**1. Introduction**

**1.1 General**

Every newly constructed pavement, by the time it is opened to traffic, is subjected to the disastrous effect of various factors, such as traffic, weather conditions, solar radiation, and so on. At the same time, a gradual deterioration of the pavement’s functional and structural quality starts. This is attributed to the ageing and wear of the surfacing material and fatigue of materials composing the pavement.

The above factors, in combination with the reliability of the design, the compliance of materials used and the quality of the construction achieved, are the only reasons for the emergence of pavement surface distresses, fatigue failure and, finally, pavement disintegration.

The construction of a new pavement should always be considered as a social investment. The administrator of the public fund is responsible and obliged not only to preserve the capital invested but also to confer a benefit.

The benefit may be direct or indirect. The direct benefits include reduction of accidents, reduction of travelling time/costs and reduction (or no increase) of vehicle maintenance cost. The indirect benefit is the social benefit arising from comfortable and safe transportation of the users for social and commercial activities.

To preserve the capital and obtain the above benefits, the pavement should be regularly maintained in order to sustain a tolerable level of service throughout its service life. The profit may be maximized by setting the limit of tolerable level of service high.



**Figure (1): Relationship between Quality and Cost**

**1.2 Pavement performance criteria**

Pavement design consists of the determination of thickness of every layer composing the pavement, to ensure that the stresses/strains caused by the traffic loads and transmitted through the pavement to the subgrade do not exceed the supportive capacity of each layer and the subgrade. The determination of thickness of each layer depends directly on the volume and composition of the traffic, the mechanical characteristics of each layer constructed and the subgrade and the temperature and moisture environment prevailing in each layer. Additionally, a set of other factors should be always taken into consideration to determine the final pavement design. These factors are construction cost, ease and cost of future maintenance and service life.

In contrast to all other design methodologies for flexible pavements, the AASHTO methodology uses a pavement performance criterion Figure 2, which, apart from cracking and subgrade deformation, includes other parameters affecting the performance of the pavement. This criterion is called serviceability, expressed as present serviceability index (PSI).

Thus, the pavement is designed in such a way that its deterioration manifested as cracking, deformation, surface irregularities, and potholes and so on, until the end of its service life, results in the pavement offering a minimum tolerable level of serviceability.



**Figure(2): Flow chart of AASHTO flexible pavement design method**

The pavement performance criterion, which is taken into account in this methodology, is the pavement serviceability level. Pavement serviceability is defined as the ability of the pavement to serve the user/traffic. This is expressed with the PSI, which obtains values ranging from 0 (impossible road) to 5 (perfect road). Since an impossible road cannot be travelled on by a user and a perfect road is almost impossible to be constructed, the terms terminal serviceability index (pt) and initial serviceability index (po) have been introduced. The terminal serviceability index (pt) expresses the lowest tolerable serviceability level before pavement resurfacing, rehabilitation or even reconstruction becomes necessary. The terminal index value is related to everything that is characterised as tolerable level by the user, depending on the road significance. AASHTO suggests a pt value equal to 2.5 or higher for highways or main road arteries and 2.0 for all other cases. The initial serviceability index (po) expresses the initial serviceability index when pavement opens to traffic. The maximum value of this index is 5.0, but given that is impossible to have an absolutely perfect construction, a lower value should always be used. The po values observed at the AASHTO road test were 4.2 for flexible pavements and 4.5 for rigid pavements.

Having established the po and pt values, the change in PSI (ΔPSI) is determined by the following equation:

ΔPSI = po – pt,

Where po is the initial serviceability index and pt is the terminal serviceability index.



**Figure(3): Effect of pavement maintenance and rehabilitation on pavement level of service and pavement life duration**

**1.3 Unique Properties of Flexible Pavements**

Pavement is unique when compared to other civil engineering structures. Some of the unique properties of flexible pavement are discussed below.

**1.3.1 Fast Deterioration with Time**

Each traffic load application contributes to some extent to pavement distresses. Different types of distress could happen and accumulate over the years such as rutting, fatigue cracking, material disintegration, roughness and bleeding. When one or more of these distresses reach a certain unacceptable level, the pavement is considered as failed. The typical life of a flexible pavement varies from case to case, with an average value of 10 to 15 years. A good method of pavement design should include the designed life, or how long the pavement is expected to last before failure. The incorporation of the designed life in the design process is one of the hardest tasks faced by the pavement designer. In many cases, the expected designed life does not match with the actual service life. Unlike pavements, the design of other civil engineering structures does not consider the factor of designed life. In such cases the designer assumes that if the structure is safe under the maximum possible load, it will be safe for an extended period of time. This concept does not work with pavements because of their fast deterioration and short service lives.

**1.3.2 Repeated Loads**

When a traffic wheel moves on the pavement surface it creates a stress pulse. This stress pulse creates a dynamic pavement response, which is harder to analyze as compared to static response. Dynamic waves propagate throughout the pavement layers and subgrade, and involve reflections and refractions at the layer interfaces.

**1.3.3 Variable Load Configuration**

Different vehicular axle configurations are available with a different number of wheels at the end of each axle. Axles can be single, tandem, tridem, or multiple, while wheels can be either single or dual. Passenger cars have single axles and single wheels. However, trucks can take different combinations of axle and wheel configurations as shown in Figures 4. Different axle and wheel configurations result in stress interactions within the pavement structure, which in turn influence pavement performance.



**Figure(4): Track with different axle and wheel configuration**

**1.3.4 Variable Load Magnitude**

Traffic loads vary from light to heavy for passenger cars and loaded trucks respectively. Since pavement materials have non-linear response, doubling the load magnitude does not result in doubling the stress or strain. More importantly, doubling the load magnitude does not result in doubling the rate of pavement deterioration. In fact, increasing the load magnitude exponentially increases the rate of pavement deterioration.

**1.3.5 Variable Tyre Pressure**

Trucks have much higher tyre pressures than passenger cars. Typical tyre pressures of passenger cars are in the order of 30 – 35 psi, while trucks have tyre pressures of 100 – 115 psi. Higher tyre pressures result in higher contact pressures at the surface of the pavement and, in turn, faster deterioration of the surface layer. Truck tyre pressures have been increasing over the years, challenging pavement engineers to improve the quality of the HMA material in order to reduce premature pavement failure.

**1.3.6 Traffic Growth**

Pavement is designed to carry future traffic, which usually increases over the years. Predicting future traffic growth is not always accurate. This inaccuracy in predicting future traffic affects the accuracy of predicting pavement performance and consequently pavement designed life.

**1.3.7 Change of Material Properties with Environmental Conditions**

Environmental conditions have large effect on the properties of pavement materials. For example, HMA gets softer at high temperatures resulting in rutting, and harder at low temperatures resulting in thermal cracking. Also, rain and freeze – thaw cycles weaken the HMA materials and reduce the load carrying capacity of base, subbase and subgrade. In addition, HMA ages with time resulting in increasing its stiffness and its susceptibility to cracking.

**1.3.8 Change of Subgrade Properties with Distance**

Since pavement is built to cover a large distance, the same road might be built over different types of subgrade materials with different properties. Moreover, the road could be built over cut or fill subgrade sections having different material properties. The change of subgrade properties requires different thicknesses of pavement layers in order to support the same traffic load and produce the same performance.

**1.3.9 Channelized Traffic Load**

Traffic load is applied in the wheel path. This channelization of traffic load results in faster deterioration in the wheel path as compared to the area between wheel paths. The design process should consider the proper stress and strain distributions within the pavement structure to determine critical locations and possible deteriorations.

**1.3.10 Multi-Layer System**

The pavement structure consists of several layers built over the subgrade. These layers have different materials with different properties. The distribution of stresses and strains within the multi-layer pavement system depends on the thickness and material properties of these layers.

**1.3 Types of Maintenance**

The terminology used for keeping the pavement at a tolerable level of service differs significantly from country to country. In most of the countries, the following terms are used: routine maintenance, preventive maintenance, corrective maintenance, major maintenance or pavement rehabilitation, strengthening and rejuvenation.

*Routine maintenance* is defined as the number of activities (works) carried out repeatedly, on a daily, weekly, monthly or annual basis on all elements of the road/highway in order to ensure serviceability at all times and under all weather conditions.

The main activities in routine maintenance are as follows: (a) the cleaning of carriageway, verges, ditches, drains, signs and signals and safety barriers, to name as few, as well as grass cutting and tree pruning; (b) repair of damaged areas around manhole covers; (c) replacement of damaged safety barriers, road signs and, generally, road furniture; and (d) winter maintenance, such as clearance of snow and prevention of ice formation on the pavement surface. It is obvious that works that are directly related to the pavement structure are not included in routine maintenance.

*Preventive maintenance* is defined as the number of activities aiming to prevent the premature emergence of distresses and consequently premature pavement destruction.

*Corrective maintenance* is defined as the number of activities aiming to correct pavement surface imperfections, which affect the safety of the user.

The activities included in the preventive and corrective maintenance are not essentially independent of each other, except perhaps crack filling, and thus they will not be individually mentioned per case. Works for preventive and corrective maintenance include crack filling, pothole filling, patching, surface skid resistance restoration and surface evenness restoration.

*Major maintenance or pavement rehabilitation strengthening* may be defined as the number of activities aiming to fully restore the qualitative state of the pavement. The works consist of constructing an asphalt layer of a certain thickness (asphalt overlay) consisting of new or recycled materials, with or without levelling course or milling of the old pavement surface. This asphalt layer may be catered to extending a pavement’s service life.

*Rehabilitation* is the extension of the pavement structure’s life when maintenance techniques are no longer viable to maintain adequate serviceability. Generally, maintenance works are considered as those for maintaining the capital invested while rehabilitation works are considered as those for increasing capital efficiency.





Maintenance programs can be classified according to the time of carrying out the maintenance operations as follows:

1. Routine Maintenance: those activities that are carried out as frequently as required during each year. It could be carried out several times per a year to ensure serviceability at all times and in all weathers.

2. Periodic Maintenance: it covers all longer-term programmable operations required within the service life of the road. These activities which may be required only at intervals of several years may include renewal or renovation of the wearing surfaces of carriageways that become worn or deformed by use, resealing of paved roads and restoring of road markings.

Pavement maintenance activities can also be grouped and classified according to the purpose of treatment:

1. Preventive Maintenance: it is used to describe actions taken to prevent premature deterioration and/or to retard the progression of deficiencies so as to reduce the rate of deterioration and effectively increase the useful life of pavement.

2. Corrective (Remedial) Maintenance: it is used to refer to maintenance actions taken to correct deficiencies which are potentially hazardous, e.g. to repair defects which seriously affects a pavement operation so as to keep the highway within a tolerable level of serviceability. Figure 5 benefit of preventive maintenance.



**Figure (5): Benefit of preventive maintenance**

In general, preventive maintenance programmes automatically include routine maintenance activities, whilst corrective maintenance actions tend to encompass many of the activities carried out in the course of routine, periodic. The purpose of the maintenance illustrated in Figure 6.

****

**Figure (6): Distress/Maintenance Spectrum**

**1.4 Objectives of maintenance**

**1.4.1 Costs**

Maintenance reduces the rate of pavement deterioration, it lowers the cost of operating vehicles on the road by improving the running surface, and it keeps the road open on a continuous basis. It also includes the process of enhancing the environment of the road itself, including the immediate surroundings. Maintenance should also be carried out to improve safety but, this is sometimes problematic as it can lead to increased speeds which, in turn, result in increased numbers and severity of accidents. Figure 7 shows the effect of maintenance time on the costs. Furthermore, inadequate maintenance leads to an increase in the other user costs.



**Figure (7): Pavement Condition deterioration effects on maintenance costs**



**Figure(8): Relative costs on an ordinary road**

**1.4.2 Reducing deterioration**

Even with adequate maintenance, pavements will deteriorate over time. The rate of deterioration will depend on a number of factors including the traffic loading, the pavement strength, the climate and the environment. Eventually, the end of a pavement's design life will be reached and there is a need for pavement reconstruction or upgrading. These are normally relatively expensive activities and should, therefore, be postponed for as long as possible by carrying out effective and timely maintenance. If the required cyclic and reactive maintenance are not carried out, drainage will become ineffective and surface defects will worsen, both of which result in water penetrating the structure of the pavement. For paved roads, the resulting distress requires that a higher level of maintenance is needed prematurely. Failure to carry out resurfacing maintenance at the appropriate time soon leads to the need to carry out strengthening overlay works, which is at least twice as expensive as resealing. If this overlay is not carried out soon enough, major deterioration sets in and pavement reconstruction will be required, which is at least three times more costly than an overlay.

It will be seen that deferring works results in a rapid escalation of costs to the road administration. The effect of axle loading and, in particular of overloaded vehicles, on the requirement for road maintenance is considerable. For example, a 10 tonne axle causes approximately 2.5 times as much deterioration to a pavement as an axle weighing 8 tonnes. It is clearly necessary, for road maintenance purposes, to know the value of the actual axle loading, since minor underestimates can shorten considerably the expected, and hence designed, life of a pavement.

**1.4.3 Lowering vehicle operating costs**

Cost savings obtained by deferring the need for reconstruction, quoted above, exclude any benefits to vehicle operators who thereby avoid the high costs of operating on badly deteriorated pavements. The relative proportions of road administration costs and vehicle operating costs in the total lifetime transport cost associated with a road vary depending on the traffic level, as shown in Figure 9. This figure is based on research carried out by the World Bank and relates to roads where optimal maintenance is. This shows that the relative proportion of vehicle operating costs rises from about 40 per cent at 50 vehicles/day to over 90 per cent at 6000 vehicles/day.



**Figure (9): Relative proportion of road and vehicle costs in total transportation cost**

A further example, shown in Figure 10, illustrates the effect of neglecting road maintenance. The figure shows the relative discounted life cycle costs of construction, maintenance and vehicle operation under different maintenance spending scenarios. For a traffic level of about 1000 vehicles/day, a road in good condition will require about 2 per cent 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 are likely to increase by about 15 per cent. If there is complete neglect of maintenance, a paved road will eventually start to disintegrate, and annual vehicle operating costs will increase by about 50 per cent.



**Figure(10): Change in discounted life cycle costs on paved road for different levels of maintenance**

**1.4.4 Keeping the road open**

The fourth reason for carrying out maintenance is to keep the road open continuously. Roads serve centers of population and industry and, if roads are closed, for whatever reason, then there are potentially serious social and economic consequences. In the case of winter maintenance, decisions need to be taken about where and when to remove snow. It is impracticable to provide 'summer-like' conditions at all times during winter months, and compromises may have to be made. This may involve decisions not to clear snow from most minor roads, or to keep only a limited number of lanes open on multi-lane roads.

**1.4.5 Safety**

Accidents have proved to be an inevitable result of road transport, and deaths and injuries are very tangible impacts of roads on the community. The factors contributing to safety are engineering, education and enforcement. In many countries, the climate also has a significant impact. In this context, education aims at changing behavior through publicity and raised awareness. While education and enforcement fall outside the scope of this book, it must be appreciated that all four factors interact, and that different combinations of factors are likely to have different impacts. However, in extreme cold climates, the special requirements associated with them will dominate.

**1.4.6 Environmental issues**

The condition of roads also affects the environment. This is important in all cases, and there is a growing public expectation for their surroundings to be managed properly. As noted above in sub-section 1.4.3, roads in poor condition also lead to wasted non-renewable resources and contribute to air pollution from vehicles that are not operating efficiently. A further example is the need to consider the noise characteristics of different pavement treatments at the treatment selection stage, particularly in sensitive areas, such as those adjacent to hospitals or schools. Similarly, street lighting plays a vital part in crime prevention and the safety of vulnerable groups.

**Example:** Find the annual revenue resulted from reduction in the vehicle operation and travel time costs as a result of rehabilitation old road in Iraq (Case study: Abu Gar quarry project).

تبين الدراسة المرورية ان نسبة سيارات الحمل الى مجموع المركبات هي (77%) مصنفة الى نوعين رئيسين من المركبات الثقيلة وهي ( 3-S2 Type ) وبنسبة (11% ) و ( TYPE 3 ) وبنسبة ( 66% ) .

سوف نعبر عن (type 3 ) كمركبة متوسطة ممثلة بالرمز ( MT ) ( Medium Truck ) أما نوع ( Type 3-S2 ) كمركبة كبيرة ممثلة بالرمز ( LT ) ( Large Truck ).

معدل حجم المرور السنوي(AADT) = 65700 (مركبة\سنة)

طول الطريق(كم)= 47.781

تصنيف المركبات الى ثلاث انواع وهي:

PC: passenger Car 23%

MT: Medium Truck 66%

LT: Large Truck 11%

**جدول(1) :كلفة وحدة الوقود والاطارات والزيوت للمركبات**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | fuel cost | tire cost | average no. tire/vehicle | Oil cost |
|  | US$/l | ID/l | US$/tire | ID/tire |  | US$/l | ID/l |
| passenger car | 0.035 | 400 | 30 | 37500 | 4 | 1.75 | 2187.5 |
| medium truck | 0.02 | 400 | 200 | 250000 | 8 | 1 | 1250 |
| large truck | 0.02 | 400 | 200 | 250000 | 16 | 1 | 1250 |

**جدول ( 2):الكلف التخمينية لاستخدام مركبة الصالونPC**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Oil consumption [l\*1000 km]** | **Tire life****[1000 km]** | **Fuel consumption****[l/km]** | **Average IRI influenced speed****[km/h]** | **IRI****[m/km]** | **Pavement condition** | **Link type** |
| 2.15 | 40.7 | 0.073 | 80 | 4 | Good | **4** |
| 7.3 | 0.8 | 0.157 | 35 | 14 | Bad- very bad | **11** |

 **جدول ( 3):الكلف التخمينية لاستخدام مركبة ثقل متوسطةMT**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Oil consumption [l\*1000 km]** | **Tire life****[1000 km]** | **Fuel consumption****[l/km]** | **Average IRI influenced speed****[km/h]** | **IRI****[m/km]** | **Pavement condition** | **Link No.** |
| 3.67 | 40.7 | 0.148 | 70 | 4 | Good | **4** |
| 10.34 | 0.8 | 0.308 | 27 | 14 | Bad- very bad | **11** |

 **جدول (4 ):الكلف التخمينية لاستخدام ثقل كبيرةLT**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Oil consumption [l\*1000 km]** | **Tire life****[1000 km]** | **Fuel consumption****[l/km]** | **Average IRI influenced speed****[km/h]** | **IRI****[m/km]** | **Pavement condition** | **Link No.** |
| 5.75 | 40.7 | 0.168 | 60 | 4 | Good | **4** |
| 14.5 | 0.8 | 0.389 | 20 | 14 | Bad- very bad | **11** |

**جدول( 5 ):قيمة الوقت للركاب**

|  |  |  |
| --- | --- | --- |
|   | time value  |   |
| year | US$ /Person-Hour | ID/Person-Hour |
| 2010 | 1.0464 | 1308 |
| 2015 | 1.2752 | 1594 |
| 2020 | 1.4519 | 1814 |
| 2025 | 1.6701 | 2087 |
| 2030 | 1.9332 | 2416 |
| 2035 | 2.1567 | 2696 |

**جدول( 6 ):قيمة الوقت للحمولة**

|  |  |  |
| --- | --- | --- |
|   | time value  |   |
| year | US$ / ton-Hour | ID/ton-Hour |
| 2010 | 0.0186 | 23.25 |
| 2015 | 0.0184 | 23 |
| 2020 | 0.0175 | 21.875 |
| 2025 | 0.0165 | 20.625 |
| 2030 | 0.0154 | 19.25 |
| 2035 | 0.0146 | 18.25 |

**كلفة تشغيل المركبات**

**كلف تشغيل PC**

الطريق المقترح link type 4

كلفة الوقود= 400x 0.073 =29.2 دينار\كم-مركبة ركاب

كلفة تبديل الاطارات =( 4 x37500 )\40700 =3.686 دينار\كم-مركبة ركاب

كلفة الزيوت =( 2.15x 2187.5 )\1000= 4.703 دينار\كم-مركبة ركاب

نفرض سعر المركبة 12000000 دينار، كلفة الصيانة 0.15 xكلفة الشراء ، 250000 كم تسير قبل ان تترك

كلفة الصيانة =(0.15 x 12000000 )\250000 =7.2 دينار\كم-مركبة ركاب

**الكلفة الكلية لتشغيل مركبة الركاب** = 44.789 دينار\كم-مركبة ركاب

الطريق الحالي link type 11

كلفة الوقود= 400x 0.157 =62.8 دينار\كم-مركبة ركاب

كلفة تبديل الاطارات =( 4 x37500 )\800 =187.5 دينار\كم-مركبة ركاب

كلفة الزيوت =( 7.3 x 2187.5 )\1000= 15.968 دينار\كم-مركبة ركاب

نفرض سعر المركبة 12000000 دينار، كلفة الصيانة 0.3 xكلفة الشراء ، 250000 كم تسير قبل ان تترك

كلفة الصيانة =(0.3 x 12000000 )\250000 =14.4 دينار\كم-مركبة ركاب

**الكلفة الكلية لتشغيل مركبة الركاب** = 280.668 دينار\كم-مركبة ركاب

**كلف تشغيل MT**

الطريق المقترح link type 4

كلفة الوقود= 400x 0.148 =59.2 دينار\كم-مركبة متوسطة

كلفة تبديل الاطارات =( 8 x250000 )\40700 =49.14 دينار\كم-مركبة متوسطة

كلفة الزيوت =( 3.67x 1250 )\1000= 4.588 دينار\كم-مركبة متوسطة

نفرض سعر المركبة 60000000 دينار، كلفة الصيانة 0.15 xكلفة الشراء ، 500000 كم تسير قبل ان تترك

كلفة الصيانة =(0.15 x 60000000 )\500000 =18.00 دينار\كم-مركبة متوسطة

**الكلفة الكلية لتشغيل مركبة متوسطة** = 130.928دينار\كم-مركبة متوسطة

الطريق الحالي link type 11

كلفة الوقود= 400x 0.308 =123.2 دينار\كم-مركبة متوسطة

كلفة تبديل الاطارات =( 8 x250000 )\800 = 2500دينار\كم-مركبة متوسطة

كلفة الزيوت =( 10.34x 1250 )\1000= 12.925 دينار\كم-مركبة متوسطة

نفرض سعر المركبة 60000000 دينار، كلفة الصيانة 0.3 xكلفة الشراء ، 500000 كم تسير قبل ان تترك

كلفة الصيانة =(0.3 x 60000000 )\500000 =36.00 دينار\كم-مركبة متوسطة

الكلفة الكلية لتشغيل مركبة الركاب = 44.789 دينار\كم-مركبة متوسطة

**الكلفة الكلية لتشغيل مركبة متوسطة** = 2672.125 دينار\كم-مركبة متوسطة

**كلف تشغيل LT**

الطريق المقترح link type 4

كلفة الوقود= 400x 0.168 =67.20 دينار\كم-مركبة كبيرة

كلفة تبديل الاطارات =( 16 x250000 )\40700 =98.28 دينار\كم-مركبة كبيرة

كلفة الزيوت =( 5.75x 1250 )\1000= 7.188 دينار\كم-مركبة كبيرة

نفرض سعر المركبة 60000000 دينار، كلفة الصيانة 0.15 xكلفة الشراء ، 500000 كم تسير قبل ان تترك

كلفة الصيانة =(0.15 x 60000000 )\500000 =18.00 دينار\كم-مركبة كبيرة

**الكلفة الكلية لتشغيل مركبة كبيرة** = 190.668دينار\كم-مركبة كبيرة

الطريق الحالي link type 11

كلفة الوقود= 400x 0.389 =155.6 دينار\كم-مركبة كبيرة

كلفة تبديل الاطارات =( 16 x250000 )\800 =5000 دينار\كم-مركبة كبيرة

كلفة الزيوت =( 14.5x 1250 )\1000= 18.125 دينار\كم-مركبة كبيرة

نفرض سعر المركبة 60000000 دينار، كلفة الصيانة 0.3 xكلفة الشراء ، 500000 كم تسير قبل ان تترك

كلفة الصيانة =(0.3 x 60000000 )\500000 =36.00 دينار\كم-مركبة كبيرة

**الكلفة الكلية لتشغيل مركبة كبيرة** = 5209.725دينار\كم-مركبة كبيرة

**جدول( 7):كلف تشغيل المركبات(الصالون،الثقيلة المتوسطة،الثقيلة الكبيرة)**

|  |  |
| --- | --- |
|   | passenger car/ Link type 4 and Link type 11 costs |
|  | **Link type 4** | **Link type 11** |
| Fuel consumption | 29.200 | 62.8 |
| tire cost | 3.686 | 187.5 |
| oil consumption cost | 4.703 | 15.96875 |
| maintenance cost | 7.200 | 14.4 |
| **Total ID/km-PC** | **44.789** | **280.66875** |
|   |  |   |
|   | Medium truck / Link 4 and Link 11 costs |
|   | **Link type 4** | **Link type 11** |
| Fuel consumption | 59.200 | 123.2 |
| tire cost | 49.140 | 2500 |
| oil consumption cost | 4.588 | 12.925 |
| maintenance cost | 18.000 | 36 |
| **Total ID/km-MT** | **130.928** | **2672.125** |
|   |  |   |
|   | Large truck / Link 4 and Link 11 costs |
|   | **Link type 4** | **Link type 11** |
| Fuel consumption | 67.200 | 155.6 |
| tire cost | 98.280 | 5000 |
| oil consumption cost | 7.188 | 18.125 |
| maintenance cost | 18.000 | 36 |
| **Total ID/km-LT** | **190.668** | **5209.725** |

**جدول ( 8 ): معدل كلف التشغيل ومعدل العوائد**

|  |  |  |  |
| --- | --- | --- | --- |
| نسبة المركبات | 0.23 | 0.66 | 0.11 |
| Link type | PC | MT | LT |
| 11 | 280.668 | 2672.125 | 5209.725 |
| 4 | 44.789 | 130.928 | 190.668 |
| العوائد (فرق كلف التشغيل) | 235.879 | 2541.197 | 5019.057 |
| معدل العوائد(عراقي دينار\كم-مركبة) | **2,283.54** |   |   |
| طول الطريق(كم)= 47.781 | **109,109** | معدل العوائد (عراقي دينار\مركبة) |   |

**عوائد زمن الرحلة Travel Time))**

بالامكان إيجاد كلف الزمن للركاب (passenger) والحمولة (fright) وللسنوات من 2010 لغاية 2039 .

تم قياس الوقت المستغرق للمركبة لطول الطريق الحالي ،حيث كانت سرعة المركبات PC على الطريق كمعدل 35 كم\ساعة وسرعة المركبات MT كمعدل 27 كم\ساعة اما المركبات LT فكانت 20 كم\ساعة.

زمن مركبة الصالون= PC= 1.365 ساعة

زمن المركبات المتوسطة MT == 1.769 ساعة

زمن المركبات الكبيرة LT = = 2.389 ساعة

اما الوقت المستغرق للمركبات على الطريق المقترح ،تم تقدير سرعة مركبة الصالون PC بـ 80 كم\ساعة و 70 كم\ساعة للمركبات MT و 60 كم\ساعة للمركبات LT

وبالتالي سيكون الوقت المستغرق في الرحلة للطريق المقترح حوالي :

زمن مركبة الصالون= PC= 0.597 ساعة

زمن المركبات المتوسطة MT == 0.682 ساعة

زمن المركبات الكبيرة LT = = 0.796 ساعة

**جدول( 9): الزمن المستغرق للمركبات للطريق الحالي والمقترح(الجديد)**

|  |  |  |
| --- | --- | --- |
| في الطريق الحالي(pc)(ساعة) | في الطريق الحالي(MT)(ساعة) | في الطريق الحالي(LT)(ساعة) |
| 1.365171429 | 1.769666667 | 2.38905 |
| 35 km/h | 27 km/h | 20km/h |
|   |   |   |
|   |   |   |
| في الطريق الجديد(pc)(ساعة) | في الطريق الجديد(MT)(ساعة) | في الطريق الجديد(LT)(ساعة) |
| 0.5972625 | 0.682585714 | 0.79635 |
| 80 km/h | 70 km/h | 60 km/h |
|   |   |   |
| فرق الزمن (ساعة) | فرق الزمن (ساعة) | فرق الزمن (ساعة) |
| **0.768** | **1.087** | **1.593** |

**محصلة العوائد(لزمن الرحلة)**

1. **معدل العائد للركاب**

على فرض وجود (2) راكب في السيارة الصالون و (1.5) في سيارة الحمل.ان فرق الزمن للمركبات بانواعها هو فرق الزمن بين استخدام الطريق الحالي والمقترح وسيكون كالاتي:

PC= 0.768 ساعة

MT= 1.087 ساعة

LT= 1.593 ساعة

 **جدول(10): معدل العائد للركاب للسنوات من (2010-2039)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **نسبة المركبات** | **0.23** | **0.66** | **0.11** |  |
| **عدد الاشخاص في المركبة** | **2** | **1.5** | **1.5** |  |
| **year** | **PC** | **MT** | **LT** | **معدل العائد للركاب (دينار\مركبة)** |
| **2010-2014** | 2,008.85 | 2,132.85 | 3,124.88 | 2,213.455 |
| **2015-2019** | 2,448.09 | 2,599.21 | 3,808.15 | 2,697.437 |
| **2020-2024** | 2,787.32 | 2,959.37 | 4,335.83 | 3,071.211 |
| **2025-2029** | 3,206.21 | 3,404.13 | 4,987.44 | 3,532.770 |
| **2030-2034** | 3,711.30 | 3,940.40 | 5,773.14 | 4,089.307 |
| **2035-2039** | 4,140.37 | 4,395.95 | 6,440.58 | 4,562.078 |

1. **معدل عائد الحمولة**

عائد الوقت للحمولة (fright) سيتم احتسابها عل فرض ان حمولة المركبة (MT) يساوي 20 طن والمركبة (LT) يساوي 34 طن.

**جدول(11): معدل العائد للحمولة للسنوات من (2010-2039)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **نسبة المركبات** | **0.23** | **0.66** | **0.11** |  |
| **وزن الحمولة (طن)** | **0** | **20** | **34** |  |
| **year** | **PC** | **MT** | **LT** | **معدل العائد للحمولة (دينار\مركبة)** |
| **2010-2014** | 0 | 505.49 | 1,259.03 | 472.12 |
| **2015-2019** | 0 | 500.06 | 1,245.49 | 467.04 |
| **2020-2024** | 0 | 475.60 | 1,184.57 | 444.20 |
| **2025-2029** | 0 | 448.42 | 1,116.88 | 418.81 |
| **2030-2034** | 0 | 418.53 | 1,042.42 | 390.89 |
| **2035-2039** | 0 | 396.78 | 988.27 | 370.59 |

**مجموع العوائد=عائد تشغيل المركبات+عائد الوقت للركاب (لسنة معينة)+عائد الوقت للحمولة(لسنة معينة)**

**=109,109+2,697+467**

**=112273 (عراقي دينار\مركبة)**

**العوائد الكلية السنوية ( (annual revenue= مجموع العوائدx حجم المرور السنوي**

**= 112273x65700**

**=7376336100 دينار عراقي**

**H.W 1:**