Transport Logistics: Potential Traffic Related Spin-off Benefits

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ABSTRACT

This paper focuses on a preliminary evaluation of the potential traffic related spin-off benefits resulting from the application of computerized transport logistics management systems (CTLMS) in the public and private trucking industry.

This study considered results from both a case study of pickup and delivery operations at a trucking terminal and various study results found in the literature. A range of potential reduction in truck traffic was considered based upon the efficiency gains found in these studies. The case study results showed that truck traffic could potentially be reduced by as much as 50% as shown by a comparative analysis between the existing manual routing and scheduling methods and CTLMS. CTLMS provided a better logistic decision making process and therefore significantly improved the efficiency.

Various effects of reducing the truck traffic on roadways were quantified. A reduction in truck traffic has a positive effect on level of service, and extends the life of a highway from this perspective. Safety benefits are also expected with a reduction in truck volumes; the corresponding reduction in truck related accidents are estimated and the economic safety benefits are quantified. The reduction in truck volumes results in a corresponding reduction in the number of axle load repetitions, and therefore a preliminary estimate of the expected increase in economic life of the pavement structure is determined.

These preliminary results suggest that using CTLMS applications is another good means to improve the efficiency of the transportation system in addition to building more highway infrastructure or improving the efficiency of the vehicles.

Key Words

Transportation Logistics Optimization, Truck Traffic Reduction, Logistics Optimization Benefits, Traffic Reduction Benefits, Vehicle Optimization Benefits

1.0 Introduction

This paper is a preliminary evaluation of the potential traffic related spin-off benefits of computerized transport logistics management systems (CTLMS) application in both the public and private trucking industry. The objective here is to demonstrate the potential spin-off benefits of implementing, in the trucking industry in general, an operating policy of using CTLMS for all truck routing and scheduling. The direct economic benefits of CTLMS applications in the trucking industry are not quantified in this paper. The preliminary evaluation of the potential traffic related spin-off benefits were grouped into three main categories: Safety, Level of Service (LOS), and Pavement Structure.

In the first phase of this study a potential percentage reduction in truck traffic was determined as a result of CTLMS applications. In the literature, potential reduction in truck traffic was found to be generally between 10% and 35% depending on the nature and the characteristics of the trucking operation [1]. A previous case study that was completed by Christie and Satir showed that truck traffic could potentially be reduced by as much as 50% in pick up and delivery operations as shown by a comparative analysis between the existing manual routing and scheduling methods and CTLMS [1]. It should also be noted that there are many computer software packages used currently by the trucking industry as a means of assisting in record keeping, which do not do real overall optimization. These packages are not considered as CTLMS applications.

Trucking routing can be grouped into arc routing and point-to-point routing. When CTLMS is applied to an arc routing operation (that is: garbage collection, sanding and salting operations, street plowing and sweeping, mail delivery, etc.), it is potentially possible to reduce (from the manual methods) the dead head and create the optimum schedule for each truck and cover the transportation network in a more efficient way by assigning vehicles to the right districts and routes, which results in trucks traveling less over the transportation network. When CTLMS is used in point-to-point routing operations (that is: pick up and delivery operations, line haul freight movements, personnel and staff routing, etc.), the significant efficacy gains come from assigning the right vehicles to destinations and determining the visiting order of the destinations, which, relative to manual assignment procedures, potentially reduces the truck traveled distance by the fleet and truck traffic [1]. Therefore, CTLMS has the potential to reduce the truck traffic whether the nature of the operation is arc routing or point-to-point routing and regardless of the configurations of the trucks that are used.

The objective of this paper is not to prove that CTLMS can improve the efficiency in transportation operations nor to quantify what these efficiency gains would potentially be, but rather to determine what the spin-off benefits would be if the truck traffic were to be reduced to certain percentages from the current levels. However, practical experience with various CTLMS software packages demonstrates the range of potential efficiency gains in the trucking industry. Optrak customers, for example, reported reductions in their distribution cost of 10 to15 percent or more [8]. Another CTLMS package, Paragon Software Systems, has resulted in up to 20 percent reduction of transport costs for users [9]. Also, TruckStops (another CTLMS package) users reported savings of 10 to 30 percent in various trucking operations [10]. Some of the TruckStops customer case studies have been published in several journals and magazines which report savings of this magnitude [11] such as Pepsi Americas [12], King Provision Company [13], and Jayway Distribution [14].

Since the objective of this paper is to evaluate CTLMS spin-off benefits in Canada, three general and conservative scenarios of truck traffic reduction and their spin-off effects were quantified. The three scenarios are, respectively, based on an assumption of reducing truck traffic nationwide by: Low 10%, Normal 20%, and High 30% with CTLMS application. It is expected that, if CTLMS applications are adopted by the public and private trucking industry, the truck traffic reduction of Low 10% will most likely initially be obtained and subsequently Normal 20% and High 30% of truck traffic reduction will be achievable if specific CTLMS were to be developed for each particular type of freight operation. Once CTLMS starts to be developed and customized for specific freight operations, it will be able to handle and satisfy more constraints of the particular freight operation type, which in turn has the potential to significantly improve the efficiency and reduce the truck traffic.

2.0 Safety Benefits

Safety is becoming an increasingly important issue, particularly as it relates to heavy truck accidents and corresponding fatalities in Canada. In general public perception, heavy trucks (drivers) cause more accidents and they have a worse driving safety record than that of normal passenger car drivers. The truth is heavy truck accidents are much less than those of passenger cars when compared in terms of the number of collisions per driven distance. The main reason for this public perception is that, when heavy trucks are involved in a collision, the personal injury percentage and, in particular, fatality percentage is greater than typical passenger car collisions.

The typical approach to solving truck traffic accident problems would be to invest in highway infrastructure, which can be an expensive solution and in most cases the investment cannot be justified if the benefit and cost ratio is not greater than one. CTLMS applications are a very promising means to reduce the number of heavy truck accidents even if the accidents per kilometer rate will remain the same.

Table 1 shows the average heavy truck accidents per year between 1994 and 1998 [5] and also shows the reduction in fatalities, personal injuries, and property damage only (PDO) collisions for the three assumed scenarios: Low 10%, Normal 20%, and High 30%. For the Low 10% scenario, a total reduction 55 fatalities, 1185 injuries, and 3522 PDO collisions is achieved, while the High 30% scenario results in a reduction of 166 fatalities, 3554 injuries and 10565 PDO collisions. Figure 1 shows the relative comparisons of annual heavy trucks involved in fatalities for different truck traffic scenarios. Although in this study the safety benefits were not quantified in terms of dollar value to avoid assuming the price of a human life, it can still be concluded that the economic benefits of the reduced truck traffic will be in the billions of dollars range nationwide if the potential dollar contributions to the economy of saving human lives, injuries, and PDO collisions were to be considered.

3.0 Level of Service Benefits

Transportation is a part of a broader economic system and it is essential to sustain a reasonable transportation system in order to have a functional and flourishing economy in the country. Approximately 80% of all goods are moved by trucks through the highway systems in Canada [6]. It has been estimated that in the next 10 years, the number of trucks on the highway system will double [6] and Transport Canada research also suggests that for-hire truck traffic is expected to increase by twice the rate of rail and marine modes [7] due to the growth in the economy and demand for freight shipments.

Potential reduction in truck traffic will have two major impacts on the highway infrastructure LOS. One, of which, will be improving the LOS directly due to the reduction in truck traffic and the other one will be extending the deadline of highway upgrades to meet and remain at a minimum LOS.

Table 2 shows that as of year 2002 the ratio of total number of trucks to the number of all vehicles [4] is only about 3.5%, while the driven distance ratio of trucks to all vehicles is about 7.5%. When fuel purchase is considered the ratio is almost 20%. The table shows clearly that while the number of trucks is relatively less compared to the other vehicles, they are driven significantly greater distances per vehicle and they also consume more fuel per driven distance which is a serious environmental concern. Table

2 also shows that, if the High 30% reduction in truck traffic is achieved, the heavy truck percentage would drop to 2.5%, the truck distance driven percentage would drop to 5.35%, and the truck fuel consumption percentage would be only 14.85%.

Figure 2 shows the drop of the annual distance driven in terms of kilometers per year for heavy trucks and savings for each of the three truck traffic reduction scenarios.

3.1 LOS Improvements Benefits

In the Highway Capacity Manual (HCM) 2000, the level of service analysis for a highway section is obtained by using passenger car volumes [3]. In reality heavy vehicles are present in almost every section of the highway. Therefore, HCM proposes to convert truck volumes to equivalent passenger car volumes with an adjusting factor since heavy vehicles in the traffic stream decreases the free-flow speed. Exhibit 20-9, in HCM, Passenger Car Equivalents for Trucks and RVs to Determine Speeds on Two-way and Directional Segments, suggests that the conversion factor should be between 1.1 to 2.5 for trucks depending on the conditions related to level or rolling terrain and the range of traffic flow rates [3].

Table 3 presents the passenger car equivalent (PCE) driven distance savings in terms of both million kilometers per year and percentage from the current distance driven for the three different conversion factors: Low 1.1, Normal 1.5, and High 2.5 for each of the three truck traffic reduction scenarios. For a Normal 1.5 factor, PCE volume saving is

1.1%, 2.2% and 3.2%, respectively, for 10%, 20% and 30% truck traffic reduction assumptions. These results suggest that LOS will improve between 1% and 5% as a general average depending on the variables such as: type of terrain, truck traffic ratio, and total traffic since LOS is directly dependent on all these factors. It should be noted that the proposed improvements would be significantly higher in some sections of the highway, especially in rolling terrain, with high truck traffic, and two-lane highway conditions.

Figure 3 shows the relative comparison of passenger car equivalent distance driven under the three truck traffic reduction scenarios with the assumption of 1.5 for the conversion factor to convert trucks to the passenger car equivalent.

3.2 LOS Upgrade-timing Benefits

Every government has the responsibility to maintain a minimum LOS for their transportation facilities. If the traffic volume is too high and causes a LOS failure, federal and provincial departments of transportation or municipal governments have to upgrade their transportation system in order to maintain its functionality. Almost every kind of LOS improvement will take a significant amount of money from their budget. CTLMS has the potential to improve LOS without any physical change to the transportation network. Since there will not be any need for investment until the minimum LOS standard is reached, governments will not have extra strain on their budget and they will be able to reallocate that money to other areas in their transportation system, depending on their priorities and needs.

Table 4 presents the number of years that will be gained with CTLMS applications under different truck traffic growth scenarios. As shown in the table, for a one time truck traffic reduction of 20%, it will take about 22.4, 7.5, and 4.6 years at 1%, 3%, and 5% annual truck traffic growth rates, respectively, for truck traffic volume to reach the same original volume.

Since table 4 represents truck traffic only, table 5 was also prepared to further analyze the effects of truck traffic reduction in terms of the total traffic and the impact on LOS. As discussed above, truck traffic is converted to passenger car equivalents (Table 3) in order to combine the truck traffic and passenger car traffic to determine a LOS for a highway.

Table 5 and Figure 4 present the number of years to be gained with CTLMS applications under different annual passenger car equivalent traffic growth rates. There are three (Low 1.5%, Normal 3%, and High 4.5%) scenarios of truck traffic reduction effects to overall traffic volumes computed for each annual PCE growth rate. There is potential to gain between 0.51 and 4.63 years on average to reach the same LOS and traffic volumes depending on the different scenarios and characteristics of different sections of the highways.

4.0 Pavement Structure Benefits

In the Pavement Design and Management Guide (PDMG), the general factors influencing pavement designs are grouped as follows [2]:

1. Traffic loading (volumes, growth rates, axle loads and distribution, tire pressures, vehicle suspension characteristics, etc.)
2. Environmental conditions (precipitation, moisture in pavement layers, temperature ranges, freeze-thaw cycles)
3. Available pavement structure(s) (materials, material properties, unit costs, thickness ranges, etc.)
4. Expected quality of construction and maintenance
5. Constraints (funds, minimum ride quality, etc.)

In the programming, design, construction, maintenance and rehabilitation of pavements, it is desirable to think of the progressive deterioration over the pavement life-cycle in terms of traffic load and environmental causes [2]. PDGM suggests that design engineers should incorporate a prediction of the number of load repetitions, and the concept of equivalent single axle loads (ESALs), in design methods, in order to have a good estimate of traffic loadings from the time a pavement is put into service through the end of the anticipated overlay or other type of rehabilitation period.

There are several methods that can be used to determine ESALs. One of the commonly used methods of pavement design is the Modified Asphalt Institute Method [2] and the general equation used is:

ESAL= AADT * HVP * HVDF * NALV * TDY

where:

ESAL= Equivalent Single Axle Loads per Lane per Year

AADT= Average Annual Daily Traffic (all lanes, both direction)

HVP= Heavy Vehicle Percentage (divided by 100)

HVDF= Heavy Vehicle Distribution Factor (percent of heavy vehicles in the design lane)

NALV= Number of equivalent axle loads per heavy vehicle (Truck Factor)

TDY= Traffic Days per Year

Another method, considered for determining the design ESAL values from traffic forecasts, uses a simplified method developed in the Strategic Highway Research Program (SHRP). This simplified method determines the annual ESAL counts based on the Average Annual Daily Traffic (AADT), percentage of heavy vehicles and heavy vehicle or truck factors as follows [2]:

For 1 lane:

ESAL= 182.5 * AADT * TP * TF

For 2 lane:

ESAL= 182.5 * AADT * TP * TF * [1.57-0.083 * ln(AADT/2)]

For >2 lane:

$$ESAL = 182.5 * AADT * TP * TF * [1.44 - 0.083 * \ln(AADT/2)]$$

Note: Lanes = Number of lanes for a given direction

where:

ESAL= Equivalent Single Axle Loads in design lane per year

AADT= Average Annual Daily Traffic (all lanes, both direction)

TP = Truck Percent (divided by 100)

TF= Truck Factor (=0.76 for flexible pavements)

In most methods to determine ESAL, the determinant contributor is primarily the heavy vehicle volumes as discussed in the Modified Asphalt Institute Method and Strategic Highway Research Program Method (for one lane). The other ESAL determination methods recognize the contribution of passenger cars, but these methods are relatively complex and at the same time not necessarily accurate or significant since the passenger car contribution is smaller than 1% of the ESAL loading of heavy trucks.

Table 6 presents the expected life improvement percentage of the pavement structure when truck traffic reduction is achieved. These life improvement percentages are also presented graphically in Figure 5. Assuming that the same distribution of trucks will remain after Low 10%, Normal 20%, and High 30% reduction in truck traffic, ESAL repetitions will drop the same percentage over the proposed design life of the pavement. If the only determinant for the life of a pavement structure were ESAL, the life extension of the pavement would increase by approximately 11 %, 25%, and 43%, respectively, for 10%, 20%, and 30% truck traffic reduction. In some areas, where the climate and other factors do not significantly contribute to the deterioration of the pavement structure, real pavement structure life improvement could potentially be as high as these expected improvements. Since climate is a big player in pavement life in Canada, the expected improvement percentages were divided by two to provide a more realistic estimate of the extended life of the pavement structure. Results suggest that the life improvement would potentially be between 6% and 21% on average depending on the truck traffic reduction. It means that, for a pavement with a 10 year design life, it would be possible to extend its life approximately between 7 months and 26 months.

5.0 Conclusions

The preliminary evaluation of the potential traffic related spin-off benefits resulting from the application of CTLMS in the trucking industry revealed that there can potentially be significant savings in safety, LOS, and pavement structure life.

In terms of safety benefits: 55 to 166 lives, 1185 to 3554 injuries, and 3522 to 10565 PDO collisions could potentially be saved annually as CTLMS applications results nationwide. The LOS benefits will occur from saving truck driven distance, which will be between 2361 and 7082 million kilometers. The passenger car equivalent traffic will reduce approximately between 1% and 5% depending on the truck traffic reductions and the highway characteristics. This reduction in traffic will benefit LOS and it would take about 6 mounts to 4.5 years to reach the same LOS experienced before CTLMS applications. The reduction in truck traffic is estimated to reduce the ESAL repetitions, which will extend the life of the pavement structure approximately between 6% and 21% or as much as 43% depending on the truck traffic reduction and other effects on the pavement such as climate.

These preliminary results suggest that using CTLMS applications is another good means to improve the efficiency of the transportation system in addition to building more highway infrastructure or improving the efficiency of the vehicles. The transportation policy makers should also consider taking a proactive role to promote CTLMS applications since its benefits are significant to the nation while its marginal cost to the public is minimal. Direct economic benefits of integrating and implementing CTLMS applications to the existing transportation operations are significantly higher than its costs. But there are not specific CTLMS available that do real overall optimization for each of the various types of truck transportation operations. Governments should take a strategic role to promote the development of such systems and develop implementation strategies as the potential return is significant.

Table 1 Annual Average of Heavy Truck Involved Accident Savings

Average Heavy Truck Involved Accidents Per Year				
	Base Case*	Low 10%	Normal 20%	High 30%
Fatal Collisions	456	410	365	319
Total Fatalities	554	499	443	388
Total Fatality Savings	-	55	111	166
Personal Injury Collisions	8169	7352	6535	5718
Total Injuries	11848	10663	9478	8294
Total Injury Savings	-	1185	2370	3554
PDO Collisions	35217	31695	28174	24652
PDO Collisions Savings	-	3522	7043	10565

*Base Case Source: [5] Heavy Truck Collisions 1994-1998, Dec. 2001, Transport Canada

Table 2 Heavy Truck Driven Distance Savings

	Base Case*	Low 10%	Normal 20%	High 30%
Total registered vehicles	18187960	18123530	18059100	17994670
Total registered heavy trucks	644301	579871	515441	451011
Total registered heavy truck savings	-	64430	128860	193290
Total registered heavy truck percentage	3.54	3.20	2.85	2.51
Estimates of all vehicles-million km/ year	315815	313454	311094	308733
Estimates of heavy trucks -million km/ year	23607	21246	18886	16525
Heavy truck million km savings	-	2361	4721	7082
Heavy truck km percentage	7.47	6.78	6.07	5.35
Vehicles fuel purchase estimate (million liters/year)	42943	42086	41230	40373
Trucks fuel purchase estimate (million liters/year)	8567	7710	6854	5997
Trucks fuel purchase savings (million liters/year)	-	857	1713	2570
Trucks fuel purchase percentage	19.95	18.32	16.62	14.85

*Base Case Source: [4] Canadian Vehicle Survey (for year 2002), Statistics Canada

Table 3 Passenger Car Equivalent Driven Distance Savings

	Base Case	Low 1.1	Normal 1.5	High 2.5
For Base Case 0% Reduction in Truck Traffic				
All vehicles-million km/ year	315815	-	-	-
Heavy truck PCE-million km/ year	23607	25968	35411	59018
PCE all vehicles-million km/ year	-	318176	327619	351226
For Low 10% Reduction in Truck Traffic Scenario				
PCE all vehicles-million km/ year	-	315579	324077	345324
PCE all vehicles saving percentage	-	0.8%	1.1%	1.7%
For Normal 20% Reduction in Truck Traffic Scenario				
PCE all vehicles-million km/ year	-	312982	320536	339422
PCE all vehicles saving percentage	-	1.6%	2.2%	3.4%
For High 30% Reduction in Truck Traffic Scenario				
PCE all vehicles-million km/ year	-	310385	316995	333520
PCE all vehicles saving percentage	-	2.4%	3.2%	5.0%

* PCE : Passenger Car Equivalent

Table 4 Number of Years to have the Original Truck Traffic Volume

	Base Case	Low 10%	Normal 20%	High 30%
Truck traffic percentage	100	90	80	70
Annual truck traffic growth : i=1%	0	10.6	22.4	35.8
Annual truck traffic growth : i=2%	0	5.2	11.3	18.0
Annual truck traffic growth : i=3%	0	3.6	7.5	12.1
Annual truck traffic growth : i=4%	0	2.7	5.7	9.1
Annual truck traffic growth : i=5%	0	2.2	4.6	7.3

Table 5 Number of Years Gained to Reach the Original PCE Traffic Volume

	Base Case	Low 1.5%	Normal 3%	High 4.5%
PCE* traffic volume percentage	100	98.5	97.0	95.5
Annual PCE traffic growth : i=1%	0	1.52	3.06	4.63
Annual PCE traffic growth : i=2%	0	0.76	1.54	2.33
Annual PCE traffic growth : i=3%	0	0.51	1.03	1.56

* Passenger Car Equivalent

Table 6 Highway Infrastructure Life Improvement Percentage

	Base Case	Low 10%	Normal 20%	High 30%
Heavy truck traffic reduction	0%	10%	20%	30%
ESAL* repetition over the design life	0%	10%	20%	30%
Expected Life Improvement based on ESAL	0.0%	11.1%	25.0%	42.9%
Real Life Improvement (half of expected)	0.0%	5.6%	12.5%	21.4%

* Equivalent Single Axle Load

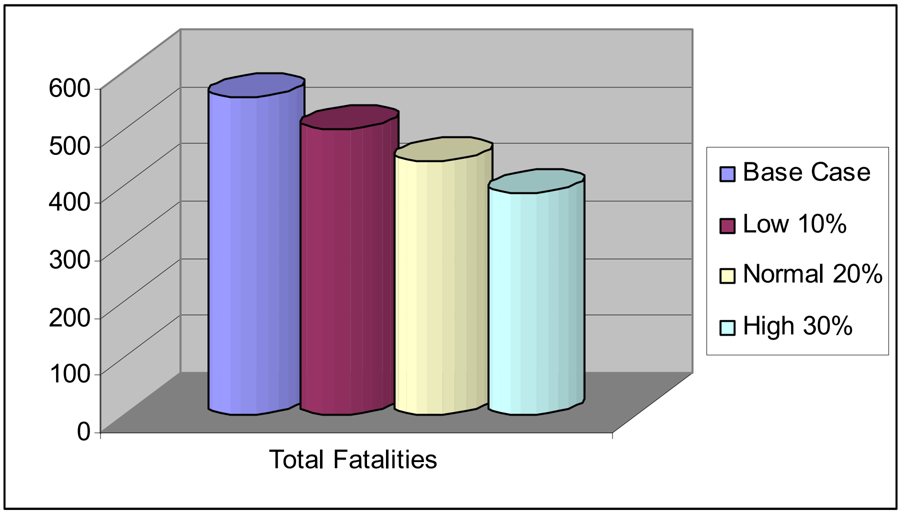

Figure 1 Annual Average Heavy Truck Involved Fatalities

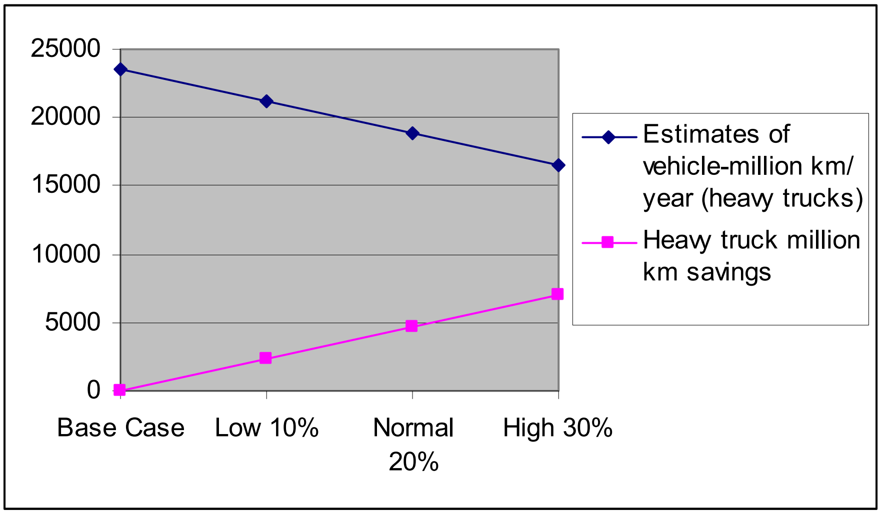

Figure 2 Heavy Truck Driven Distance Savings

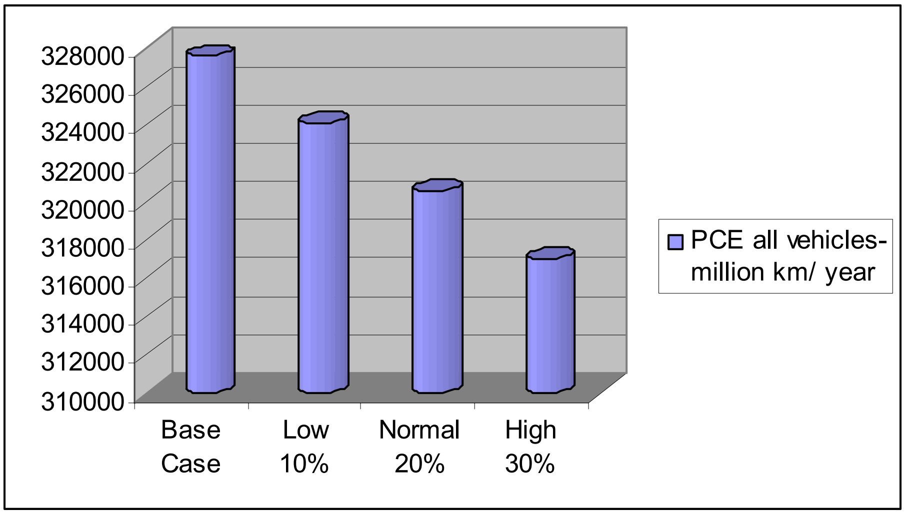

Figure 3 Reduction in Passenger Car Equivalent Distance Driven

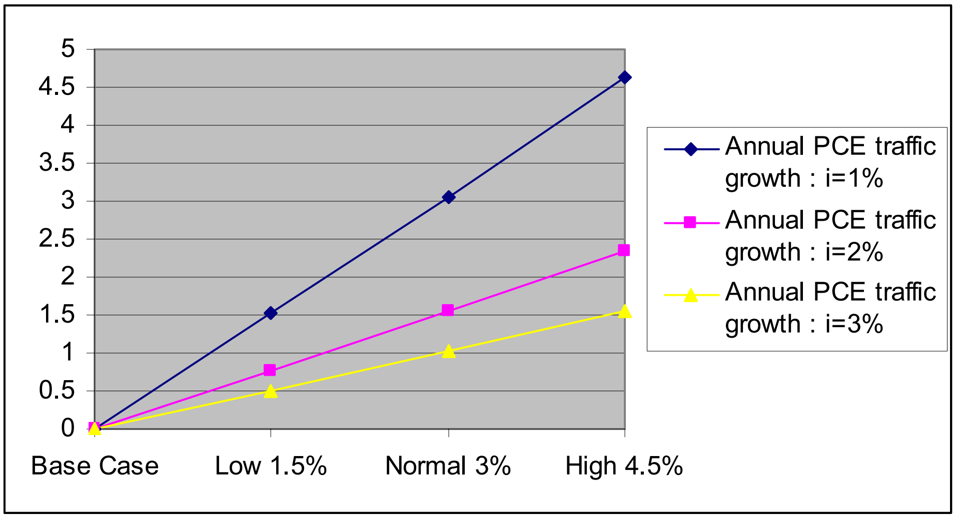

Figure 4 Number of Years Gained to Reach Original PCE Traffic Volume

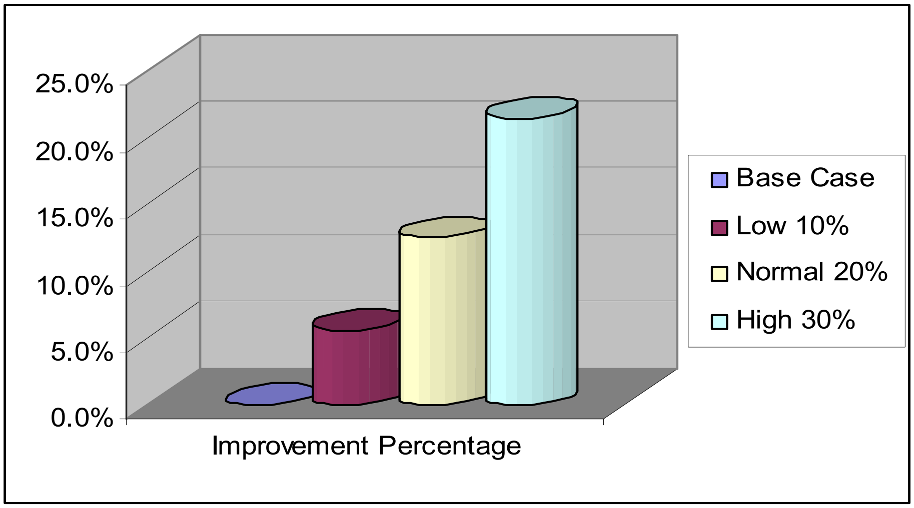

Figure 5 Pavement Structure Life Improvement Percentages

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