to develop maintenance management plan based on economics of life cycle costs using HDM-4 and he selected Inner Ring Road of New Delhi for the study. The effect of different maintenance budget allocation on road network conditions has been analyzed. Mechanical strategies shall be judged based upon economical analysis considering various existing alternatives/treatments available. HDM-4 has emerged as a very powerful tool for developing various aspects of PMS such as predicting the pavement deterioration, programming of maintenance and rehabilitation works and carrying out lifecycle cost analysis and cost optimization. The study observed that poor resource allocation for maintenance of roads may be due to the poor decision making which is mainly to non-availability of analytical tools to strengthen their decisions. It is also shown that subjective budgeting process could be replaced by rational, economic, need based budgeting approach in which budget are based on life cycle road costs. Project and programme analysis is very useful in establishing the economic viability of pavement maintenance and rehabilitation alternatives and to evolve the work programme against budget constraints.

3.2 Pavement Management System Studies in Abroad

Liu (2006) developed Pavement management system in china .Over1, 900,000 km roads had been constructed in China, among them 40,000 km roads were expressways, another 15,000 expressways would have been constructed by 2010(liu 2006).By 2020, a national highway network would be completed with 85,000 expressways. Clearly, China needed a pavement management plan to address past and future pavements. In 1984, China initialized and developed a PMS and since its introduction significant progress, in terms of pavement management, has been made. The implementation of this PMS has not gone so well, due to less focus and acceptance. Most transportation departments in China are more focused on road construction.

Crispino et al. (2004): The first experience of PMS in Italy was through the Province of Milano. Following the adoption of a new law in 2001, major portions of the interurban state road network had been transferred from the national road agency (ANAS) to the jurisdiction of the provincial governance. This transferral of competences brought up a number of consequences in the field of maintenance and management and in particular the need for the Provinces to optimise budget funds dedicated to the new additions to their road network. The latter situation led the Province of Milano to the adoption of a new approach for the task of pavement maintenance aiming at a more rational solution based on objective criteria for intervention planning

McQueen et al. (2001): In South Africa (SA), many roads were constructed more than fifty years ago and have been subjected to unanticipated increases in the weights and the numbers of the vehicles using them (National Department of Transport 1998). These increases have occurred during a time when governments at all levels have faced, and are facing, escalating demands on their financial resources. It is not surprising that the emphasis today is to plan and budget for their maintenance and rehabilitation. This can be attained by using modern management and engineering techniques. The need for having a PMS in South Africa (SA) was identified by the South African Roads Board (SARB) through the South African Roads Agency Limited (SANRAL) (National Department of Transport 1996). SANRAL, as mandated by SARB, developed a PMS plan and the aim of the plan was to provide PMS Managers with the guidelines regarding the requirements of the PMS. Guided by the PMS plan, different road maintenance authorities (local, metropolitan and provincial) took a mandate of developing and managing their PMS.

Anderson et al. (1994): PMS in Australia, like in other countries across the world, is managed at the district and state level, only. It was developed as an in-house software to serve as a decision support tool for the road asset maintenance policy and strategy at the state and district levels. Other states use commercially available software for this purpose. All states use pavement data collection systems. Data gathered includes, but is not limited to roughness, rutting, strength, texture, cracking; skid resistance and seal coat age.

Burger et al. (1994): In Germany the design of a new, complete pavement management system is under way. Major components are already operational. Meanwhile, data on road conditions have been collected with high-speed monitoring systems over the national road network, including the Autobahn. The data is assembled according to evenness, skid resistance, and surface damage and subsequently classified via a special grading system. By applying special algorithms, a service value, a structural value, and an overall condition value are being developed. The results of the survey are then presented in lists, route section graphs, and network graphs with different colours indicating where specific target, warning, and threshold values are exceeded. By means of continuous feedback, the information collected is used to improve and adjust the system's components and the plausibility of the output. There is an agreement that for an effective PMS application, repeated automated network monitoring is necessary. To minimize necessary monitoring and evaluation efforts, the use of multifunctional automated monitoring systems is used to collect all necessary data during a single pass.

3.3 Various Studies

Study conducted at California

The California Department of Transportation (Caltrans) has developed a PMS that is designed to assist management in making cost effective decisions regarding pavement maintenance and rehabilitation. Caltrans has given rating system for flexible pavements which includes alligator and block cracking, longitudinal cracking, transverse cracking, raveling, rutting and patching. The Caltrans system brings together the following system approach [Petuson 1981]

Study conducted at Germany

In Germany the design of a new, complete pavement management system is under way. Major components are already operational. Meanwhile, data on road conditions have been collected with high-speed monitoring systems over the national road network. The data is assembled according to evenness, skid resistance, and surface damage and subsequently classified via a special grading system. By applying special algorithms, a service value, a structural value, and an overall condition value are being developed.

The results of the survey are then presented in lists, route section graphs, and network graphs with different colours indicating where specific target, warning, and threshold values are exceeded. By means of continuous feedback, the information collected is used to improve and adjust the system's components and the plausibility of the output. There is an agreement that for an effective PMS application, repeated automated network monitoring is necessary. To minimize necessary monitoring and evaluation efforts, the use of multifunctional automated monitoring systems is used to collect all necessary data during a single pass (Burger *et al.* 1994).

Pavement management program: City of Rosemount, Minnesota, USA

The City has developed and maintains a Pavement Management Program, designed to protect and extend the usual life of paved surfaces throughout the City. As part of the Pavement Management Program (PMP), the City utilizes ICON, a specialized software application which allows staff to identify, inventory and track the growth of the street system, its structural performance and overall condition. Field inspections are used to rate the physical conditions of the street sections, and are completed every three years. Based on the information gathered from the field inspections, ICON assigns a Pavement Condition Index (PCI) ranging from 1 to 100 to identify surfaces most in need of improvements. Improvements can range from seal coating, to a complete Reconstruction with utility upgrades [*City of Rosemount Website 2008*]

Study conducted at Utah, USA

The Utah Department of Transportation faced with a serious shortage of funds for rehabilitating failed pavements. It was decided to find out at what level of service, the pavement performance would be most economical for the state and for the users. Cost Curves and Cost estimates were prepared for updating pavements to an acceptable level of performance from its present condition. User cost, maintenance costs, and rehabilitation costs were included in the analysis. These cost varied with the condition of the pavement. Cost Curves and Cost estimates were prepared for updating pavements to an acceptable level of performance from its present condition. User cost, maintenance costs, and rehabilitation costs were included in the analysis. These cost varied with the condition of the pavement.

4.1 General

A World Bank Study on road deterioration in developing countries found that road maintenance is a very cost-effective option since the rate of return on investment on maintenance is supposed to be as high as 50% . Thus, it becomes important to review even the present policy of expansion of the network at the cost of maintenance of existing roads. The importance of having a proper road maintenance programme can be gauged from the fact that nearly 90% of freight on National and State Highways is carried by two-axle trucks, which are generally overloaded and cause significantly more damage than vehicles with more axles which have a better load distribution. Thus, more expenditure is required in India in comparison to other countries because of the particular composition of its commercial vehicular fleet.

4.2 Necessity of Pavement Maintenance Management System

An amount of nearly Rs. 38,000 crores has been spent on road development during the various plan periods up to the end of Ninth Five-Year Plan (1997-2002). The road network build at such a huge cost is showing signs of deterioration and disintegration. Complacency and inadequacy of road maintenance have caused irreparable damage to economic growth rate, as poorly maintained roads cause congestion, delay, road accidents, and higher vehicle operating costs. For preservation of assets made out of huge public investment, their timely upkeep and maintenance of roads is an inescapable necessity. Any neglect of maintenance activity is self-defeating as one Rupee spent on maintenance saves 2 to 3 Rupees in vehicle operating cost [MORT&H 2001c]. Moreover, such neglect accelerates the process of deterioration leading to much higher cost of rehabilitation and reconstruction. The past investments made in the construction and maintenance of roads in India just cannot be sacrificed, and all that is feasible, needs to be done to preserve the road network.

The principal cause of road deterioration and consequent remedial measures often remain undetected due to non-availability of objective data required for the analysis of various aspects of design, construction and maintenance of pavements. Managers and

Engineers who have adopted pavement technology understand that pavement management is a matter of 'Pay Now or Pay Much, Later'. Highway agencies responsible for maintenance cannot afford to pay later, as it is very costly to rehabilitate badly deteriorated pavements. Failure to approach the problem of pavement management in a systematic manner not only risks part of the very significant resources spent on pavement repairs, but far more resources need to be spent subsequently to restore the pavement to a serviceable condition.

4.3 Use of PMMS

With an understanding of the database, an examination of the typical uses of a PMMS can be undertaken. The following material briefly describes the main areas where a PMMS is applied and the benefits achieved from each:

a) Pavement Inventory Data

The most immediate use of the PMMS is in having a complete and readily accessible inventory of city road system including up-to-date conditions. This information is frequently very valuable for day-to-day use in tracking maintenance work and for reference in preparing reports or studies.

b) Developing Maintenance Budgets

Rather than preparing the typical 1-year maintenance budget, a PMMS allows to prepare a series of budgets. These budgets can be in the form of a multi-year program, identifying not only short-term (1 year) needs, but outlining needs over the course of many years. Further, alternatives can be prepared and presented to the budget decision makers.

c) Prioritization

A PMMS allows for the prioritization of maintenance projects based on cost and condition ratings and other factors such as traffic. It further can be used for selecting and ranking of projects for the upcoming budget year, as well as for long term financial planning.

4.4 Consequences of poor maintenance timings

The consequences of poor maintenance timing are illustrated in Figure 3.1. If adequate and timely maintenance measures are not taken, the pavement condition deteriorates very sharply from 'good' to 'poor' during a very short span of pavement life, leading to 4-5 times more fund requirements for rehabilitation of the pavement at that stage. Thus, if maintenance and rehabilitation is performed during the early stages of deterioration, before a sharp decline in pavement condition, over 75% of the maintenance costs can be avoided [Shahin 1994].

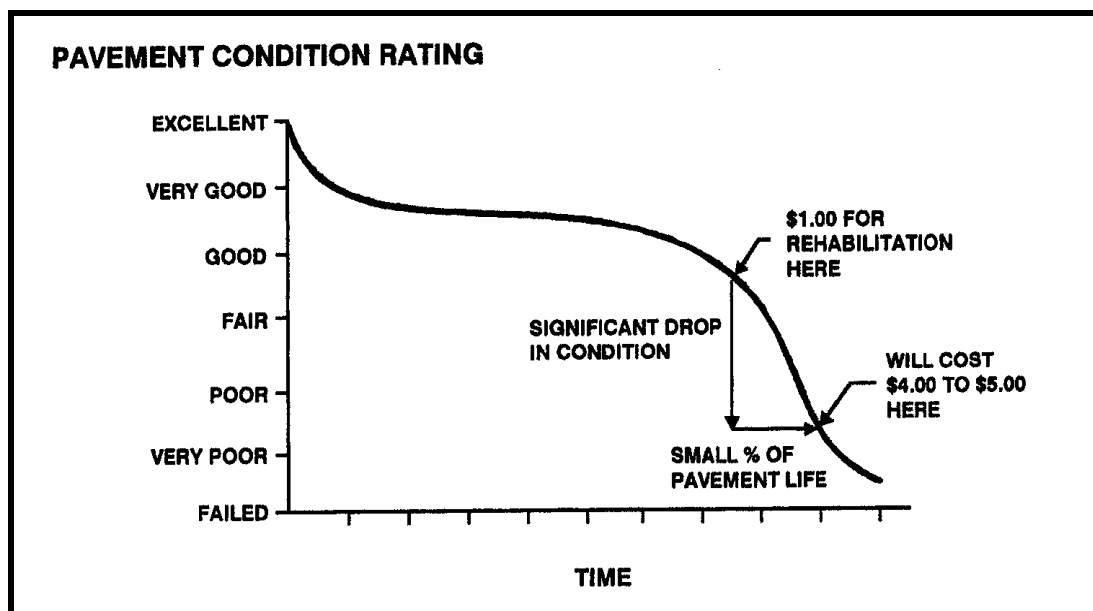


Figure 3.1 Consequences of Poor Maintenance Timings [Shahin 1994]

4.5 Effect of neglecting road maintenance - A further example, shown in Figure 3.2, illustrates the effect of neglecting road maintenance. This figure shows the relative discounted life cycle costs of construction, maintenance and vehicle operation under different maintenance investment scenarios. For a traffic level of about 1000 vehicles/day, a road in good condition will require about 2 percent of the total discounted costs to be spent on maintenance. However, if maintenance funds are reduced, the pavement will start to crack and potholes will gradually appear. With this level of deterioration, vehicle-operating costs (VOC) are likely to increase by about 10 percent. If there is a complete neglect of maintenance, a paved road will eventually start to disintegrate, and annual vehicle operating costs will increase by about 40 percent [Robinson 1998].

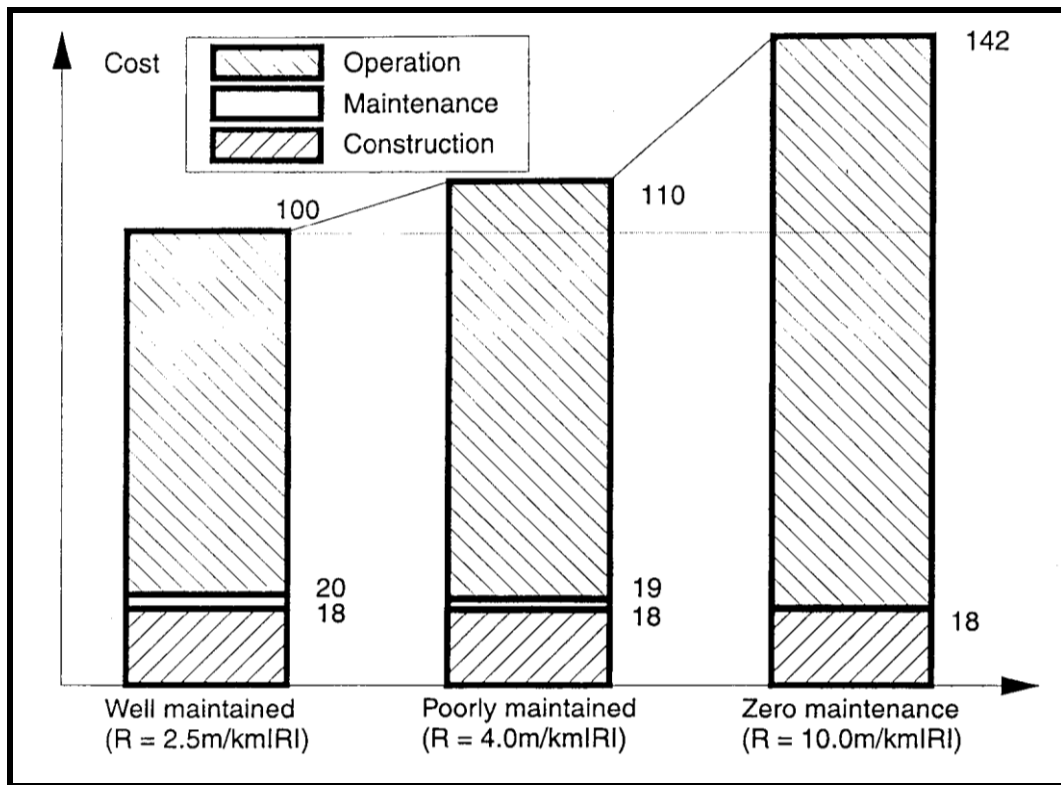


Figure 3.2 Change in Discounted Life Cycle Costs for Different Levels of Pavement Maintenance [Robinson 1998]

A systematic approach, therefore, needs to be considered for deciding about maintenance and rehabilitation strategies which should incorporate all the processes involved in the formulation of pavement maintenance plans and programs. There is also an urgent need for reviewing and updating the existing design practices and standards of road construction and maintenance. The government may also consider not treating maintenance of roads as a non-plan activity. Besides, the need exists for upgradation of the existing roads to cater to the present day's requirements of large traffic volumes and heavy traffic loads.

4.6 Scientific Approach towards Maintenance Management of Roads

During the first few years after construction, the deterioration of road is almost negligible as it is subjected to gradual weakening process by ever increasing traffic loading and climatic factors such as rain, solar radiation and temperature changes etc.

The speed of deterioration also depends on the quality and standards of the original construction. Neglect of maintenance accelerates the pace of deterioration and would cut down the design life considerably. Once the road enters the critical stage, i.e. the pavement structure loses its ability to withstand the load of vehicles; it is necessary to strengthen the pavement. This would involve a thorough knowledge of pavement condition, prediction of the rate of deterioration in terms of traffic repetitions so as to estimate in advance the appropriate time for different maintenance interventions.

Thus, in order to address condition assessment of pavements and maintenance treatments in a scientific manner, tools like Pavement Management System (PMMS) have been developed around the world. The main objectives of all these PMMSs have been twofold:

- (i) To develop a database which will allow for a scientific assessment of rehabilitation and maintenance needs of highways including inventorisation, visual inspection and rating, and instrumented measurements.
- (ii) To develop and implement a computer based management system for highways, having capability of evaluating the economic effects of various levels of intervention and optimizing the maintenance treatments within the given budget.

In the last twenty years, the pavement management systems have improved significantly due to the advances in computer technologies. Today, highway administrators have a series of tools or mechanisms that allow them to make a better use of the available resources for the maintenance and the rehabilitation of the highway networks. A notable effort in this direction relates to the development of Highway Development and Management System (HDM-4) by the World Bank, and the integration of existing pavement management systems with Geographical Information Systems (GIS).

4.7. Maintenance operations

4.7.1 Routine maintenance: Routine maintenance may be defined as those treatments that are applied to a pavement, in order to keep the pavement functioning properly. As such, routine maintenance is sometimes referred to as “reactive maintenance.” This suggests that it is work that is performed as a reaction to a specific distress. Routine maintenance is performed on pavements as they begin to show signs of deterioration, but is generally considered to be a wasted effort on pavements that are severely distressed. Filling a pothole is an example of a routine maintenance activity: It cannot be scheduled before the pothole appears and it should not be left unattended once the pothole has developed. However, if there are too many potholes present, a more comprehensive repair may be needed. In addition to pothole repair, routine maintenance treatments applied to pavements include edge patching, crack sealing and filling, and shoulder repair. Routine maintenance works are divided into the following works types:

- Non Pavement type: These include all the activities that are accomplished outside of the road surface, like clearing side drains & culverts, vegetation control, line-marking, road signs repair, guard rail repair, etc.
- Pavement type: These are works responding to minor pavement defects caused by a combination of traffic and environmental effects, for example, crack sealing, patching, edge repair, shoulders re-gravelling and grading.

4.7.2. Periodic maintenance: In contrast to routine maintenance treatments, periodic maintenance treatments are ideally applied on pavements prior to their manifestation of distresses. These treatments are intended to prolong the life of a pavement by restoring (or maintaining) desirable properties while such measures are still cost-effective. Periodic maintenance can delay future deterioration, or correct existing distresses, therefore they can be classified in preventive or corrective (reduce deterioration progress, or correct existing deterioration producing a step in the distress curve). Periodic maintenance works are divided into the following works types:

- Preventive Treatments: This is the addition of a thin film of surfacing to improve surface integrity and waterproofing without increasing the strength of the pavement. Preventive maintenance treatments are most effective when they are

applied to a surface that is intact (i.e., free from significant cracking or disintegration). Preventive maintenance treatments often do not contain any aggregate, or will contain an aggregate with a maximum size of 6,7 mm. Preventive treatments are not an effective means of addressing structural deterioration such as rutting and crocodile cracking.

- Resurfacing: This is the addition of a thin surfacing to improve surface integrity and waterproofing, or to improve skid resistance, without increasing the strength of the pavement significantly. They are sometimes referred to as “functional overlays,” as they are intended to restore or enhance the ability of the roadway to serve its purpose (function), but do not increase the load-carrying capabilities of the structure.

4.7.3 Strengthening: Strengthening typically includes maintenance treatments such as the addition of thick surfacing, or the removal of part of the existing pavement structural layers and the addition of layers to restore or improve structural integrity and to increase the strength of the pavement. It is normally applied at the end of a pavement’s structural life, when the pavement’s problems are only structural of nature and no quality of service problems is anticipated in the medium to long term. Strengthening works are divided into the following works types:

- Rehabilitation: Rehabilitation is most effective on pavements that are exhibiting signs of structural deterioration (crocodile cracking and rutting, in particular) but not to such an extent that complete reconstruction (removal and replacement of the base and/or sub-base) will be more economical. Rehabilitation could include the reworking (but not removing) of the top 150 mm of the existing pavement to form a uniform platform for the addition of new pavement layers. Rehabilitation increases the structural capacity of the pavement to a condition that is very near or equal to that of an equivalent new pavement.
- Reconstruction: This is the removal of part (both bound and unbound layers) or all of the existing pavement layers and the construction of a new pavement. Reconstruction is appropriate when the pavement has structurally failed and the subgrade requires strengthening (including subdrainage construction) in order for the new pavement to perform properly. Since reconstruction consists of the

removal of the structure of the existing pavement, it offers the opportunity to correct subgrade or base deficiencies, to slightly adjust the vertical geometry, to add drainage structures, etc. These options are not viable when the pavement is only rehabilitated. Reconstruction increases the structural capacity of the pavement to a level that is required for the medium to long term.

4.7.4 Special Maintenance: As with routine maintenance, special maintenance could be classified as “reactive” road works due to unplanned circumstances. These circumstances could be the result of natural phenomena such as flash floods, or damage caused due to accidents. Special maintenance is divided into the following works types:

- Non-Pavement type: This comprises works undertaken to clear a road that has been cut or blocked. Included under here are traffic accident removal, clearing debris, and repairing washout/subsidence.
- Pavement type: This normally involves the repair of selected pavement areas that fail due to latent defects, thus enabling the rest of the pavement to achieve its anticipated design performance or life.

4.8. Highway Development and Management System (HDM-4)

The Highway Development and Management System (HDM-4) developed by the World Bank is a powerful pavement management software tool capable of performing technical and economic appraisals of road projects, investigating road investment programs, and analyzing road network preservation strategies. Its effectiveness is dependent on the proper calibration of its predictive models to local conditions. The scope of the new HDM-4 tool have been broadened considerably beyond traditional project appraisals, to provide a powerful system for the analysis of road management and investment alternatives. In addition to updating the HDM-III technical relationships for vehicle operating costs, and pavement deterioration for flexible and unsealed pavements, new technical relationships have been introduced to model rigid concrete pavement deterioration, accident costs, traffic congestion, energy consumption and environmental effects.

The HDM-4 incorporates three dedicated applications tools for project level analysis, road work programming under constrained budgets, and for strategic planning of long term network performance and expenditure needs. It is designed to be used as a

decision support tool within a road management system. Standard data import and export facilities are provided for linking HDM-4 to various database management systems. Local adaptation and calibration of HDM-4 models can be achieved by specifying default data sets that represent pavement performance and vehicle resource consumption in the country where the model is being used.

The HDM-4 software applications developed to cater for the following components within the highway management process: Strategic Planning, Work Programming, and Project Preparation. Strategic planning involves the analysis of the road system as a whole, typically requiring the preparation of long term, or strategic, planning estimates of expenditure for road development and preservation under various budgetary and economic scenarios. Work Programming involves the preparation, under budget constraints, of multi-year road work and expenditure programmes in which sections of the network likely to require improvement, are identified and prioritized. Project preparation is the final stage where the economic benefits of road schemes are analyzed prior to implementation.

4.9. Input Data

The input data to HDM-4 is held in four data managers, which are described below:

4.9.1 Road network - Defines the physical characteristics of road sections in a network or sub-network that form the basis of analysis. Sections are lengths of roads over which physical characteristics are reasonably constant.

4.9.2 Vehicle fleet - Defines the characteristics of the vehicle fleet that operate on the road network to be analysed. These include vehicle speeds, operating costs, travel time costs and other vehicle effects.

4.9.3 Road works standards - Defines maintenance and improvement standards, together with their unit costs, which will be applied to the different road sections to be analysed. These refer to the targets or levels of conditions and response that a road administration aims to achieve.

4.9.4 HDM configuration - Defines the default data to be used in the applications, which is to be modified to reflect local environments and circumstances. It provides

facilities to customize the default data set to reflect the conditions encountered in environment under study.

4.10 Technical Models

Technical analysis within the HDM-4 is undertaken using the following four sets of models:

- **Road Deterioration (RD)** - Predicts pavement deterioration for various types of pavements such as bituminous, concrete, and unsealed roads.
- **Works Effects (WE)** - Simulates the effects of road works on pavement condition and determines the corresponding costs.
- **Road User Effects (RUE)** - Determine costs of vehicle operation, and travel time.
- **Social and Environment Effects (SEE)** - Determines the effects of vehicle emissions and noise, and predicts the number of road accidents and amounts of energy consumption.

However, the SEE model does not have any direct relevance to pavement management. Therefore, this model has not been considered in the present study.

4.11 Application Modules

There are three main areas of application of HDM-4, i.e., Project Analysis, Program Analysis, and Strategic Planning [Kerali 2000]. These are described below:

4.11.1 Project analysis - This project level application is concerned with the evaluation of one or more road projects or investment options. Road sections with pre specified maintenance and rehabilitation treatments are analysed over a specified life cycle. Project analysis can be used to estimate the economic or engineering viability of road investment projects by performing life cycle analysis of pavement performance, maintenance and/or improvement effects together with estimates of road user costs.

4.11.2 Program analysis - This network level application can be used to prepare rolling work programmes in which candidate road sections are identified and assigned maintenance or improvement options. HDM-4 calculates the NPV and expenditure requirements of each option. The main output from Program analysis is a schedule of

optimum pavement maintenance and rehabilitation projects, which can be carried out within specified budget constraints.

4.11.3 Strategy analysis - This network level application is used for strategic planning to prepare medium to long term planning estimates of funding needs for road network development and maintenance. The road network is characterized by lengths of road in different categories defined by parameters such as road class, surface type, pavement condition, traffic loading, etc. The main outputs are estimates of medium to long-term budget requirements for the entire road system together with forecasts of pavement performance and road user effects.

The main difference between strategy analysis and program analysis is the way in which the road links and sections are physically identified. Program analysis deals with individual links and sections that are unique physical units, identifiable from the highway network throughout the analysis. In strategy analysis, the highway network essentially loses its individual link and section characteristics by grouping all road segments with similar characteristics into the highway network matrix categories.

4.12 Interfaces to External Systems

The HDM-4 system design is modular in structure to enable highway agencies to implement the HDM-4 application modules independently within their pavement management systems. The system is designed to interface with external road network information systems through its databases. Data transformation rules may need to be implemented for converting the data held in the external database to the format used by HDM-4. Data required by HDM-4, such as pavement deterioration calibration factors should be inserted as pre-defined default values according to the type of pavement, road class and other defined factors. Other data required for the HDM-4 analyses can be directly stored within the HDM-4 internal database. These include data on vehicle fleet characteristics, road maintenance and improvement standards, unit costs and economic analysis parameters such as discount rate and analysis period etc [Kerali 2000].

4.13 Life-cycle Analysis

The underlying operation of HDM-4 is similar for each of project, program or strategy analysis. In each case, HDM-4 simulates total life cycle conditions and costs for an analysis period under a specified scenario of circumstances. The model stimulates, for each pavement section, year-by-year, the pavement condition and resources used for maintenance under each strategy, as well as the vehicle speeds and physical resources consumed by vehicle operation. Interacting sets of costs related to those incurred by the road administration and those incurred by the road user, are added together over time in discounted present values. Economic benefits are then determined by comparing the total cost streams for various maintenance alternatives with a base case, usually representing minimal routine maintenance [Odoki and Kerali 2000].

LIFE CYCLE COST ANALYSIS (LCCA) OF ROAD NETWORK

5.1. Life Cycle Cost Analysis of Noida Urban City Network

This study demonstrates the development of a pavement maintenance management programme for 10 no. selected urban city network of Noida, and budget forecasting for an analysis period of 15 years. The main objective of this study is to prepare an unconstrained works programme, to determine the required funding levels for defined network performance standards, and to prepare an optimized and prioritized works programme for reduced budget allocation.

5.1.1 Input data - The selection of databases and other input data for this study is shown in Figure 5.1. All 10-pavement sections included in the 'Noida City Network' database have been selected for this study, as shown in Figure 5.2. All 17 classes of vehicles included in the 'Noida Vehicle Fleet' database have been selected for this study as shown in Figure 5.3.

The screenshot shows the 'Programme: Noida Programme' window with the following input data:

- Study Description:** Noida City Road Network
- Type of analysis:** Life-cycle (selected), Multi-Year Forward Programme
- Start year:** 2013
- Analysis period:** 15 years
- Road Network:** Noida Road Network
- Vehicle Fleet:** Noida Vehicle Fleet
- Currencies:**
 - Fleet: Rupees × 1 = output currency
 - Works: Rupees × 1 = output currency
 - Output: Rupees
 - Discount rate: 12

Navigation buttons on the left include: Define Programme Details, Specify Standards Assignments, Generate Programme, Perform Budget Optimisation, Generate Reports, Save, and Close. A status bar at the bottom indicates 'For Help, press F1'.

Figure 5.1 Input Data for Life-Cycle Cost Analysis

5.1.2. Defining alternative maintenance strategies – The life cycle cost analysis requires a comparison to be made between a Base alternative and one or more alternatives. For this study, eight alternatives have been defined for each pavement section, namely; a Base Alternative, ST 20mm PC, ST 25mm SDBC, ST 40mm BC, Overlay 20mm PC + 50mm BC, Overlay 20mm PC + 50mm DBM, Overlay 25mm SDBC + 75mm DBM and Reconstruction . The Base Alternative comprise of routine pavement maintenance activities in terms of Drainage cleaning, edge repair, pothole repair, crack seal and shoulder make-up. The other alternative includes surface treatments, overlays and reconstruction work activities. The maintenance works included in the Base Alternative are the same for all pavement sections. But in case of other alternatives, the applicable maintenance works for each pavement section will vary depending upon the Maintenance Serviceability Level. The selected maintenance strategies and the corresponding intervention criteria are given in Table 5.1 and are shown in Figure 5.4 to 5.6.

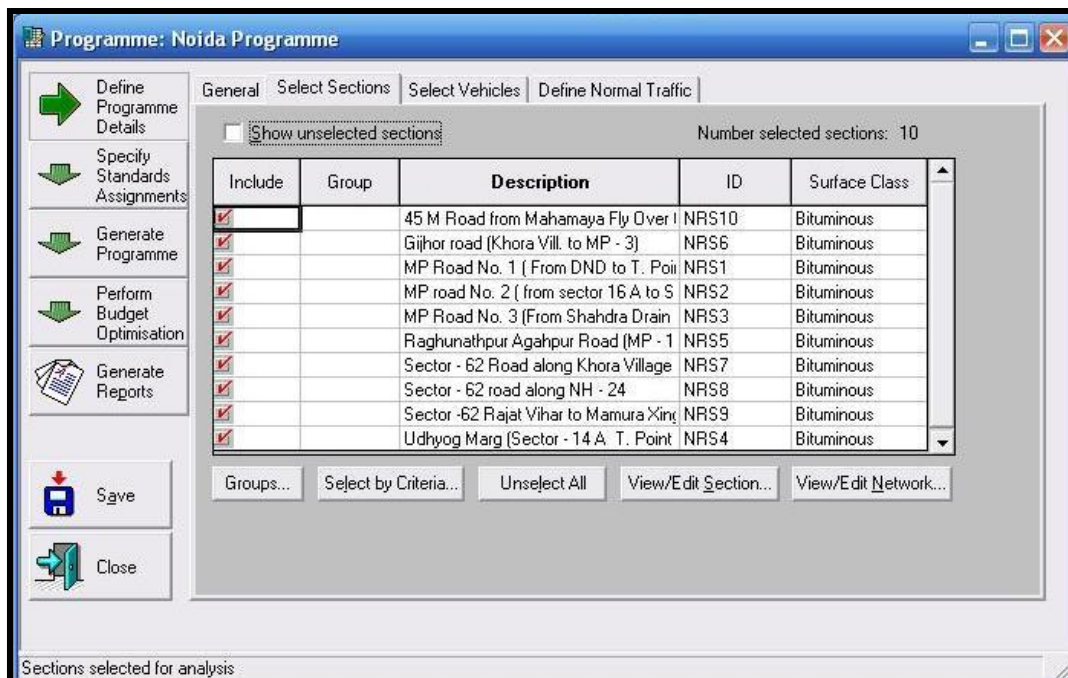


Figure 5.2 Selected Pavement Sections of the Noida Road Network

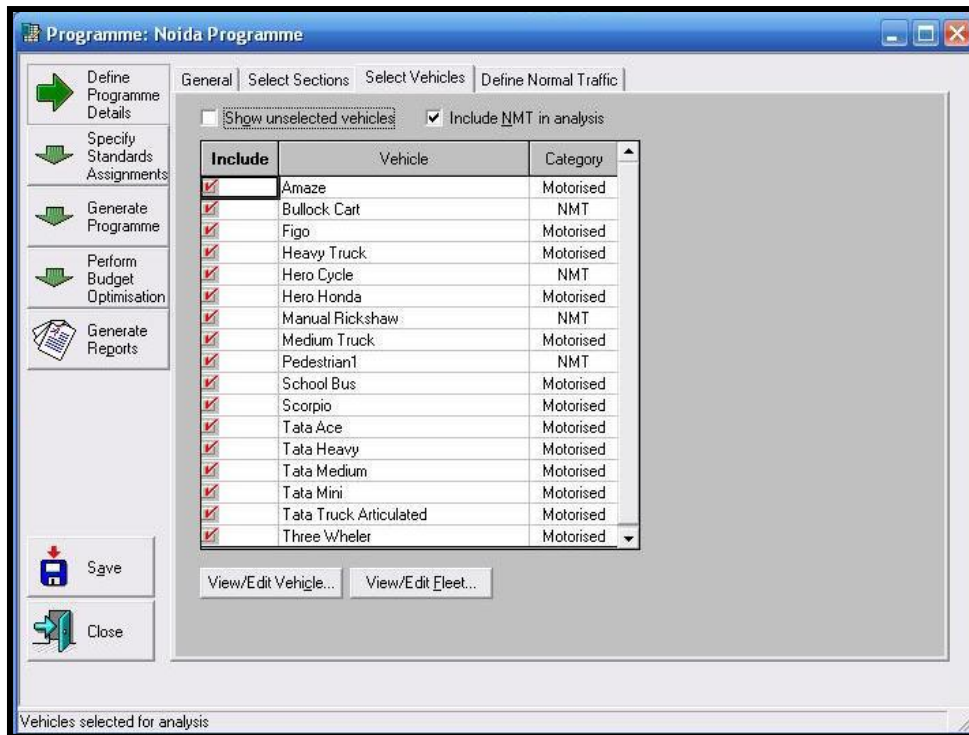


Figure 5.3 Selected Vehicles of the Noida Vehicle Fleet

Table 5.1 Details of Selected maintenance Strategies for Program Analysis

Alternative Strategies	Works Standard	Maintenance Works	Intervention Criteria
Base Alternative	Routine Maintenance	Drainage cleaning, edge repair, pothole repair, crack seal and shoulder make-up	Scheduled Annually
Surface treatment 20mm PC	Periodic Maintenance	Overlay 20 mm Premix Carpet	Roughness ≥ 2.5 <3 IRI
Surface treatment 25mm SDBC	Periodic Maintenance	Overlay 25 mm SDBC	Roughness $\geq 3 < 4$ IRI
Surface treatment 40mm BC	Periodic Maintenance	Overlay 40 mm BC	Roughness $\geq 4 < 4.5$ IRI

Overlay 20mm PC + 50 mm BM	Strengthening	Overlay 20 mm Premix Carpet + Overlay 50 mm BC	Roughness $\geq 4.5 < 5.0$ IRI
Overlay 25mm BC + 50 mm DBM	Strengthening	Overlay 25 mm BC + Overlay 50 mm DBM	Roughness $\geq 5 < 5.5$ IRI
Overlay 25mm SDBC + 75 mm DBM	Strengthening	Overlay 25 mm SDBC + Overlay 75 mm DBM	Roughness $\geq 5.5 < 6.5$ IRI
Reconstruction	Reconstruction	Reconstruction	Roughness ≥ 6.5 IRI

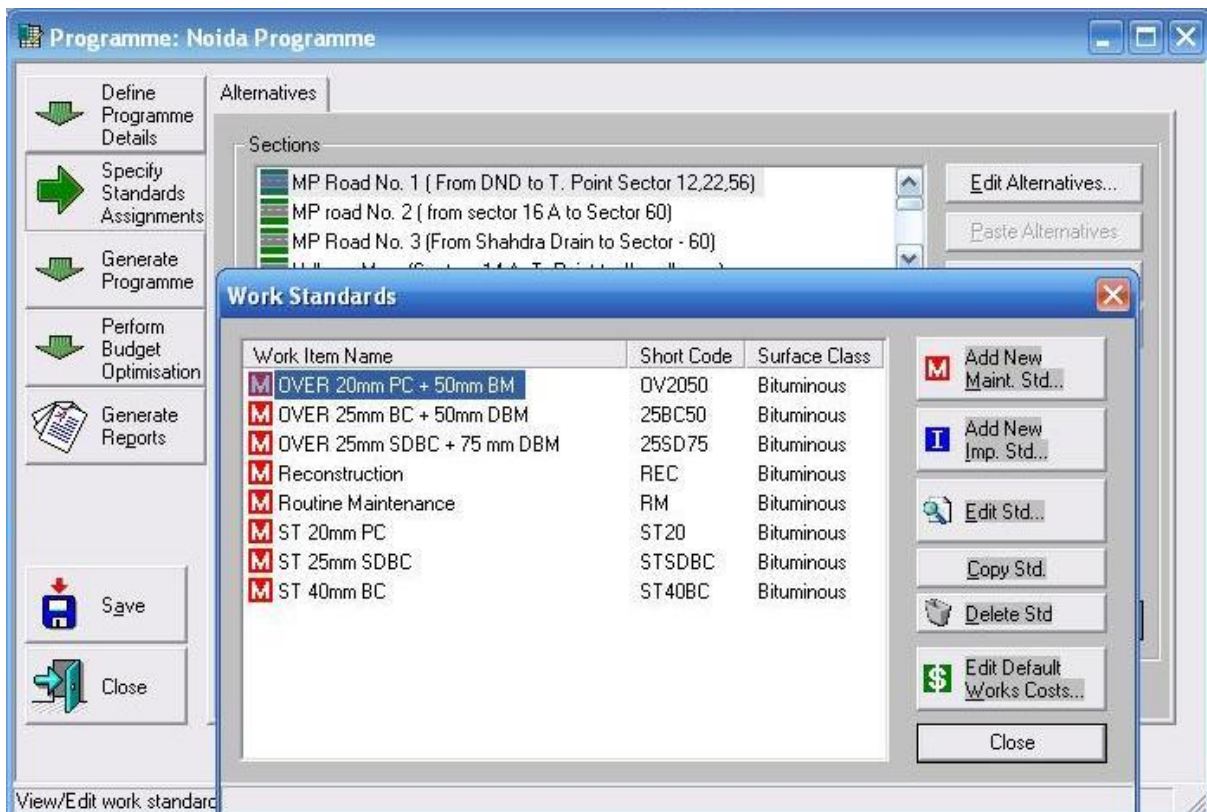


Figure 5.4 Selected Work Standards for the Noida City Network

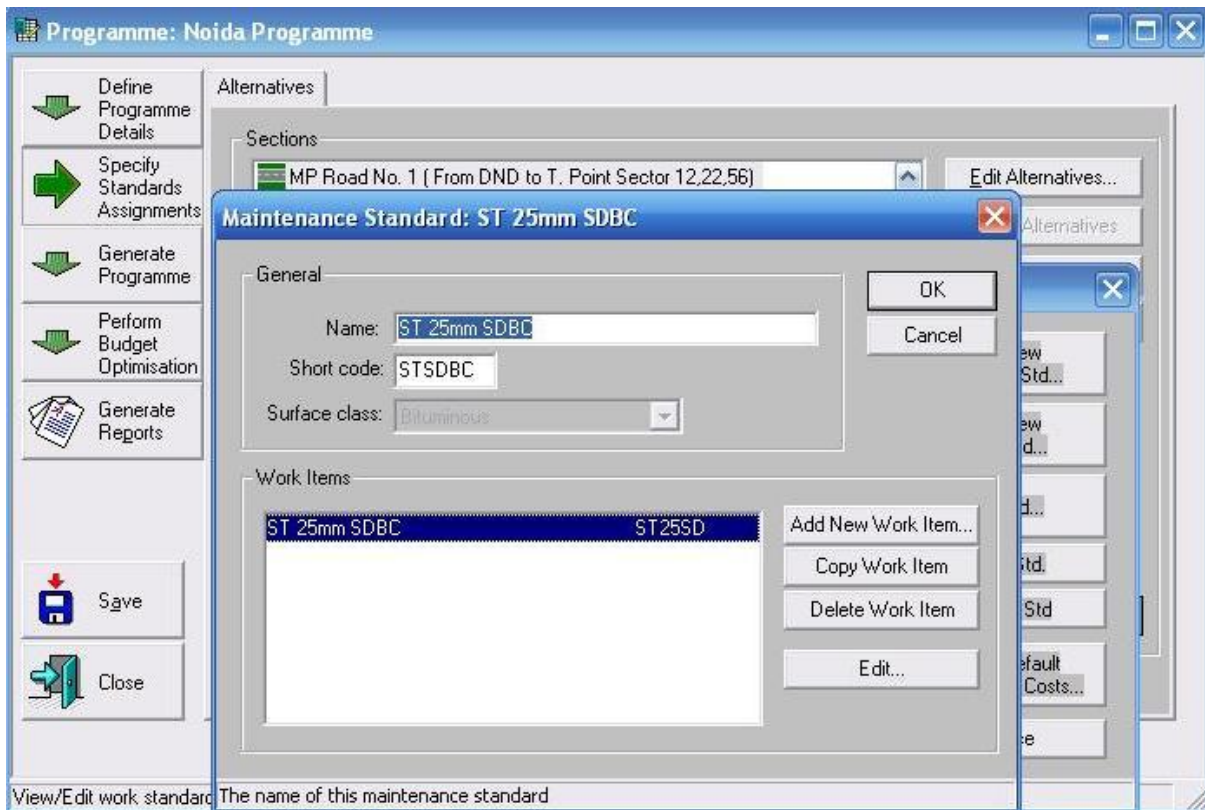


Figure 5.5 Maintenance Standards for the Noida City Network

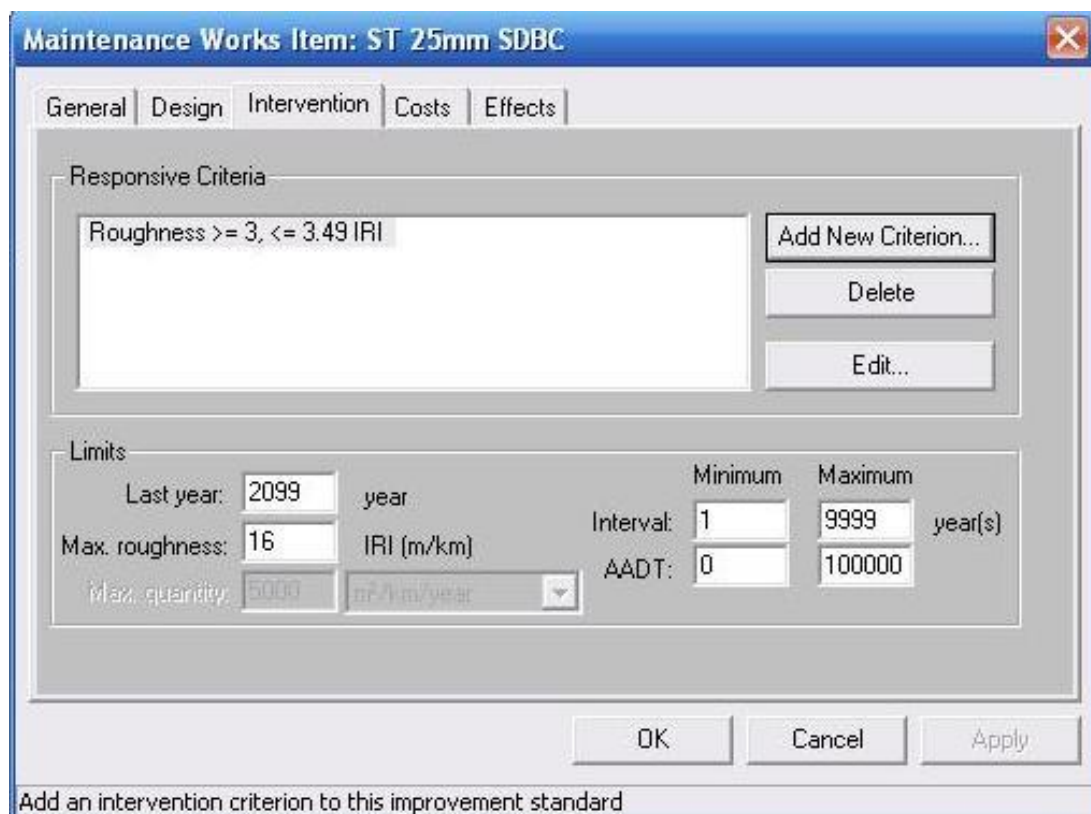


Figure 5.6 Intervention for Maintenance Work Items for the Noida City Network

5.1.3 Life-cycle cost analysis - After selection of the alternative maintenance strategies, the Program Analysis application module of HDM-4 has been used to compare the total life-cycle costs, including the highway agency costs and road user costs, predicted under the Base Alternative of scheduled routine maintenance, against those predicted for the condition responsive maintenance alternative. The program application is run, as shown in Figure 5.7, for life cycle cost analysis of the whole Noida city network comprising of 10 pavement sections.

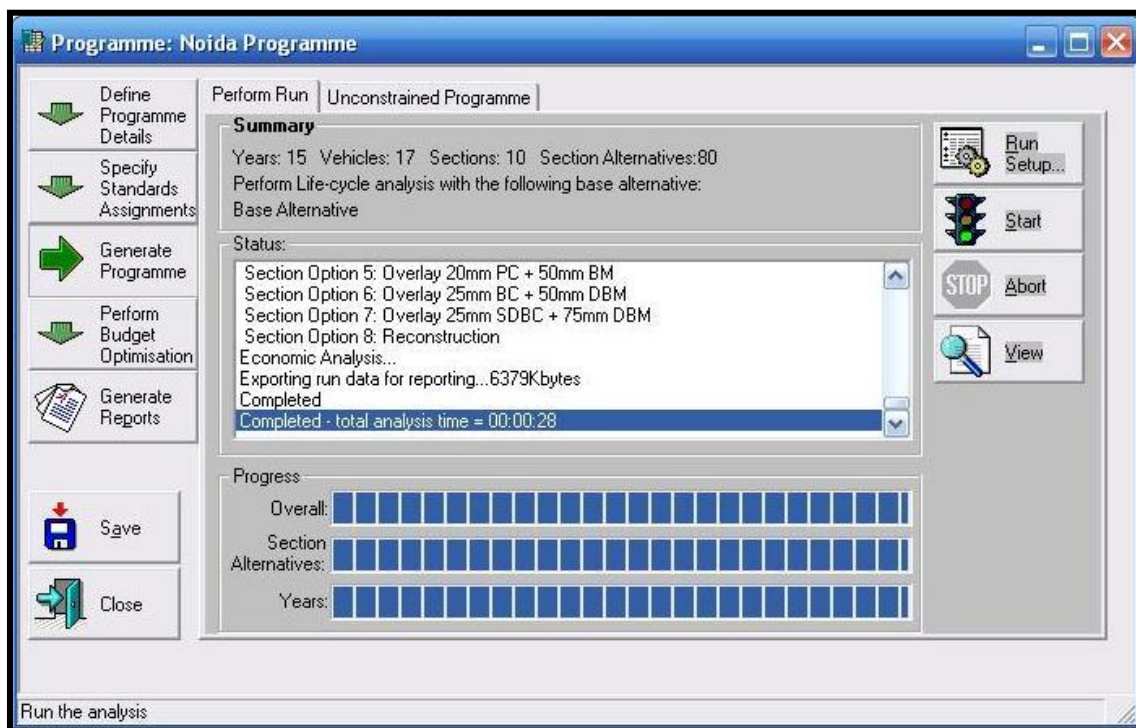


Figure 5.7 Life-Cycle Cost Analysis for Program Analysis

5.1.4 Summary of Life-cycle cost analysis – As a result of this analysis, the alternatives with the highest NPV are assigned for each pavement section. A summary of the life-cycle cost analysis, showing the increase in road agency costs and decrease in road user costs, as a result of selecting the maintenance alternative in comparison to the base alternative, is given in Table 5.2. All these costs have been discounted to the base year 2013, with a discount rate of 12%.

5.1.5 Unconstrained works programme – The life-cycle cost analysis of pavement sections results in a tentative unconstrained works programme determined by the specified maintenance work standards. The unconstrained works programme list, as

shown in Table 5.2, gives details of the optimum maintenance work activities for the candidate pavement sections, year of their application, corresponding financial costs involved, and the cumulative budget requirements. The total agency cost required for maintenance management of the whole highway network for the analysis period of 10 years comes out to be 1014.20 million Indian Rupees. If sufficient budget is available, this unconstrained works programme can be taken up for final application on the highway network.

Table 5.2 Summary of Life Cycle Cost Analysis

Pavement Section	Traffic (AADT)	Year	Maintenance Work	B/C Ratio	Financial Cost*	Cumulative Cost*
45 M Road from Mahamaya Fly Over to Sector - 97, 98	8953	2013	ST 40 mm BC	4.89	66.00	66.00
	14140	2022	ST 40 mm BC	4.89	66.00	132.00
Gijhor road (Khora Vill. to MP - 3)	10492	2013	ST 40 mm BC	6.27	54.00	186.00
	16571	2022	ST 40 mm BC	6.27	54.00	240.00
MP Road No. 1 (From DND to T. Point Sector 12,22,56)	8124	2015	ST 40 mm BC	2.38	49.00	289.00
	14975	2027	ST 40 mm BC	2.38	49.00	338.00
MP road No. 2 (from sector 16 A to Sector 60)	9909	2013	ST 40 mm BC	4.55	120.00	458.00
	16468	2023	ST 40 mm BC	4.55	120.00	578.00
MP Road No. 3 (From Shahdra Drain to Sector - 60)	11247	2020	Reconstruction	7.15	90.00	668.00
Raghunathpur Agahpur	11087	2013	ST 40 mm BC	5.76	30.80	698.80

Road (MP - 1 to MP - 3 Road)	21482	2026	ST 40 mm BC	5.76	30.80	729.60
Sector - 62 Road along Khora Village	10430	2015	ST 40 mm BC	3.97	35.20	764.80
Sector - 62 road along NH - 24	8983	2013	ST 40 mm BC	3.81	34.00	798.80
	15713	2024	ST 40 mm BC	3.81	34.00	832.80
Sector -62 Rajat Vihar to Mamura Xing	10441	2013	ST 40 mm BC	9.19	36.30	869.10
	16489	2022	ST 40 mm BC	9.19	36.30	905.40
Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	9324	2013	ST 40 mm BC	3.22	54.40	959.80
	17165	2025	ST 40 mm BC	3.22	54.40	1014.20

* All costs are expressed in million Indian Rupees

5.1.6 Budget requirements - the year-wise budget requirements for the Noida City network under the Maintenance Alternatives are shown in Figure 5.8 and the Section wise budget requirements for the Noida City network under the Maintenance Alternatives are shown in Figure 5.9. It is quite clear from this figure that more than 39% (Rs. 395.50 million) of the total budget requirements need to be met with in the very first year (2013) of the analysis period itself, as majority of the pavement sections (7 sections) become candidate sections for maintenance works to be undertaken in this year itself. The remaining two pavement sections will become candidates in the third year (2015) and one pavement in the eighth year (2020) of the analysis period. Thereafter, there will be no immediate budget requirements for carrying out maintenance works. However, the need for maintenance works on most of the sections appears again in the following years, i.e. 2022 and 2023, as indicated by almost 27% (Rs. 276.30 million) of the total fund requirements during these two years. Some leftover pavement sections become candidates for maintenance works in the next year 2024. Thereafter, from year 2025 onwards, the yearly fund requirements show a variable trend till the end of the analysis period, depending upon the number of pavement sections becoming candidate sections for maintenance in a particular year.

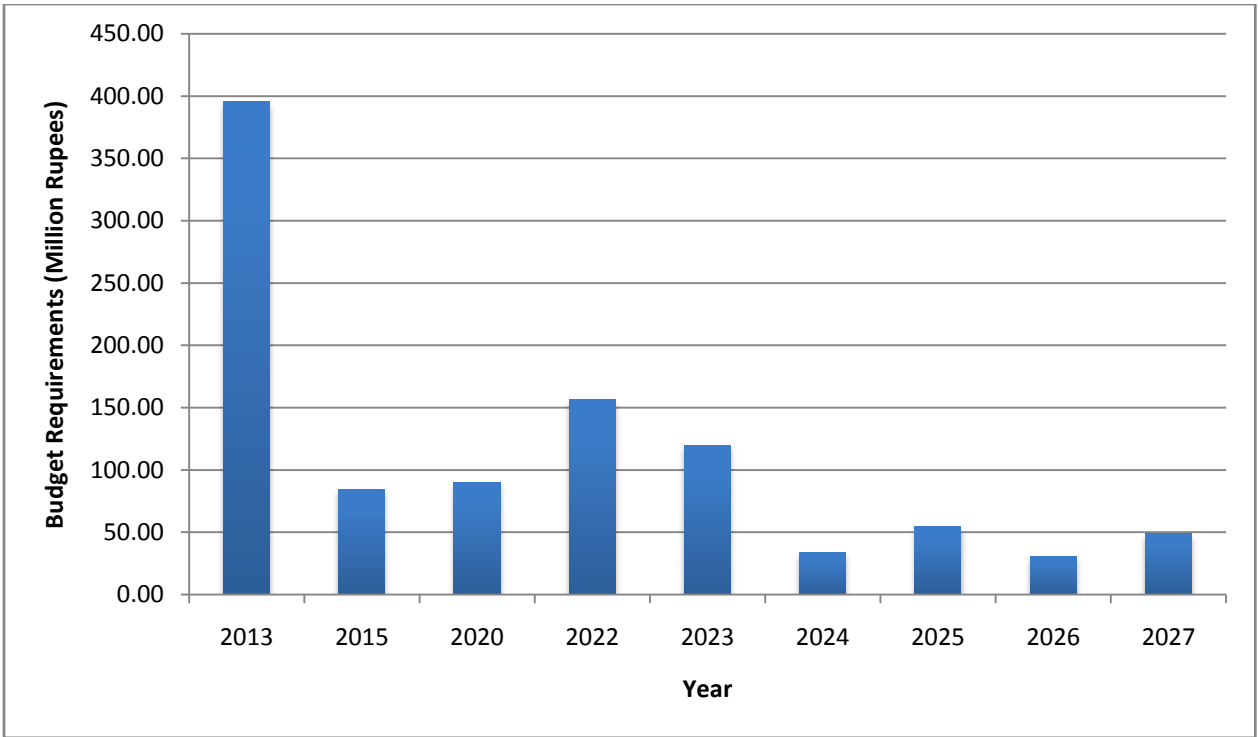


Figure 5.8 Year-wise Budget Requirements for the Noida City Network

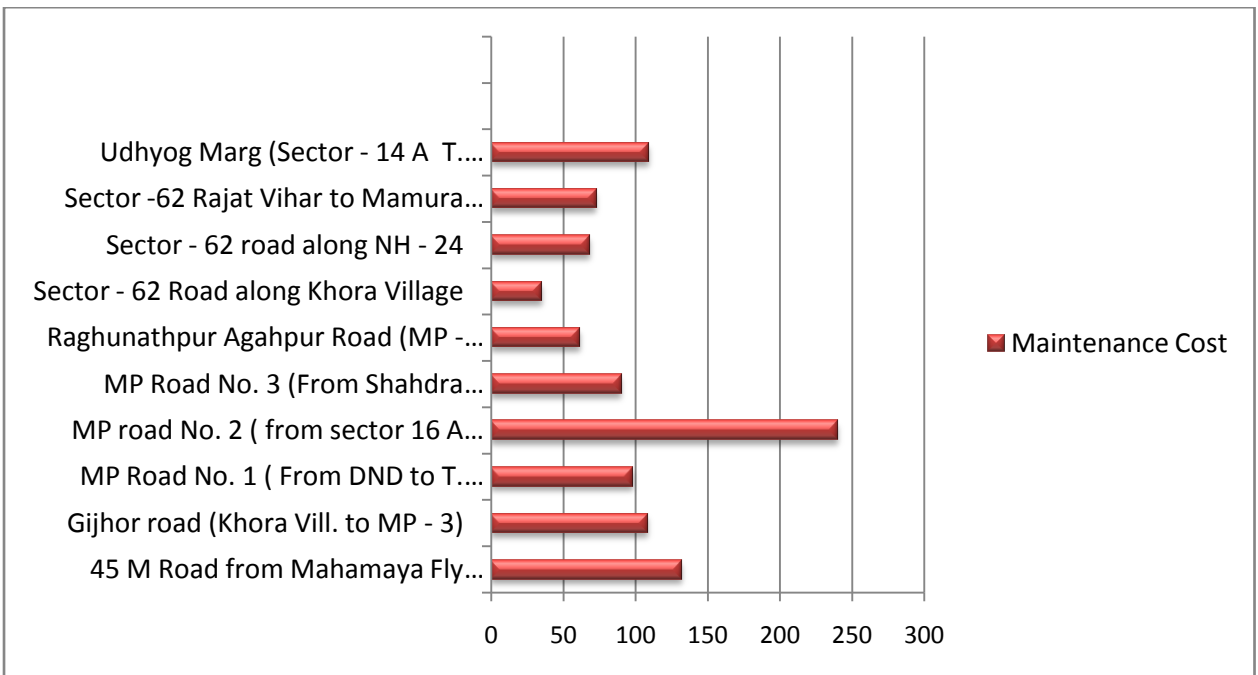


Figure 5.9 Graphical Presentation of Section-wise Budget Requirements for the Noida City Network

5.1.7 Condition of the Noida city network

As a result of the above analysis, the predicted average roughness progression of the city network as a whole, under the Base Alternative and the Maintenance Alternative is shown in Figure 5.10 and the average roughness progression by each section is shown in Figure 5.11 to 5.20. The average roughness keep on increasing in case of Base Alternative because the routine maintenance operations do not help in reducing roughness, though it retards the rate of progression of roughness to some extent. However, in case of maintenance alternative, the average roughness value for the city road network decreases because of timely application of maintenance works.

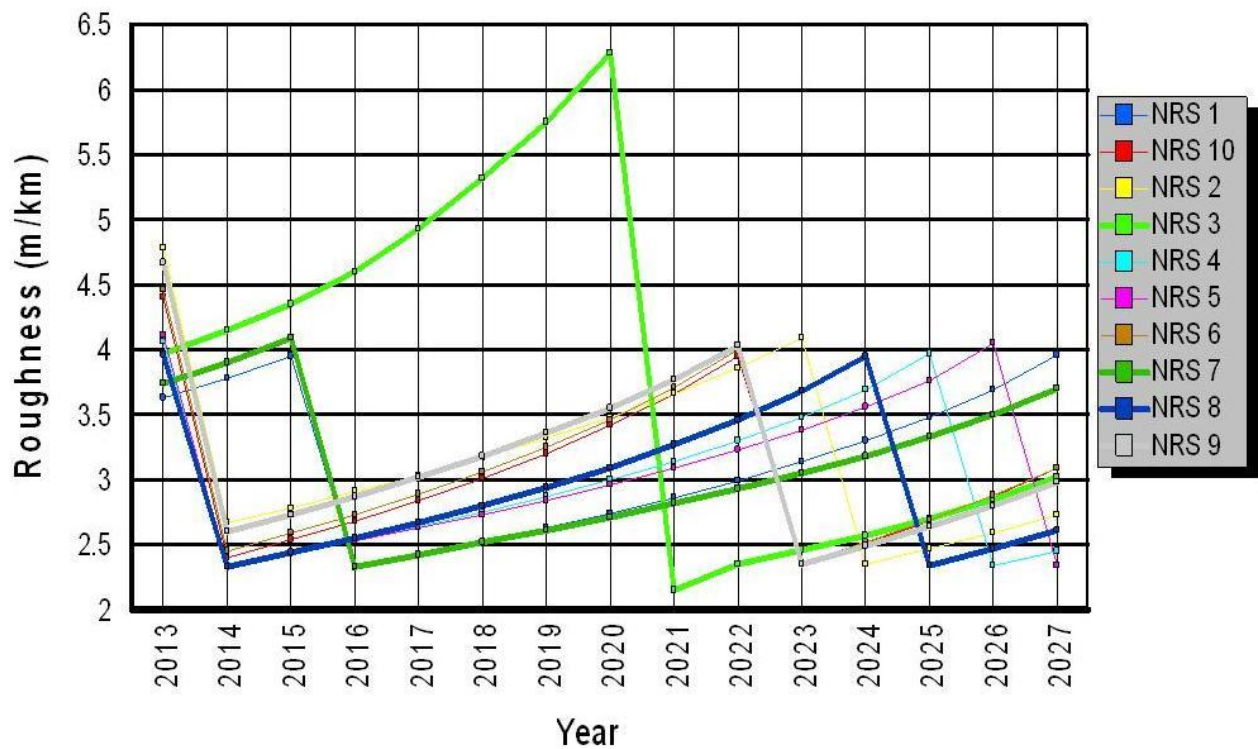


Figure 5.10 Average Roughness Value for the Noida City Network

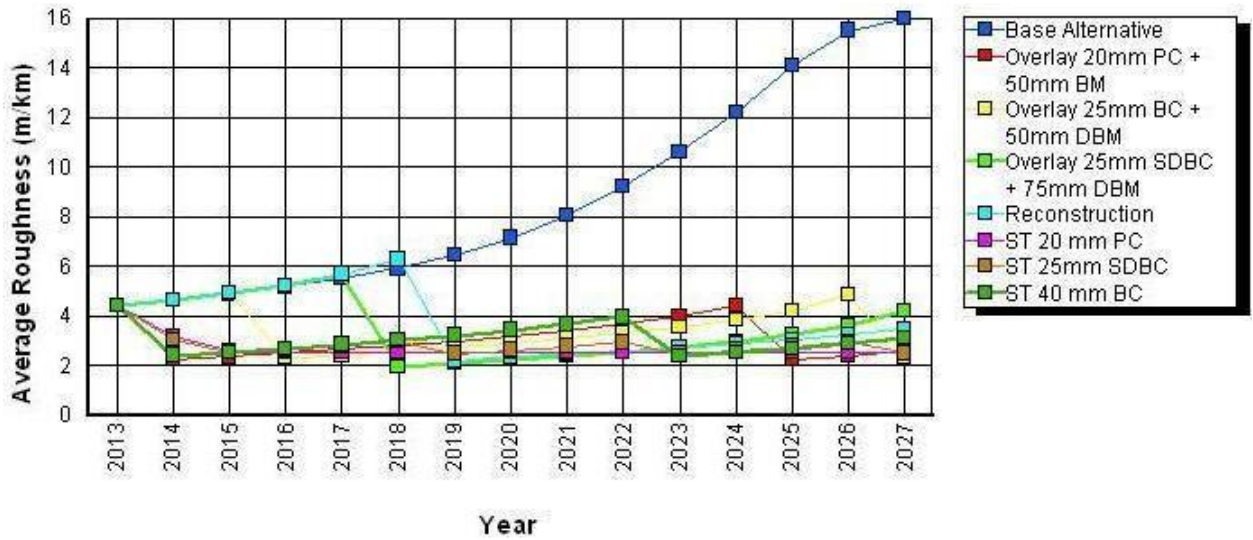


Figure 5.11 Average Roughness Value for the 45 M Road from Mahamaya Fly over to Sector - 97, 98

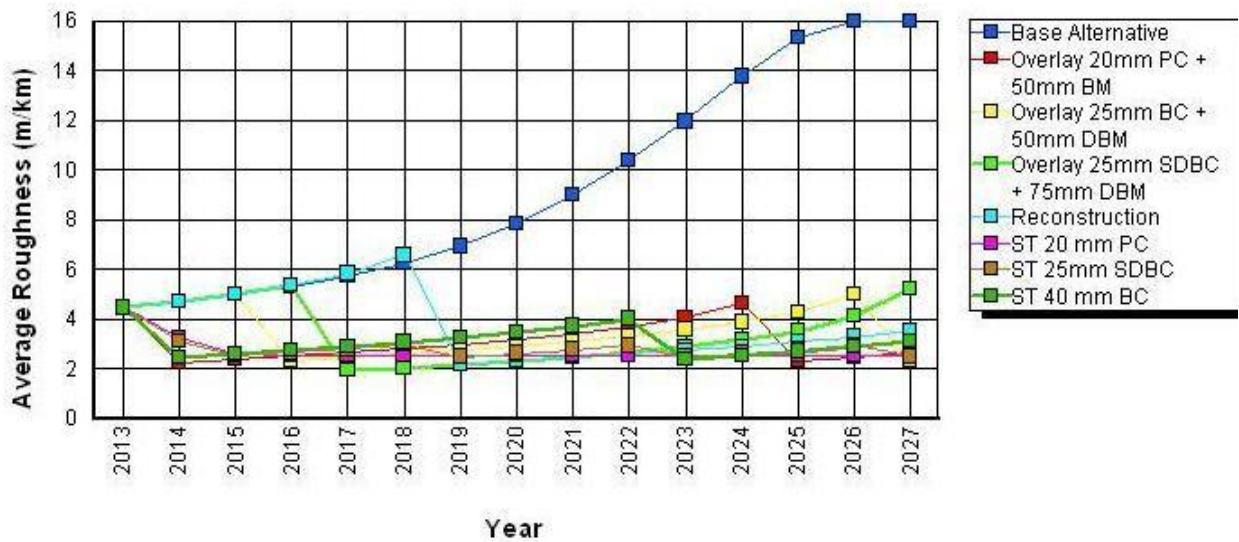


Figure 5.12 Average Roughness Value for the 45 M Road from Gijhor road (Khora Vill. to MP - 3)

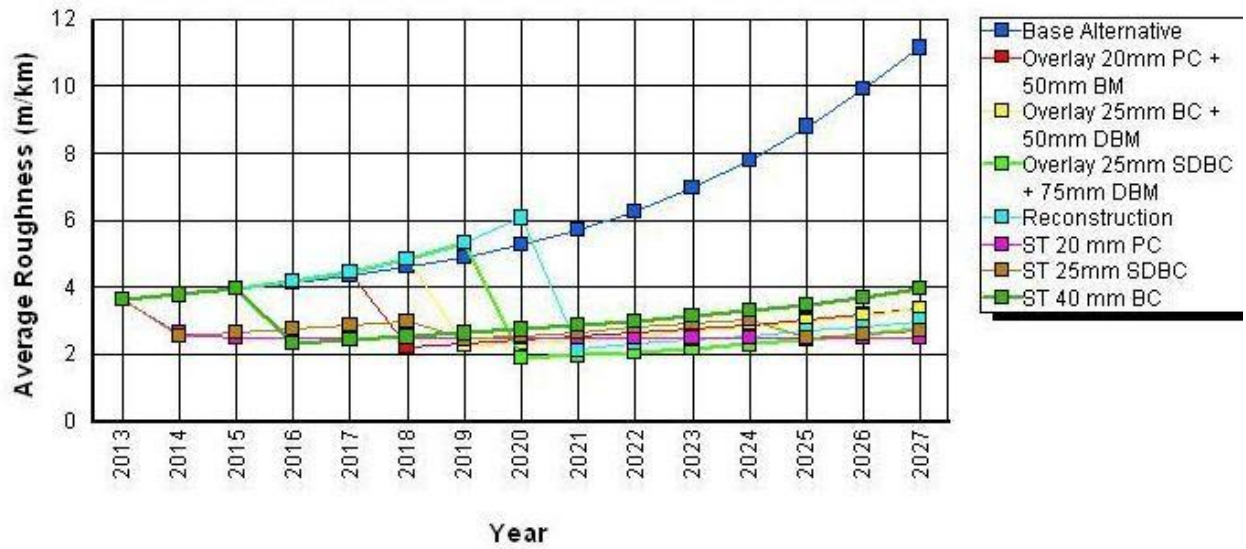


Figure 5.13 Average Roughness Value for the 45 M Road from MP Road No. 1 (From DND to T. Point Sector 12, 22, 56)

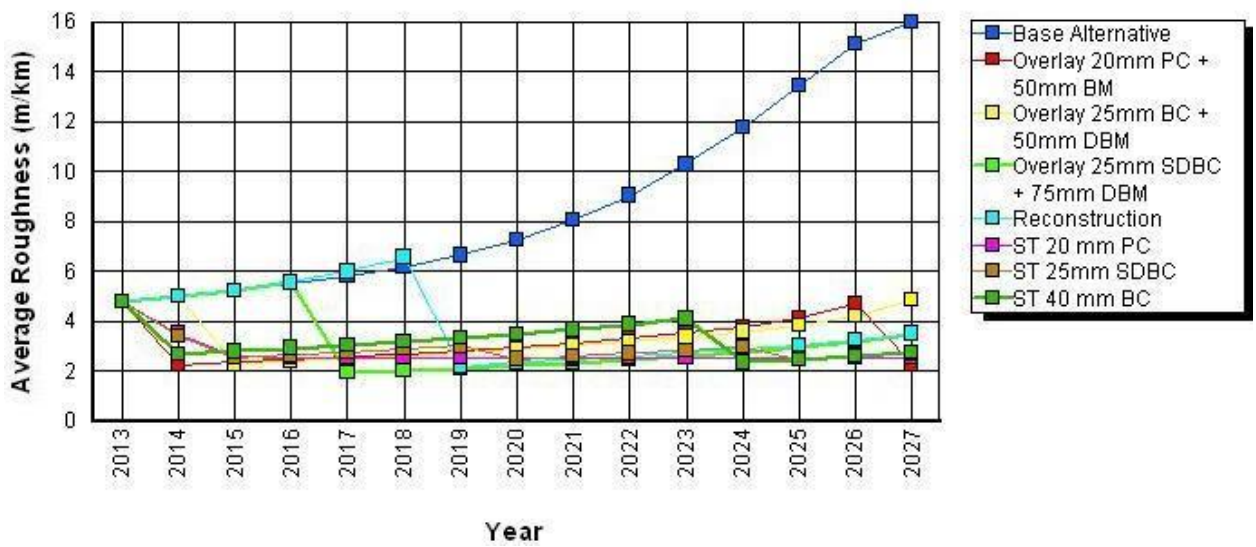


Figure 5.14 Average Roughness Value for the 45 M Road from MP road No. 2 (from sector 16 A to Sector 60)

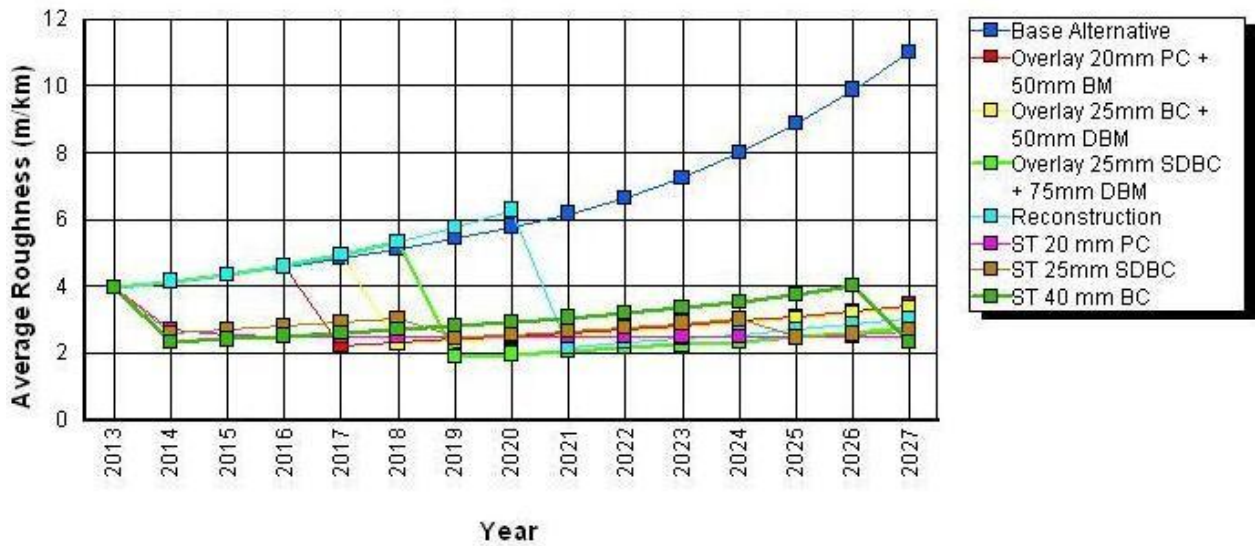


Figure 5.15 Average Roughness Value for the 45 M Road from MP Road No. 3 (From Shahdra Drain to Sector - 60)

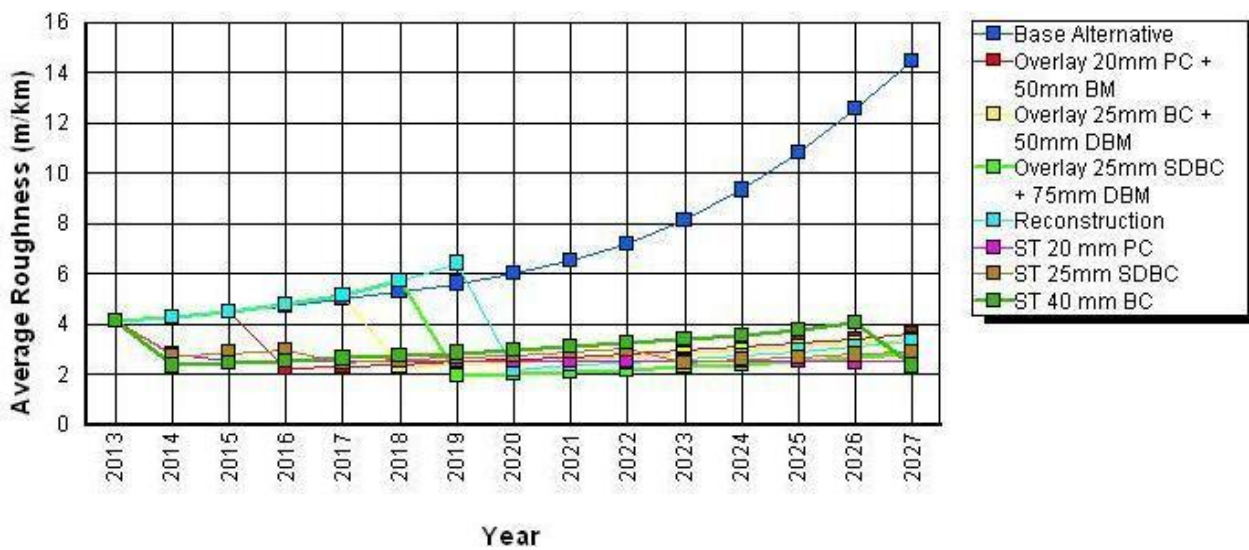


Figure 5.16 Average Roughness Value for the 45 M Road from Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)

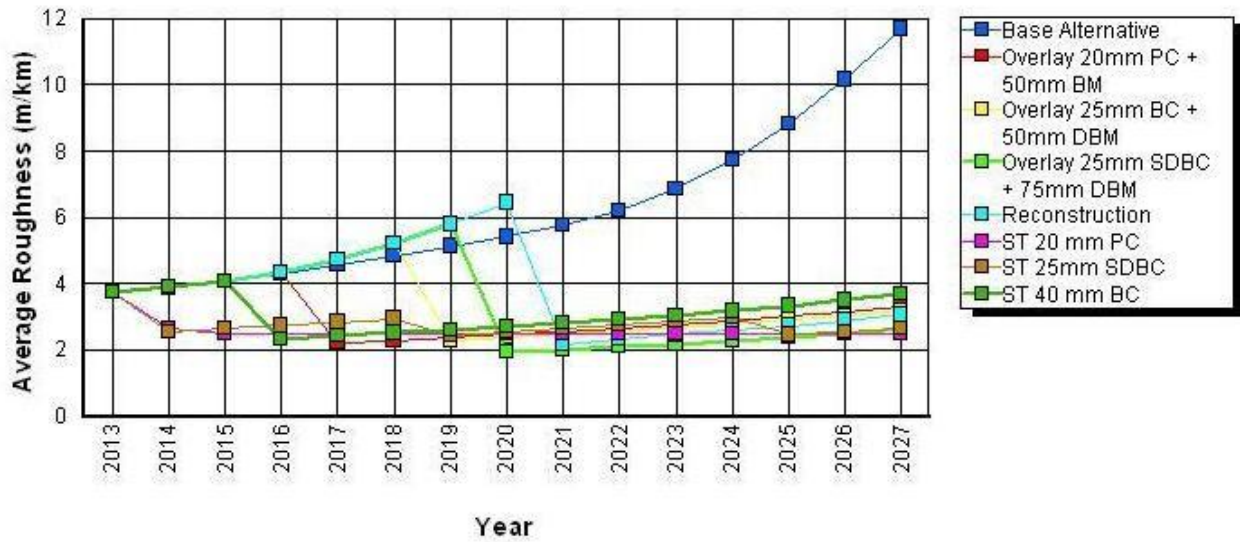


Figure 5.17 Average Roughness Value for the 45 M Road from Sector - 62 Road along Khora Village

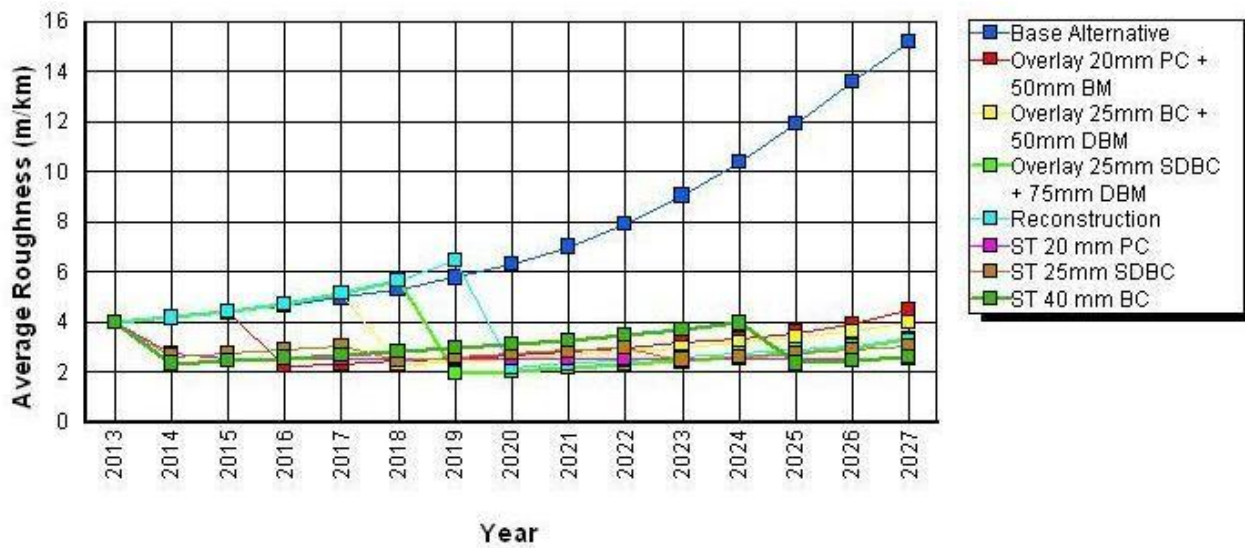


Figure 5.18 Average Roughness Value for the 45 M Road from Sector - 62 road along NH - 24

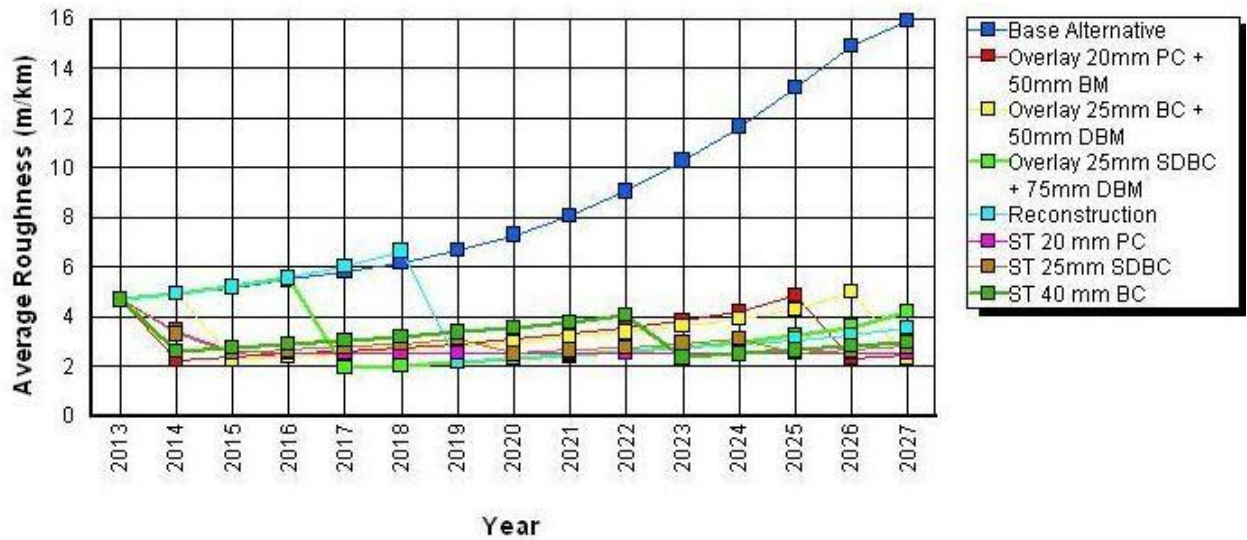


Figure 5.19 Average Roughness Value for the 45 M Road from Sector -62 Rajat Vihar to Mamura Xing

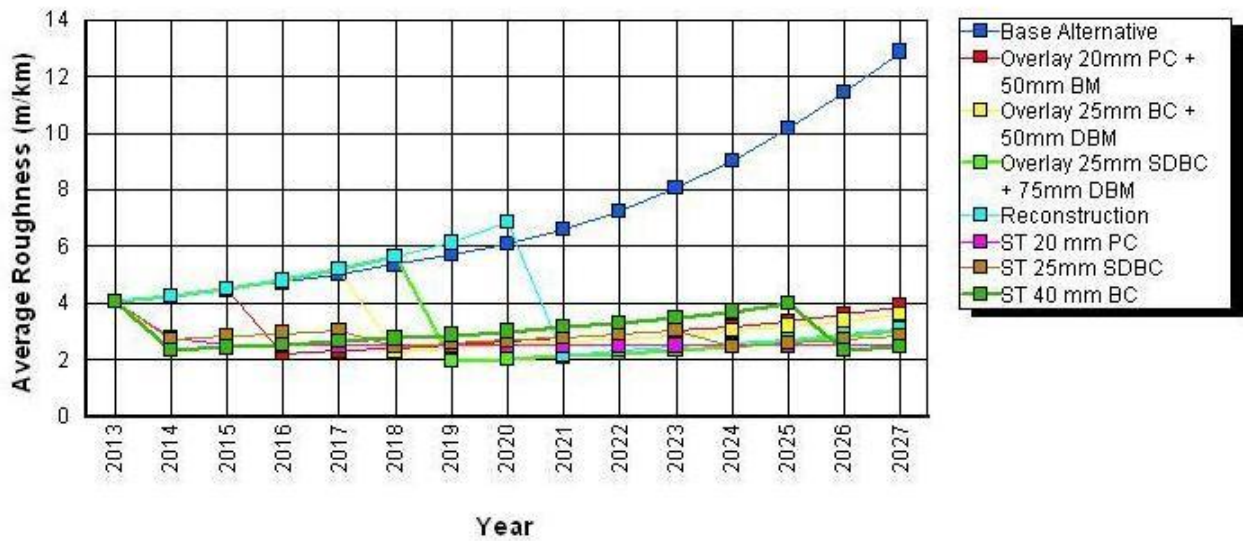


Figure 5.20 Average Roughness Value for the 45 M Road from Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)

5.1.8 Budget optimisation - In the unconstrained works programme, if the budget required for each period is below the available budget, no further economic analysis is necessary, and the unconstrained works programme can be adopted as such. However, if the budget needs are higher than the available budget, the following two options may be considered:

- (i) Revise maintenance standards and run the life-cycle analysis again
- (ii) Execute budget optimisation

Since the maintenance standards have already been fixed, keeping in view the minimum requirements of the candidate pavement sections, very little scope exists for their revision. Hence, under most of the circumstances, the second option of budget optimisation would usually be selected. The budget optimisation provides a facility to select road sections that can be included within a specified budget in order to maximize the economic benefits. After performing the budget optimisation, a revised work programme is worked out. This works programme has a total cost requirement that is within the specified budget.

5.1.9 Optimized works programme - In case, sufficient funds are not available to carry out all the maintenance activities, as obtained for the unconstrained works programme, the works programme need to be optimized depending upon the available budget. The budget optimisation process is performed with Rs. 800 million budget availability, as against the requirement of Rs. 1014.20 million, over the analysis period of 15 years. The optimisation process is set up by specifying the minimum incremental value for NPV and the budget optimisation is performed using the 'Incremental Analysis Method', as shown in Figure 5.21 and 5.22. This process results in an optimized works programme list, as given in Table 5.3. This optimized works programme has total budget requirements of Rs. 790.20 million, which is almost equal to the available budget of Rs. 800 million.

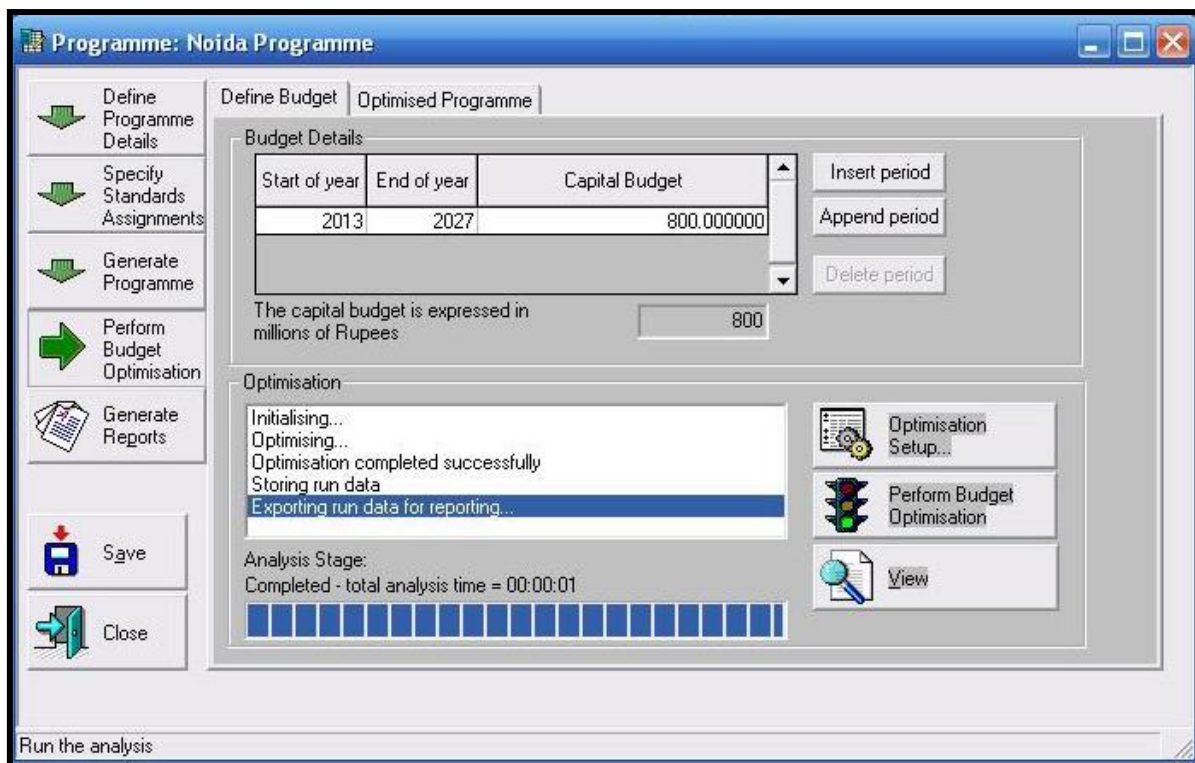


Figure 5.21 Budget Optimisation Process for Program Analysis

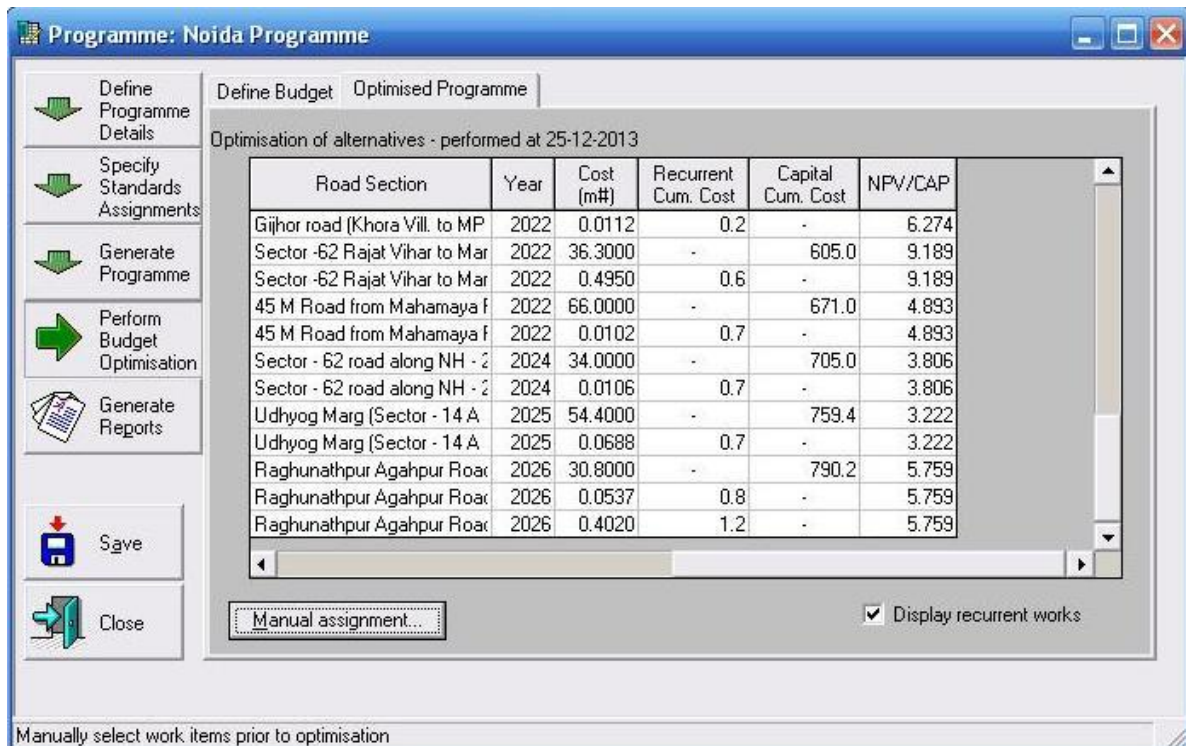


Figure 5.22 Optimisation of alternatives for Program Analysis

Table 5.3 Section-wise Optimized Works Programme List

Pavement Section	Traffic (AADT)	Year	Maintenance Work	B/C Ratio	Financial Cost*	Cumulative Cost*
45 M Road from Mahamaya Fly Over to Sector - 97, 98	8953	2013	ST 40 mm BC	4.89	66.00	66.00
	14140	2022	ST 40 mm BC	4.89	66.00	132.00
Gijhor road (Khora Vill. to MP - 3)	10492	2013	ST 40 mm BC	6.27	54.00	186.00
	16571	2022	ST 40 mm BC	6.27	54.00	240.00
MP Road No. 1 (From DND to T. Point Sector 12,22,56)	10472	2020	Reconstruction	6.31	62.00	282.00
MP road No. 2 (from sector 16 A to Sector 60)	12765	2018	Reconstruction	18.82	142.00	354.00
MP Road No. 3 (From Shahdra Drain to Sector - 60)	11247	2020	Reconstruction	7.15	90.00	444.00
Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	11087	2013	ST 40 mm BC	5.76	30.80	474.80
	21482	2026	ST 40 mm BC	5.76	30.80	505.60
Sector - 62 Road along Khora Village	10430	2015	ST 40 mm BC	3.97	35.20	540.80
Sector - 62 road along NH - 24	8983	2013	ST 40 mm BC	3.81	34.00	574.80
	15713	2024	ST 40 mm BC	3.81	34.00	608.80
Sector -62 Rajat Vihar to Mamura Xing	10441	2013	ST 40 mm BC	9.19	36.30	645.10
	16489	2022	ST 40 mm BC	9.19	36.30	681.40
Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	9324	2013	ST 40 mm BC	3.22	54.40	735.80
	17165	2025	ST 40 mm BC	3.22	54.40	790.20

* Cost is expressed in million Indian Rupees

5.1.10 Road Work Summary

The programme analysis of the selected urban city network has been carried out, the following is the road work summary (By Year) for the given road network. The different alternatives are represented annually in the Table 5.5.

Table 5.4 Road work summary (By Year) for the Noida City network

Base Alternative			Financial	
Year	Section	Works Description	Cost	Work Quantity
2013	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	2,251	5.63 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	1,592	3.98 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	20,655	41.31 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	922	2.31 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km

	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	411,418	822.84 sq. m
		Pothole Repair	1,091	2.73 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
Total Annual Cost:			2,098,430	
2014	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	40,121	80.24 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	2,608	6.52 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	34,101	68.20 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	647	1.62 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	718,487	1,436.97 sq. m

	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	1,293	3.23 sq. m
Total Annual Cost:			2,457,757	
2015	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	26,082	52.16 sq. m
		Pothole Repair	2,956	7.39 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	4,728	11.82 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	4,650	11.63 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	2,916	7.29 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	37,830	75.66 sq. m
		Pothole Repair	2,650	6.63 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	3,099	7.75 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	2,014	5.04 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	1,886	4.71 sq. m

	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	797,488	1,594.98 sq. m
		Pothole Repair	3,487	8.72 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	3,237	8.09 sq. m
Total Annual Cost:			2,553,526	
2016	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	28,888	57.78 sq. m
		Pothole Repair	4,512	11.28 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	10,157	25.39 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	8,784	21.96 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	4,202	10.50 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	42,000	84.00 sq. m
		Pothole Repair	4,103	10.26 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	4,569	11.42 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km

		Pothole Repair	3,804	9.51 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	3,382	8.46 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	886,613	1,773.23 sq. m
		Pothole Repair	6,026	15.07 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	6,448	16.12 sq. m
Total Annual Cost:			2,673,987	
2017	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	32,011	64.02 sq. m
		Pothole Repair	5,591	13.98 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	11,532	28.83 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	8,266	20.67 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	3,693	9.23 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	46,679	93.36 sq. m
		Pothole Repair	4,525	11.31 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km

		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	4,528	11.32 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	3,661	9.15 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	3,165	7.91 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	987,883	1,975.77 sq. m
		Pothole Repair	5,658	14.15 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	7,646	19.11 sq. m
Total Annual Cost:			2,785,337	
2018	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	35,493	70.99 sq. m
		Pothole Repair	5,386	13.47 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	10,476	26.19 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	6,976	17.44 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	2,884	7.21 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km

		Drainage Cleaning	11,000	2.20 km
		Edge Repair	51,964	103.93 sq. m
		Pothole Repair	4,030	10.08 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	11,788	29.47 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	3,137	7.84 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	2,705	6.76 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,104,157	2,208.31 sq. m
		Pothole Repair	5,016	12.54 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	7,319	18.30 sq. m
Total Annual Cost:			2,911,830	
2019	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	39,392	78.78 sq. m
		Pothole Repair	4,943	12.36 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	27,225	68.06 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	5,180	12.95 sq. m

	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	2,065	5.16 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	57,984	115.97 sq. m
		Pothole Repair	3,223	8.06 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	17,173	42.93 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	2,366	5.92 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	7,791	19.48 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,239,876	2,479.75 sq. m
		Pothole Repair	14,427	36.07 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	17,761	44.40 sq. m
Total Annual Cost:			3,099,905	
2020	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	43,786	87.57 sq. m
		Pothole Repair	12,654	31.64 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km

		Pothole Repair	40,123	100.31 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	14,297	35.74 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	10,237	25.59 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	64,895	129.79 sq. m
		Pothole Repair	9,982	24.95 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	24,375	60.94 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	10,427	26.07 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,406,531	2,813.06 sq. m
		Pothole Repair	17,742	44.36 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	25,779	64.45 sq. m
Total Annual Cost:			3,341,327	
2021	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	48,837	97.67 sq. m

		Pothole Repair	18,522	46.30 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	53,695	134.24 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	26,603	66.51 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	17,647	44.12 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	73,071	146.14 sq. m
		Pothole Repair	14,006	35.02 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	29,414	73.53 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	8,135	20.34 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	16,471	41.18 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,616,472	3,232.94 sq. m
		Pothole Repair	27,501	68.75 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	36,351	90.88 sq. m

Total Annual Cost:			3,647,224	
2022	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	54,803	109.61 sq. m
		Pothole Repair	24,525	61.31 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	71,753	179.38 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	43,392	108.48 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	25,828	64.57 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	83,266	166.53 sq. m
		Pothole Repair	22,457	56.14 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	34,484	86.21 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	14,407	36.02 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	21,893	54.73 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,633,500	3,267.00 sq. m

		Pothole Repair	36,739	91.85 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	41,574	103.94 sq. m
Total Annual Cost:			3,769,121	
2023	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	62,121	124.24 sq. m
		Pothole Repair	32,788	81.97 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	86,694	216.73 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	59,216	148.04 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	32,774	81.93 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	96,863	193.73 sq. m
		Pothole Repair	30,233	75.58 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	38,358	95.89 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	22,056	55.14 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km

		Pothole Repair	26,367	65.92 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,633,500	3,267.00 sq. m
		Pothole Repair	44,572	111.43 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	49,090	122.72 sq. m
Total Annual Cost:			3,875,133	
2024	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	71,632	143.26 sq. m
		Pothole Repair	39,619	99.05 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	96,460	241.15 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	72,410	181.03 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	38,384	95.96 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	116,321	232.64 sq. m
		Pothole Repair	36,675	91.69 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	41,742	104.35 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km

		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	28,700	71.75 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	29,846	74.61 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,633,500	3,267.00 sq. m
		Pothole Repair	48,210	120.53 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	55,566	138.92 sq. m
Total Annual Cost:			3,969,564	
2025	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	84,533	169.07 sq. m
		Pothole Repair	43,793	109.48 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	104,239	260.60 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	82,798	207.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	42,617	106.54 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	144,433	288.87 sq. m
		Pothole Repair	41,728	104.32 sq. m

	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	44,765	111.91 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	34,135	85.34 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	31,959	79.90 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,633,500	3,267.00 sq. m
		Pothole Repair	50,690	126.73 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	61,180	152.95 sq. m
Total Annual Cost:			4,060,871	
2026	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	101,921	203.84 sq. m
		Pothole Repair	47,426	118.56 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	111,285	278.21 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km
		Pothole Repair	90,360	225.90 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	45,443	113.61 sq. m

	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	183,574	367.15 sq. m
		Pothole Repair	45,146	112.86 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	47,563	118.91 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	38,316	95.79 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	33,904	84.76 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,633,500	3,267.00 sq. m
		Pothole Repair	53,314	133.29 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	66,124	165.31 sq. m
Total Annual Cost:			4,158,375	
2027	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Shoulder Make-up	140,000	3.50 km
		Drainage Cleaning	17,500	3.50 km
		Edge Repair	124,711	249.42 sq. m
		Pothole Repair	50,693	126.73 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	Shoulder Make-up	240,000	6.00 km
		Drainage Cleaning	30,000	6.00 km
		Pothole Repair	117,923	294.81 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Shoulder Make-up	300,000	7.50 km
		Drainage Cleaning	37,500	7.50 km

		Pothole Repair	95,437	238.59 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Shoulder Make-up	128,000	3.20 km
		Drainage Cleaning	16,000	3.20 km
		Pothole Repair	47,879	119.70 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Edge Repair	235,363	470.73 sq. m
		Pothole Repair	47,267	118.17 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Shoulder Make-up	120,000	3.00 km
		Drainage Cleaning	15,000	3.00 km
		Pothole Repair	50,262	125.66 sq. m
	Sector - 62 Road along Khora Village	Shoulder Make-up	88,000	2.20 km
		Drainage Cleaning	11,000	2.20 km
		Pothole Repair	41,263	103.16 sq. m
	Sector - 62 road along NH - 24	Shoulder Make-up	80,000	2.00 km
		Drainage Cleaning	10,000	2.00 km
		Pothole Repair	35,797	89.49 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Shoulder Make-up	132,000	3.30 km
		Drainage Cleaning	16,500	3.30 km
		Edge Repair	1,633,500	3,267.00 sq. m
		Pothole Repair	56,079	140.20 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Shoulder Make-up	160,000	4.00 km
		Drainage Cleaning	20,000	4.00 km
		Pothole Repair	70,603	176.51 sq. m
Total Annual Cost:			4,267,278	
Total Costs for Alternative:			49,669,665	
<u>Overlay 20mm PC + 50mm BM</u>				
			Financial	
Year	Section	Works Description	Cost	Work Quantity

2013	MP road No. 2 (from sector 16 A to Sector 60)	50mm BM	180,000,000	60,000.00 sq. m
		Prep. Patching	375	0.94 sq. m
		Prep. Edge Repair	690	1.38 sq. m
	Gijhor road (Khora Vill. to MP - 3)	50mm BM	81,000,000	27,000.00 sq. m
		Prep. Patching	183	0.46 sq. m
		Prep. Edge Repair	1,150	2.30 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	50mm BM	54,450,000	18,150.00 sq. m
		Prep. Patching	331	0.83 sq. m
		Prep. Edge Repair	124,672	249.34 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	50mm BM	99,000,000	33,000.00 sq. m
		Prep. Patching	278	0.69 sq. m
		Prep. Edge Repair	1,065	2.13 sq. m
Total Annual Cost:			414,578,744	
2015	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	50mm BM	81,600,000	27,200.00 sq. m
		Prep. Patching	1,559	3.90 sq. m
		Prep. Edge Repair	1,420	2.84 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	50mm BM	46,200,000	15,400.00 sq. m
		Prep. Patching	1,205	3.01 sq. m
		Prep. Edge Repair	42,085	84.17 sq. m
	Sector - 62 road along NH - 24	50mm BM	51,000,000	17,000.00 sq. m
		Prep. Patching	1,322	3.31 sq. m
		Prep. Edge Repair	900	1.80 sq. m
Total Annual Cost:			178,848,491	
2016	MP Road No. 3 (From Shahdra Drain to Sector - 60)	50mm BM	225,000,000	75,000.00 sq. m
		Prep. Patching	2,312	5.78 sq. m
		Prep. Edge Repair	670	1.34 sq. m
	Sector - 62 Road along Khora Village	50mm BM	52,800,000	17,600.00 sq. m
		Prep. Patching	3,511	8.78 sq. m
		Prep. Edge Repair	1,560	3.12 sq. m
Total Annual Cost:			277,808,053	

2017	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	50mm BM	73,500,000	24,500.00 sq. m
		Prep. Patching	4,204	10.51 sq. m
		Prep. Edge Repair	36,317	72.63 sq. m
Total Annual Cost:			73,540,521	
2024	Gijhor road (Khora Vill. to MP - 3)	50mm BM	81,000,000	27,000.00 sq. m
		Prep. Patching	130,127	325.32 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	50mm BM	99,000,000	33,000.00 sq. m
		Prep. Patching	68,716	171.79 sq. m
Total Annual Cost:			180,198,843	
2025	Sector -62 Rajat Vihar to Mamura Xing	50mm BM	54,450,000	18,150.00 sq. m
		Prep. Patching	97,917	244.79 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
Total Annual Cost:			55,042,917	
2026	MP road No. 2 (from sector 16 A to Sector 60)	50mm BM	180,000,000	60,000.00 sq. m
		Prep. Patching	171,731	429.33 sq. m
Total Annual Cost:			180,171,731	
2027	Sector - 62 road along NH - 24	50mm BM	51,000,000	17,000.00 sq. m
		Prep. Patching	130,724	326.81 sq. m
Total Annual Cost:			51,130,724	
Total Costs for Alternative:			1,411,320,024	
<u>Overlay 25mm BC + 50mm DBM</u>				
			Financial	
Year	Section	Works Description	Cost	Work Quantity
2014	MP road No. 2 (from sector 16 A to Sector 60)	50mm DBM	156,000,000	60,000.00 sq. m
		Prep. Patching	443	1.11 sq. m
		Prep. Edge Repair	690	1.38 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	50mm DBM	47,190,000	18,150.00 sq. m
		Prep. Patching	394	0.98 sq. m
		Prep. Edge Repair	342,395	684.79 sq. m

Total Annual Cost:			203,533,922	
2015	Gijhor road (Khora Vill. to MP - 3)	50mm DBM	70,200,000	27,000.00 sq. m
		Prep. Patching	1,033	2.58 sq. m
		Prep. Edge Repair	1,150	2.30 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	50mm DBM	85,800,000	33,000.00 sq. m
		Prep. Patching	1,188	2.97 sq. m
		Prep. Edge Repair	1,065	2.13 sq. m
Total Annual Cost:			156,004,437	
2017	MP Road No. 3 (From Shahdra Drain to Sector - 60)	50mm DBM	195,000,000	75,000.00 sq. m
		Prep. Patching	3,728	9.32 sq. m
		Prep. Edge Repair	670	1.34 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	50mm DBM	70,720,000	27,200.00 sq. m
		Prep. Patching	4,756	11.89 sq. m
		Prep. Edge Repair	1,420	2.84 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	50mm DBM	40,040,000	15,400.00 sq. m
		Prep. Patching	6,143	15.36 sq. m
		Prep. Edge Repair	82,406	164.81 sq. m
	Sector - 62 road along NH - 24	50mm DBM	44,200,000	17,000.00 sq. m
		Prep. Patching	5,458	13.64 sq. m
		Prep. Edge Repair	900	1.80 sq. m
Total Annual Cost:			350,065,481	
2018	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	50mm DBM	63,700,000	24,500.00 sq. m
		Prep. Patching	6,423	16.06 sq. m
		Prep. Edge Repair	46,467	92.93 sq. m
	Sector - 62 Road along Khora Village	50mm DBM	45,760,000	17,600.00 sq. m
		Prep. Patching	8,536	21.34 sq. m
		Prep. Edge Repair	1,560	3.12 sq. m
Total Annual Cost:			109,522,987	
2026	Gijhor road (Khora Vill. to MP - 3)	50mm DBM	70,200,000	27,000.00 sq. m
		Prep. Patching	154,572	386.43 sq. m

	Sector -62 Rajat Vihar to Mamura Xing	50mm DBM	47,190,000	18,150.00 sq. m
		Prep. Patching	98,352	245.88 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	50mm DBM	85,800,000	33,000.00 sq. m
		Prep. Patching	126,683	316.71 sq. m
Total Annual Cost:			204,064,608	
2027	MP road No. 2 (from sector 16 A to Sector 60)	50mm DBM	156,000,000	60,000.00 sq. m
		Prep. Patching	172,167	430.42 sq. m
Total Annual Cost:			156,172,167	
Total Costs for Alternative:			1,179,363,601	
<u>Overlay 25mm SDBC + 75mm DBM</u>				
			Financial	
Year	Section	Works Description	Cost	Work Quantity
2016	MP road No. 2 (from sector 16 A to Sector 60)	75mm DBM	174,000,000	60,000.00 sq. m
		Prep. Patching	3,271	8.18 sq. m
		Prep. Edge Repair	690	1.38 sq. m
	Gijhor road (Khora Vill. to MP - 3)	75mm DBM	78,300,000	27,000.00 sq. m
		Prep. Patching	2,731	6.83 sq. m
		Prep. Edge Repair	1,150	2.30 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	75mm DBM	52,635,000	18,150.00 sq. m
		Prep. Patching	3,439	8.60 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
Total Annual Cost:			305,441,282	
2017	45 M Road from Mahamaya Fly Over to Sector - 97, 98	75mm DBM	95,700,000	33,000.00 sq. m
		Prep. Patching	5,501	13.75 sq. m
		Prep. Edge Repair	1,065	2.13 sq. m
Total Annual Cost:			95,706,566	
2018	MP Road No. 3 (From Shahdra Drain to Sector - 60)	75mm DBM	217,500,000	75,000.00 sq. m
		Prep. Patching	5,189	12.97 sq. m

		Prep. Edge Repair	670	1.34 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	75mm DBM	78,880,000	27,200.00 sq. m
		Prep. Patching	6,452	16.13 sq. m
		Prep. Edge Repair	1,420	2.84 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	75mm DBM	44,660,000	15,400.00 sq. m
		Prep. Patching	9,433	23.58 sq. m
		Prep. Edge Repair	106,108	212.22 sq. m
	Sector - 62 road along NH - 24	75mm DBM	49,300,000	17,000.00 sq. m
		Prep. Patching	21,015	52.54 sq. m
		Prep. Edge Repair	900	1.80 sq. m
Total Annual Cost:			390,491,187	
2019	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	75mm DBM	71,050,000	24,500.00 sq. m
		Prep. Patching	17,813	44.53 sq. m
		Prep. Edge Repair	57,759	115.52 sq. m
	Sector - 62 Road along Khora Village	75mm DBM	51,040,000	17,600.00 sq. m
		Prep. Patching	11,494	28.73 sq. m
		Prep. Edge Repair	1,560	3.12 sq. m
Total Annual Cost:			122,178,626	
2027	Gijhor road (Khora Vill. to MP - 3)	75mm DBM	78,300,000	27,000.00 sq. m
		Prep. Patching	211,571	528.93 sq. m
Total Annual Cost:			78,511,571	
Total Costs for Alternative:			992,329,232	
<u>Reconstruction</u>				
			Financial	
Year	Section	Works Description	Cost	Work Quantity
2018	MP road No. 2 (from sector 16 A to Sector 60)	Reconstruction	72,000,000	0.00 sq. m
	Gijhor road (Khora Vill. to MP - 3)	Reconstruction	36,000,000	0.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	Reconstruction	39,600,000	0.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	Reconstruction	48,000,000	0.00 sq. m

Total Annual Cost:			195,600,000	
2019	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	Reconstruction	26,400,000	0.00 sq. m
	Sector - 62 road along NH - 24	Reconstruction	24,000,000	0.00 sq. m
Total Annual Cost:			50,400,000	
2020	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	Reconstruction	42,000,000	0.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	Reconstruction	90,000,000	0.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	Reconstruction	38,400,000	0.00 sq. m
	Sector - 62 Road along Khora Village	Reconstruction	26,400,000	0.00 sq. m
Total Annual Cost:			196,800,000	
Total Costs for Alternative:			442,800,000	
ST 20 mm PC				
			Financial	
Year	Section	Works Description	Cost	Work Quantity
2013	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Patching	181	0.45 sq. m
		Prep. Edge Repair	4,733	9.47 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
		Prep. Patching	375	0.94 sq. m
		Prep. Edge Repair	690	1.38 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
		Prep. Patching	311	0.78 sq. m
		Prep. Edge Repair	670	1.34 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
		Prep. Patching	498	1.24 sq. m
		Prep. Edge Repair	1,420	2.84 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Patching	238	0.60 sq. m
		Prep. Edge Repair	9,389	18.78 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m

		Prep. Patching	183	0.46 sq. m
		Prep. Edge Repair	1,150	2.30 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
		Prep. Patching	419	1.05 sq. m
		Prep. Edge Repair	1,560	3.12 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
		Prep. Patching	278	0.69 sq. m
		Prep. Edge Repair	900	1.80 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Patching	331	0.83 sq. m
		Prep. Edge Repair	124,672	249.34 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
		Prep. Patching	278	0.69 sq. m
		Prep. Edge Repair	1,065	2.13 sq. m
Total Annual Cost:			314,999,340	
2014	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	6,731	13.46 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	15,501	31.00 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	217,723	435.45 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,089,954	
2015	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m

		Prep. Edge Repair	7,432	14.86 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	17,102	34.20 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	239,028	478.06 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,113,563	
2016	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	8,224	16.45 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	18,945	37.89 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	264,142	528.28 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,141,311	
2017	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	9,102	18.20 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m

	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	20,997	41.99 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	292,317	584.63 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,172,416	
2018	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	10,075	20.15 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	23,277	46.55 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	323,558	647.12 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,206,910	
2019	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	11,153	22.31 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m

	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	25,809	51.62 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	358,180	716.36 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,245,143	
2020	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	12,348	24.70 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	28,623	57.25 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	396,551	793.10 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,287,521	
2021	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	13,672	27.34 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	31,750	63.50 sq. m

	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	439,079	878.16 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,334,500	
2022	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	15,140	30.28 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	35,232	70.46 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	486,220	972.44 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,386,591	
2023	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	16,767	33.53 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	39,108	78.22 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m

	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,400,876	
2024	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	18,571	37.14 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	43,422	86.84 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,406,993	
2025	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	20,572	41.14 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	48,223	96.45 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m

		Prep. Edge Repair	495,000	990.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,413,795	
2026	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	22,790	45.58 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	53,569	107.14 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m
Total Annual Cost:			315,421,359	
2027	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 20mm PC	24,500,000	24,500.00 sq. m
		Prep. Edge Repair	25,251	50.50 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 20mm PC	60,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 20mm PC	75,000,000	75,000.00 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 20mm PC	27,200,000	27,200.00 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 20mm PC	15,400,000	15,400.00 sq. m
		Prep. Edge Repair	59,523	119.05 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 20mm PC	27,000,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 20mm PC	17,600,000	17,600.00 sq. m
	Sector - 62 road along NH - 24	ST 20mm PC	17,000,000	17,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 20mm PC	18,150,000	18,150.00 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 20mm PC	33,000,000	33,000.00 sq. m

Total Annual Cost:			315,429,773	
Total Costs for Alternative:			4,729,050,046	
ST 25mm SDBC				
			Financial	
Year	Section	Works Description	Cost	Work Quantity
2013	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 25mm SDBC	39,200,000	24,500.00 sq. m
		Prep. Patching	181	0.45 sq. m
		Prep. Edge Repair	4,733	9.47 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 25mm SDBC	96,000,000	60,000.00 sq. m
		Prep. Patching	375	0.94 sq. m
		Prep. Edge Repair	690	1.38 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 25mm SDBC	120,000,000	75,000.00 sq. m
		Prep. Patching	311	0.78 sq. m
		Prep. Edge Repair	670	1.34 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 25mm SDBC	43,520,000	27,200.00 sq. m
		Prep. Patching	498	1.24 sq. m
		Prep. Edge Repair	1,420	2.84 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 25mm SDBC	24,640,000	15,400.00 sq. m
		Prep. Patching	238	0.60 sq. m
		Prep. Edge Repair	9,389	18.78 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 25mm SDBC	43,200,000	27,000.00 sq. m
		Prep. Patching	183	0.46 sq. m
		Prep. Edge Repair	1,150	2.30 sq. m
	Sector - 62 Road along Khora Village	ST 25mm SDBC	28,160,000	17,600.00 sq. m
		Prep. Patching	419	1.05 sq. m
		Prep. Edge Repair	1,560	3.12 sq. m
	Sector - 62 road along NH - 24	ST 25mm SDBC	27,200,000	17,000.00 sq. m
		Prep. Patching	278	0.69 sq. m
		Prep. Edge Repair	900	1.80 sq. m

	Sector -62 Rajat Vihar to Mamura Xing	ST 25mm SDBC	29,040,000	18,150.00 sq. m
		Prep. Patching	331	0.83 sq. m
		Prep. Edge Repair	124,672	249.34 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 25mm SDBC	52,800,000	33,000.00 sq. m
		Prep. Patching	278	0.69 sq. m
		Prep. Edge Repair	1,065	2.13 sq. m
Total Annual Cost:			503,909,340	
2014	MP road No. 2 (from sector 16 A to Sector 60)	ST 25mm SDBC	96,000,000	60,000.00 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 25mm SDBC	43,200,000	27,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 25mm SDBC	29,040,000	18,150.00 sq. m
		Prep. Edge Repair	217,723	435.45 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 25mm SDBC	52,800,000	33,000.00 sq. m
Total Annual Cost:			221,257,723	
2016	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 25mm SDBC	24,640,000	15,400.00 sq. m
		Prep. Edge Repair	51,553	103.11 sq. m
Total Annual Cost:			24,691,553	
2017	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 25mm SDBC	43,520,000	27,200.00 sq. m
	Sector - 62 road along NH - 24	ST 25mm SDBC	27,200,000	17,000.00 sq. m
Total Annual Cost:			70,720,000	
2018	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 25mm SDBC	39,200,000	24,500.00 sq. m
		Prep. Edge Repair	41,571	83.14 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 25mm SDBC	120,000,000	75,000.00 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 25mm SDBC	43,200,000	27,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 25mm SDBC	28,160,000	17,600.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 25mm SDBC	52,800,000	33,000.00 sq. m
Total Annual Cost:			283,401,571	
2019	MP road No. 2 (from sector 16 A to Sector 60)	ST 25mm SDBC	96,000,000	60,000.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 25mm SDBC	29,040,000	18,150.00 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
Total Annual Cost:			125,535,000	

2022	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 25mm SDBC	24,640,000	15,400.00 sq. m
		Prep. Edge Repair	165,734	331.47 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 25mm SDBC	43,200,000	27,000.00 sq. m
	Sector - 62 road along NH - 24	ST 25mm SDBC	27,200,000	17,000.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 25mm SDBC	52,800,000	33,000.00 sq. m
Total Annual Cost:			148,005,734	
2023	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 25mm SDBC	43,520,000	27,200.00 sq. m
Total Annual Cost:			43,520,000	
2024	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 25mm SDBC	39,200,000	24,500.00 sq. m
		Prep. Edge Repair	87,677	175.35 sq. m
	MP road No. 2 (from sector 16 A to Sector 60)	ST 25mm SDBC	96,000,000	60,000.00 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 25mm SDBC	120,000,000	75,000.00 sq. m
	Sector - 62 Road along Khora Village	ST 25mm SDBC	28,160,000	17,600.00 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 25mm SDBC	29,040,000	18,150.00 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
Total Annual Cost:			312,982,677	
2026	Gijhor road (Khora Vill. to MP - 3)	ST 25mm SDBC	43,200,000	27,000.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 25mm SDBC	52,800,000	33,000.00 sq. m
Total Annual Cost:			96,000,000	
2027	Sector - 62 road along NH - 24	ST 25mm SDBC	27,200,000	17,000.00 sq. m
Total Annual Cost:			27,200,000	
Total Costs for Alternative:			1,857,223,599	
ST 40 mm BC				
			Financial	
Year	Section	Works Description	Cost	Work Quantity
2013	MP road No. 2 (from sector 16 A to Sector 60)	ST 40 mm BC	120,000,000	60,000.00 sq. m
		Prep. Patching	375	0.94 sq. m
		Prep. Edge Repair	690	1.38 sq. m
	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 40 mm BC	150,000,000	75,000.00 sq. m

		Prep. Patching	311	0.78 sq. m
		Prep. Edge Repair	670	1.34 sq. m
	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 40 mm BC	54,400,000	27,200.00 sq. m
		Prep. Patching	498	1.24 sq. m
		Prep. Edge Repair	1,420	2.84 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 40 mm BC	30,800,000	15,400.00 sq. m
		Prep. Patching	238	0.60 sq. m
		Prep. Edge Repair	9,389	18.78 sq. m
	Gijhor road (Khora Vill. to MP - 3)	ST 40 mm BC	54,000,000	27,000.00 sq. m
		Prep. Patching	183	0.46 sq. m
		Prep. Edge Repair	1,150	2.30 sq. m
	Sector - 62 road along NH - 24	ST 40 mm BC	34,000,000	17,000.00 sq. m
		Prep. Patching	278	0.69 sq. m
		Prep. Edge Repair	900	1.80 sq. m
	Sector -62 Rajat Vihar to Mamura Xing	ST 40 mm BC	36,300,000	18,150.00 sq. m
		Prep. Patching	331	0.83 sq. m
		Prep. Edge Repair	124,672	249.34 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 40 mm BC	66,000,000	33,000.00 sq. m
		Prep. Patching	278	0.69 sq. m
		Prep. Edge Repair	1,065	2.13 sq. m
Total Annual Cost:			545,642,448	
2015	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 40 mm BC	49,000,000	24,500.00 sq. m
		Prep. Patching	845	2.11 sq. m
		Prep. Edge Repair	18,915	37.83 sq. m
	Sector - 62 Road along Khora Village	ST 40 mm BC	35,200,000	17,600.00 sq. m
		Prep. Patching	1,496	3.74 sq. m
		Prep. Edge Repair	1,560	3.12 sq. m
Total Annual Cost:			84,222,816	
2022	Gijhor road (Khora Vill. to MP - 3)	ST 40 mm BC	54,000,000	27,000.00 sq. m
		Prep. Patching	11,173	27.93 sq. m

	Sector -62 Rajat Vihar to Mamura Xing	ST 40 mm BC	36,300,000	18,150.00 sq. m
		Prep. Edge Repair	495,000	990.00 sq. m
	45 M Road from Mahamaya Fly Over to Sector - 97, 98	ST 40 mm BC	66,000,000	33,000.00 sq. m
		Prep. Patching	10,242	25.60 sq. m
Total Annual Cost:			156,816,414	
2023	MP road No. 2 (from sector 16 A to Sector 60)	ST 40 mm BC	120,000,000	60,000.00 sq. m
Total Annual Cost:			120,000,000	
2024	Sector - 62 road along NH - 24	ST 40 mm BC	34,000,000	17,000.00 sq. m
		Prep. Patching	10,552	26.38 sq. m
Total Annual Cost:			34,010,552	
2025	Udhyog Marg (Sector - 14 A T. Point to Jhundhpura)	ST 40 mm BC	54,400,000	27,200.00 sq. m
		Prep. Patching	68,843	172.11 sq. m
Total Annual Cost:			54,468,843	
2026	MP Road No. 3 (From Shahdra Drain to Sector - 60)	ST 40 mm BC	150,000,000	75,000.00 sq. m
		Prep. Patching	82,597	206.49 sq. m
	Raghunathpur Agahpur Road (MP - 1 to MP - 3 Road)	ST 40 mm BC	30,800,000	15,400.00 sq. m
		Prep. Patching	53,724	134.31 sq. m
		Prep. Edge Repair	401,980	803.96 sq. m
Total Annual Cost:			181,338,301	
2027	MP Road No. 1 (From DND to T. Point Sector 12,22,56)	ST 40 mm BC	49,000,000	24,500.00 sq. m
		Prep. Patching	51,874	129.69 sq. m
		Prep. Edge Repair	183,861	367.72 sq. m
Total Annual Cost:			49,235,735	
Total Costs for Alternative:			1,225,735,109	

5.2. Comparison of HDM4 output with experimental result

The data collection of a pavement section at Patiala City was done and analysis on HDM-4 was performed. The following data has been collected for roughness, cracking, pot holes and Rut depth. The comparison is performed in HDM-4. Following are the results of the comparison.

Table 5.5 Roughness values of actual and results from HDM-4 in IRI m/Km

Section ID UR-04	July 2012	April 2013	Dec 2013
Actual	2.50	2.54	2.63
HDM4	2.50	2.60	2.72

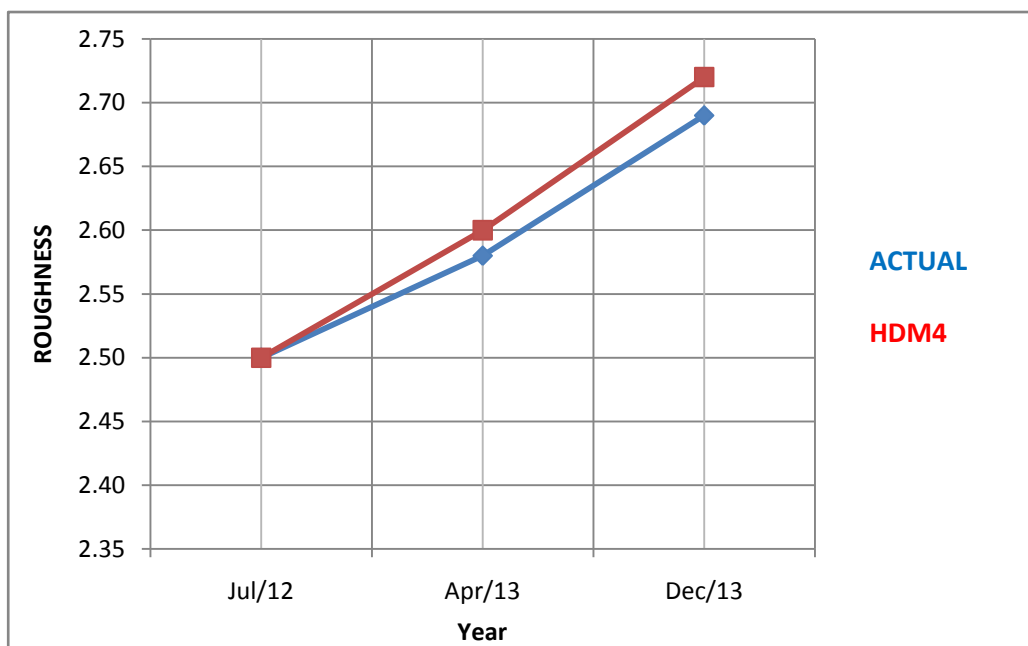


Figure 5.23 Graphical representation Roughness values of actual and results from HDM-4 in IRI m/Km

Table 5.6 Cracking values of actual and results from HDM-4 in percentage

Section ID UR-04	July 2012	April 2013	Dec 2013
Actual	2.40	4.68	8.59
HDM4	2.40	5.09	9.48

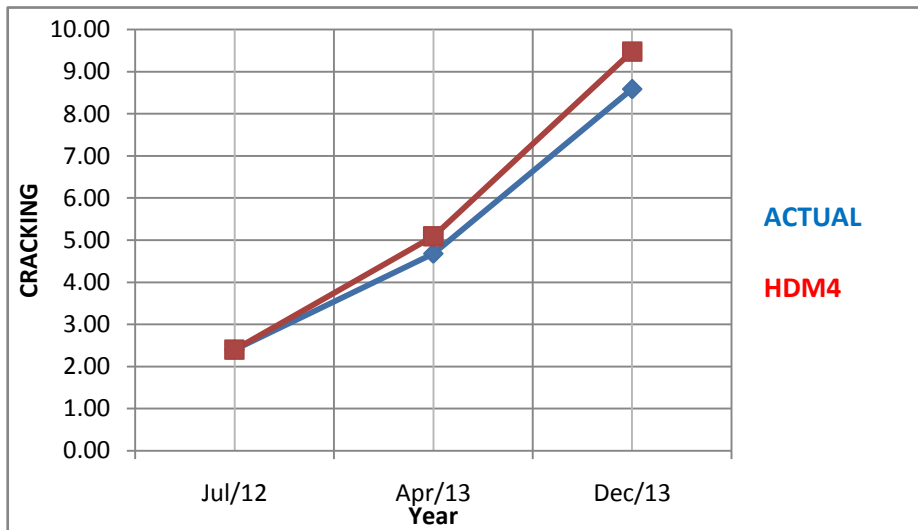


Figure 5.24 Graphical representation Cracking values of actual and results from HDM-4 in percentage

Table 5.7 Pot Holes values of actual and results from HDM-4 in numbers/Km

Section ID UR-04	July 2012	April 2013	Dec 2013
Actual	3.00	5.00	7.00
HDM4	3.00	4.00	4.00

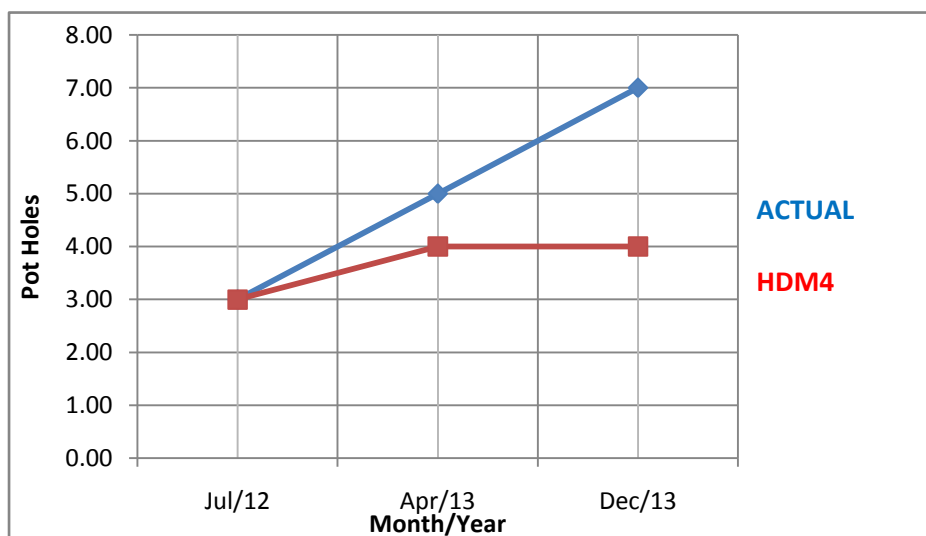


Figure 5.25 Graphical representation Pot hole values of actual and results from HDM-4 in number/Km

Table 5.8 Rut Depth values of actual and results from HDM-4 in mm.

Section ID UR-04	July 2012	April 2013	Dec 2013
Actual	3.35	3.8	3.95
HDM4	3.35	3.70	4.05

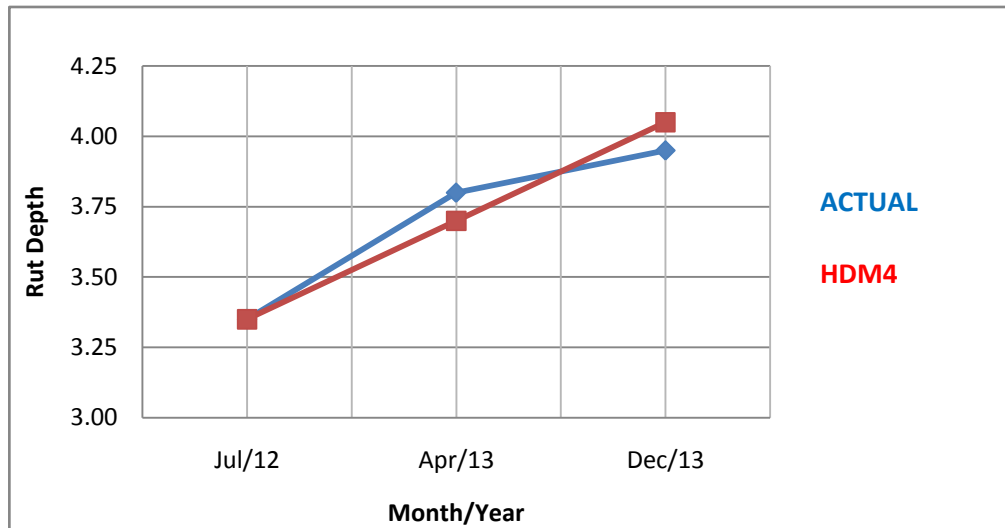


Figure 5.26 Graphical representation Pot hole values of actual and results from HDM-4 in number/Km

1. The network level pavement management analysis has been carried out using the 'Program Analysis' application module of HDM-4. The life-cycle cost analysis of the selected urban city network has been carried out, and an unconstrained works programme has been prepared for the defined analysis period of 15 years. The total budget requirements for maintenance management of the whole city network at a pre-defined, optimum serviceability level have been determined, which comes out to be equal to Rs. 1014.20 million. The budget optimisation process is performed with Rs. 800 million budget availability. The Comparison of Unconstrained and Constrained Budget Analysis is presented in the Table 7.1. It is observed that in the section 'NRS3', in Unconstrained Budget Analysis strengthening alternative 'ST 40mm BC' is applied two times in years 2015 and 2027 respectively. When the Constrained Budget Analysis is performed, then only Reconstruction alternative is applied in the year 2020 at roughness greater than 6.5 IRI value. Similar is in the case of Section 'NRS4'.
2. The motorized vehicles have higher growth rates, which cause the increase in volume of traffic and the pavement condition gets deteriorated. Hence require a large amount of funds to maintain such urban roads. When the funds are limited, the PMMS can be used to optimize the budget for the urban roads as per the available amount of resources.
3. The average roughness value of the city network will not change much if the maintenance is delayed by one year, but in case the application of maintenance activities is deferred by two years, the roughness value will rise very sharply to 7.57 m/km IRI in the year 2020. A further delay of one year will cause rise in roughness value up to 8.65 m/km IRI in the year 2021. This will result in very high vehicle operation cost for the road users. Therefore, the maintenance activities should be carried out as and when they become due as per the unconstrained works programme.

Table 7.1 Comparison of Unconstrained and Constrained Budget Analysis

Pavement Section ID	Year		Maintenance Work		B/C Ratio		Financial Cost*		Cumulative Cost*	
	U. Budget	C. Budget	U. Budget	C. Budget	U. Budget	C. Budget	U. Budget	C. Budget	U. Budget	C. Budget
NRS1	2013	2013	ST 40 mm BC	ST 40 mm BC	4.89	4.89	66.00	66.00	66.00	66.00
	2022	2022	ST 40 mm BC	ST 40 mm BC	4.89	4.89	66.00	66.00	132.00	132.00
NRS2	2013	2013	ST 40 mm BC	ST 40 mm BC	6.27	6.27	54.00	54.00	186.00	186.00
	2022	2022	ST 40 mm BC	ST 40 mm BC	6.27	6.27	54.00	54.00	240.00	240.00
NRS3	2015	2020	ST 40 mm BC	Reconstruction	2.38	6.31	49.00	62.00	289.00	282.00
	2027		ST 40 mm BC		2.38		49.00		338.00	
NRS4	2013	2018	ST 40 mm BC	Reconstruction	4.55	18.82	120.00	142.00	458.00	354.00
	2023		ST 40 mm BC		4.55		120.00		578.00	
NRS5	2020	2020	Reconstruction	Reconstruction	7.15	7.15	90.00	90.00	668.00	444.00
NRS6	2013	2013	ST 40 mm BC	ST 40 mm BC	5.76	5.76	30.80	30.80	698.80	474.80
	2026	2026	ST 40 mm BC	ST 40 mm BC	5.76	5.76	30.80	30.80	729.60	505.60

NRS7	2015	2015	ST 40 mm BC	ST 40 mm BC	3.97	3.97	35.20	35.20	764.80	540.80
NRS8	2013	2013	ST 40 mm BC	ST 40 mm BC	3.81	3.81	34.00	34.00	798.80	574.80
	2024	2024	ST 40 mm BC	ST 40 mm BC	3.81	3.81	34.00	34.00	832.80	608.80
NRS9	2013	2013	ST 40 mm BC	ST 40 mm BC	9.19	9.19	36.30	36.30	869.10	645.10
	2022	2022	ST 40 mm BC	ST 40 mm BC	9.19	9.19	36.30	36.30	905.40	681.40
NRS10	2013	2013	ST 40 mm BC	ST 40 mm BC	3.22	3.22	54.40	54.40	959.80	735.80
	2025	2025	ST 40 mm BC	ST 40 mm BC	3.22	3.22	54.40	54.40	1014.20	790.20

Table 7.2 Road work summary (By Year)

Year	Base Alternative	Overlay 20mm PC + 50mm BM	Overlay 25mm BC + 50mm DBM	Overlay 25mm SDBC + 75mm DBM	Re construction	ST 20 mm PC	ST 25mm SDBC	ST 40 mm BC	Total
2013	1604944	386922995	0	0	0	251999472	440909472	491063958	1572500841
2014	1892406	0	187835138	0	0	252071964	193584179	0	635383686

2015	1969021	166918792	144003549	0	0	252090850	0	75798253	640780466
2016	2065390	259286442	0	284310026	0	252113049	21601242	0	819376149
2017	2154469	68632417	323124384	89105253	0	252137933	61880000	0	797034456
2018	2255664	0	101090389	363540949	162999998	252165528	247973257	0	1130025786
2019	2406124	0	0	113740901	42000000	252196114	109806000	0	520149138
2020	2599262	0	0	0	164000000	252230017	0	0	418829279
2021	2843979	0	0	0	0	252267600	0	0	255111580
2022	2941497	0	0	0	0	252309273	129492587	141083131	525826489
2023	3026306	0	0	0	0	252320700	38080000	108000000	401427007
2024	3101851	168159075	0	0	0	252325595	273816142	30608442	728011104
2025	3174897	51294334	0	0	0	252331036	0	49015074	355815341
2026	3252900	168137385	188259686	0	0	252337087	84000000	163150641	859137700
2027	3340022	47704579	144137734	73069257	0	252343819	23800000	44288588	588683999
Total	38628732	1317056020	1088450881	923766385	368999998	3783240037	1624942879	1103008087	10248093019

4. The HDM-4 makes provision for a much wider range of upgrading options, pavement types, seal types and other maintenance options.
5. All three alternatives of pavement maintenance are compared to each other on economic analysis. The Alternative of providing 40 mm BC has been found as the optimum pavement maintenance management strategy.
6. The scope of present study may be extended for the development of PMMS methodology for the urban city network having rigid pavements.
7. A summary of the works applied on the Noida city network during life-cycle cost analysis, showing the increase in road agency costs and decrease in road user costs, as a result of selecting the maintenance alternative in comparison to the base alternative, is given in Table 7.2. All these costs have been discounted to the base year 2013, with a discount rate of 12%.
8. The Comparison of HDM4 output with experimental result has been done for the Patiala City road section. The data for roughness, cracking, pot holes and Rut depth was collected from the field and the comparison is performed in HDM-4 results. The validation of HDM-4 pavement deterioration models is proved as the slopes of the experimental result and the HDM-4 output are nearly same.
9. The life cycle approach requires not only an in-depth evaluation of the pavement under consideration, but also prediction of its future condition.

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