Evaluation of Treatment Choice, User Cost and Fuel Consumption of Two Roadways in Hamilton County Tennessee using HDM-4

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Lack of sufficient funding for infrastructure management is an issue in many State Departments of Transportation in the USA. This leads to deteriorating infrastructure that calls for proper management of resources. Pavement Management System (PMS) has demonstrated to be an essential tool for proper management of infrastructure and proper utilization of available funds. Numerous software have been developed for this purpose. The University of Tennessee at Chattanooga conducted a study that utilized HDM-4 software to determine the optimal utilization of available funds for Hamilton County in Tennessee using PMS. The software was used to assess the existing pavement conditions and predict future conditions of one state route and one interstate. Two pavement treatment options were assessed and results indicated that although micro-surfacing seemed to cost less, it does not necessarily improve all the distresses, while an overlay improves the roadway section significantly. In this study, HDM-4 software was used not only to provide the cost-effective maintenance treatment needed for a particular section or funding optimization, but also to estimate fuel consumption for the vehicle fleet, and to calculate the road agency and road user costs. From this study, fuel consumption was found to be higher at peak hours due to reduced traffic speeds. The road user cost was higher on the state route than the interstate due to traffic signals and stop and go motion. The road agency cost for the state route is calculated to be about four times higher than the agency cost for the interstate.

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Introduction

The city of Chattanooga in Hamilton County is the fourth largest city in the state of Tennessee. The county population was about 340,855 in 2011, (U.S. Census Bureau, 2012) and an annual traffic growth rate of 1.8% as provided by Tennessee Department of Transportation (TDOT). According to the American Society of Civil Engineers (ASCE) Infrastructure Report Card (2009), the state of Tennessee received an overall infrastructure grade of B minus (B^-), which is "good" but the funding aspect is lacking (C^-). Table 1 shows the 2009 ASCE Infrastructure report card for the state of Tennessee. From the table it can be seen that the quality of the pavement is good; however, capacity falls within the average scale and funding falls within average/poor scale. Proper allocation of limited available funds is required. ASCE encourages the use of cost-benefit analysis to properly utilize the available funds/resources, and improve the infrastructure performance and hence its grade (ASCE, 2009).

Table 1. *Assessment of Tennessee Roads [ASCE, 2009]*

	Weight	Grade
Pavement Quality	25%	87
Capacity	20%	76
Operation & Maintenance	15%	83
Funding & Future Need	15%	70
Public Safety	15%	83
Resilience	10%	85
Final Grade		81 = B-

Grading Scale		
A	Excellent	90 - 100%
B	Good	80 - 89%
C	Average	70 - 79%
D	Poor	51 - 69%
F	Failing	< 50%

Objective and Methodology

Due to limited state funding, the objective of this study was to use the World Bank pavement management software HDM-4 to facilitate a complete pavement analysis and funding prioritization for Hamilton county pavements. Input data and current pavement condition was provided by TDOT. Pavement deterioration models in HDM-4 were used for the analysis. An annual budget of one million dollars for interstates and two million for state routes was used to determine a cost-effective pavement treatment choice between micro-surfacing and overlay. The analysis output is the information on immediate maintenance requirements, user cost and fuel consumption especially if nothing is done on the pavements was required from the analysis.

Literature Review

Pavement management system is used to perform numerous analyses that provide relevant information for decision makers to select candidate projects according to available resources. Current pavement condition evaluation is performed before any maintenance or funding decisions can be made for each pavement section. (Baladi et al., 2000; Beckheet et al., 2008; Haas et al. 1975; Jordaan et al., 1986).

Other analyses such as travel time, fuel consumption, vehicle emissions, user costs and agency costs are performed to evaluate their effects on the project, road network and the environment. Huang, Bird, and Bell (2009) estimated fuel consumption using speed, flow, and queuing data provided by pavement management alternatives. To evaluate the alternatives that provide minimum delay to road users, they used a micro-simulation model, VISSIM (VISual SIMulation) (Huang et al., 2009). Studies have also indicated a reduction in fuel consumption with reduction in roughness index (IRI) (Gillespie and McGhee, 2007). Travel time and driver characteristics also affect fuel consumption. For this study, fuel consumption is estimated using HDM-4 by observing the quantity of fuel being consumed by each vehicle fleet during various flow periods (peak, medium, low).

According to Gillespie and McGhee (2007), pavement roughness reduces the ride quality for road users and increases vehicle operating cost. The time period required during roadworks (due to lane closures and detours) increases both agency and road users' costs. As a result, higher initial surface smoothness leads to reduced road user costs (Gillespie and McGhee, 2007). This study applies an overlay or micro-surfacing alternatives HDM-4 to determine the road user and agency costs.

HDM-4 Software

The Highway Development and Management Model version 4 (HDM-4) is a computer software program developed by the World Bank. This is a decision making tool for verifying the engineering and economic capability of investments in road projects. It incorporates features such as effects of traffic congestion on speed, fuel consumption, maintenance cost and impacts of vehicle emission. These features allow HDM-4 to be applied in any area of the world with any environmental and engineering situations. HDM-4 is capable of performing project analysis, program analysis and strategic analysis, in order to help determine the performance of a road (HDM).

Project analysis allows assembling of several road sections (or more than one road section) together under one agreement. Information such as project title, road network, and vehicle fleet are required to create a project. For a project analysis, work standards, general traffic composition and growth rate, extra benefits, and costs must be specified (Li et al., 2004). The major issues that the project analysis estimates are pavement structural performance, life cycle prediction of deterioration, maintenance effects and costs, road user costs and benefits, and economic comparison of project alternatives (Kerali, 2013). HDM-4 uses an analytical model to calculate the structural strength of the pavements under the given traffic loadings. The software calculates the deterioration of the road structure and the surface for each year of the analysis period. HDM-4 provides the cost of maintenance and the effects resulting from the cost. For instance, if the option is provided that whenever the roughness index reaches a value of 6 IRI (International Roughness Index), an overlay has to be applied. The software then calculates the increase in the roughness index every year after the application of traffic loading and whenever the roughness reaches 6 IRI, HDM-4 will recommend an overlay to be applied (HDM).

The program analysis deals primarily with the prioritization of a long list of candidate road projects into a one-year or multi-year work program under budget constraints. Program analysis deals with individual sections that have distinctive physical units distinguishable from the road network throughout the analysis (Kerali, 2013). Using program analysis, yearly maintenance program can be analyzed. The multi-year program method performs at least one preservation treatment assigned to each road section. These treatments are prompted based on distress threshold (Li et al., 2004). This study identified road sections in need of maintenance under the given budget using the program analysis option of HDM-4 software. The selection of candidate roads is by maximization of NPV/Cost. Alternative improvements can be determined and an optimized list of projects for the budget period is provided (HDM).

Strategic analysis is performed on the entire road network for long term budget planning or for optimizing the maintenance strategies (HDM). In strategy analysis, road segments with similar characteristics are grouped into the road network matrix categories (Kerali, 2013). The road network can be subdivided into sub-networks according to the main qualities that control the pavement performance, such as traffic volume or loading; pavement types; pavement condition; environment climatic zones; functional classification, etc. (Kerali, 2013). A life cycle analysis is performed for the analysis period by running the sub-networks to see which maintenance option will be appropriate for which sub-network, what is the total budget required and if enough money is not available, then optimization will be performed (HDM).

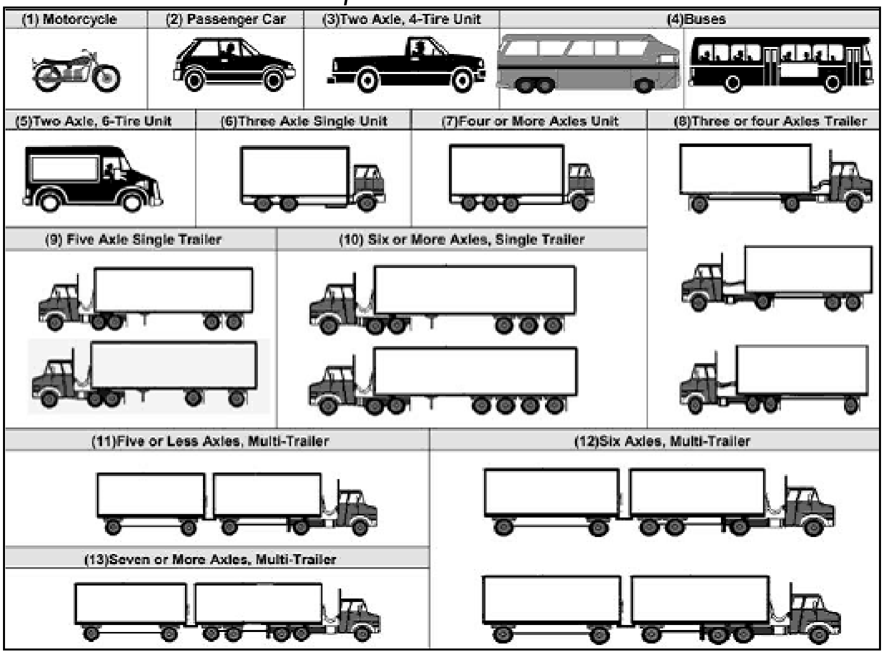
Life Cycle Analysis

For each case of project, program or strategic analysis, HDM-4 performs total life cycle conditions and costs analysis for the design/analysis period under a user-specified set of conditions. The main set of costs for the life cycle analysis comprises of the costs of capital investment, maintenance, vehicle operation, travel time, and accidents as an option. (Kerali, 1998). Environmental effects, such as vehicle emissions and energy consumption, can be calculated; however, they are not included in the cost streams. The Economic benefits are then determined by comparing the total cost streams for various maintenance and construction options with a case of doing nothing, usually representing minimal routine maintenance (Kerali, 1998). Environmental effects, accidents and vehicle emissions were not considered in this study due to lack of enough and relevant input information.

HDM-4 Input Data

From the Federal Highway Administration (FHWA) vehicle classification (Figure 1), passenger cars, single-unit (2-axle truck), and tractor trailers (multi-axle truck) were designated to represent vehicle fleets in Hamilton County. The annual traffic growth of 1.8% was used as provided by TDOT. The default values in HDM-4 were used for the basic vehicle fleet (physical and tires) characteristics. The physical characteristics include passenger car space equivalent which accounts for the relative space taken up by the vehicle, the number of wheels per vehicle, and the number of axles per vehicle. For a passenger car, there are 4 wheels per vehicle, 2 axles per vehicle, and the passenger car space equivalent factor is 1. Details on the vehicle characteristic input and utilization can be obtained on "Pavement Management Analysis of Hamilton County using HDM-4 & HPMA" (Sen, 2013).

Figure 1. *FHWA Vehicle Classification*



Source: onlinemanuals.txdot.gov

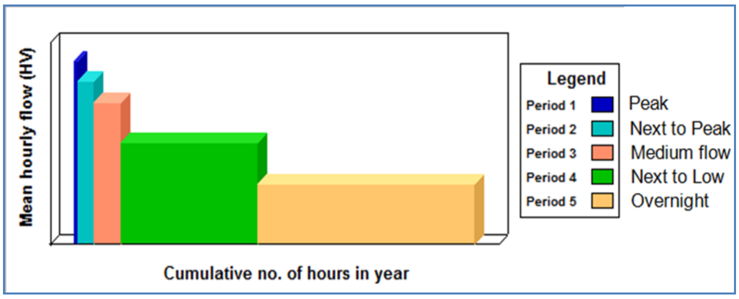
The equivalent single axle load (ESAL) factors for the vehicles were: 0.0001 for cars, 0.7 for single unit, and 1.25 for tractor trailer and the gross vehicle weight in tons. Each vehicle economic unit cost was determined based on the current fuel, vehicle, and labor costs. Each interstate and state route was defined based on length, carriageway width, traffic flow, shoulder width, and surface class. Carriageway width is the width of road including shoulder and auxiliary lanes devoted to the use of vehicles.

The default flow periods (Table 2) and default traffic flow distribution period (Figure 2) were used since they are similar to Hamilton County traffic flow. In order to take into account different levels of traffic congestion at different hours of the day, and on different days of the week and year, HDM-4 considers the number of hours of the year (traffic flow period) for which different hourly flows are applicable. For example, the first flow period or the peak period accounts for 87.6 hours a year with an hourly volume of 0.09.

Table 2. *Flow Distribution Data (World Bank, 2010)*

Period	Description	Hrs. per year	Hourly Volume (pcse/ln/hr)	Percentage of Annual Traffic on Each Period		
				Seasonal Road	Commuter Road	Inter-Urban Road
1	Peak	87.6	0.09	4.25	3.05	2.17
2	Next to Peak	350.4	0.08	13.24	11.33	7.59
3	Medium flow	613.2	0.07	16.60	16.55	11.64
4	Next to Low	2978.4	0.05	40.32	56.26	40.24
5	Overnight	4730.4	0.03	25.59	12.81	38.36

Figure 2. *Flow Distributions in HDM-4*



Source: HDM-4 Manual

The speed flow characteristics include the ultimate capacity of the road which is the maximum number of vehicles that can pass a point in one hour. The ultimate capacity (Qult) for local conditions is 2400 passenger car space equivalent per lane per hour (pcse/ln/hr) based on Level of Service (LOS) E, at a free flow speed of 75 mph for a two lane road. Level of Service (LOS) E is defined as when the operation is unstable and at or near capacity. Densities vary depending on the free-flow speed (HCM, 2000). For economic analysis, a discount rate of 4% was used as provided by TDOT. The costs were discounted at 4% to calculate the future value. Calibration values, such as pavement deterioration, were adjusted to local condition to receive accurate pavement performance predictions.

Analysis

HDM 4 was used to analyze state routes in Hamilton County and prioritize them according to maintenance need. A detailed analysis was performed on two road sections, Interstate 75 Sequence 1 and State Route 319 (Hixson Pike) Sequence 1. These particular roadway sections are shown in Figures 3 and 4. The term sequence is used for road sections identification. The route located within Hamilton County is identified as Sequence 1, when it leaves the county is identified as Sequence 2. For the two sections, detailed analysis on effects of the treatment choice, fuel consumption and user cost was performed.

Figure 3. *Interstate 75 Sequence 1 (TDOT Website, December 17, 2012)*

Figure 4. *State Route 319 Sequence 1 (TDOT Website, December 17, 2012)*

Input data required by HDM-4 was entered manually; data can be uploaded from access database if available in that format. The data entered include: surface class, pavement type, section length, traffic flow, shoulder width, speed flow type, traffic flow pattern, climate zone, road class, and Average Annual Daily Traffic (AADT). As stated earlier, two treatment alternatives were selected for each section: overlay maintenance and micro-surfacing. The project analysis tool on HDM-4 was performed for 10 years analysis period. Sections of Interstate 75 and SR 319 (Hixson Pike) of Hamilton County were selected to demonstrate these results.

Results

Treatment Choice / Pavement Condition

Parameters used to rate pavement roughness are given in Table 3. Figure 5 and Figure 6 are results from HDM analysis for I-75 and SR 319. On Figure 5, the average roughness for I-75, a primary road, deteriorates but remains within "very good" region (IRI < 2.5) if either overlay or micro-surfacing is applied in 2012. The roughness in Figure 6 for SR 319, a secondary road, shows that if either overlay or micro-surfacing is applied, the road section will remain within "good" condition (IRI = 2.0 - 3.0). It should be noted that, as expected, although for both cases the road condition is "good", micro surfacing treatment shows more deterioration as compared to overlay treatment.

Table 3. *Roughness Parameters for Bituminous Pavement in IRI*

Road Class	Very Good	Good	Fair	Mediocre	Poor
Primary	< 2.5	2.5 - 3.85	3.90 - 4.88	4.92 - 6.97	> 6.97
Secondary	< 2.0	2.0 - 3.0	3.12 - 3.90	3.94 - 5.58	> 5.58
Tertiary	< 1.6	1.6 - 2.46	2.50 – 3.12	3.16 – 4.47	> 4.47

Figure 5. *Average Roughness for I-75*

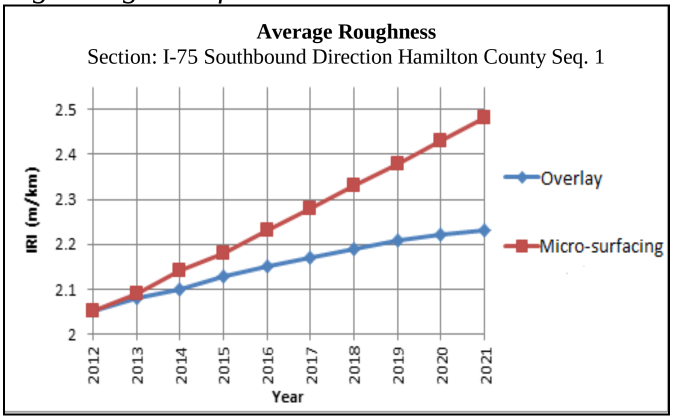
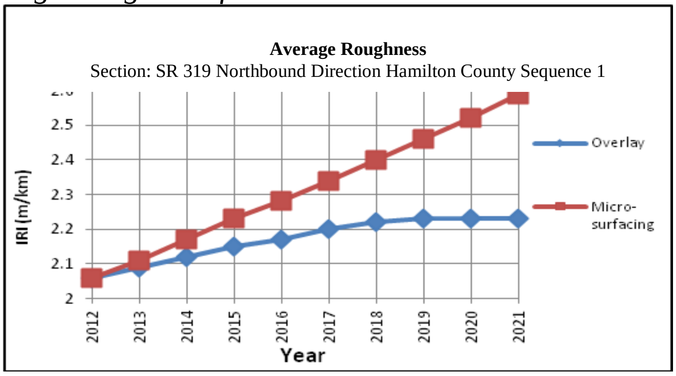


Figure 6. *Average Roughness for SR 319*



Defects resulting from damaged road surface such as cracking, potholes, edge break, and raveling in pavements, take time to occur. In HDM-4 a defect will have an initiation phase (a time delay before a defect occurs). This time is a function of the level of traffic, axle loads and a number of other pavement attributes, such as pavement strength. The intervention period $2 < IRI \leq 3$ placed for both maintenance alternatives suggest that when roughness falls within this range, the maintenance alternative should be applied. This roughness constraint is placed by TDOT in order to prevent the increase in maintenance cost. From the analysis using the two treatment alternatives, if the overlay is applied the pavement will remain in good condition for the analysis period. Micro-surfacing improves some of the parameters, the rut depth, for instance, is not significantly improved by this treatment choice.

Agency and User Cost

The road agency cost can be capital or recurrent cost depending on the pavement condition which defines the reasonable set of rehabilitation alternatives available for a particular pavement type. For this study, micro surfacing was considered as recurrent cost and overlay as capital cost. The Road Agency and User costs are summarized in Table 4 and Table 5 for the overlay alternative for I-75 and SR 319 respectively. All the costs are discounted at 4%.

Roadway construction/repairs can result in the increased road user cost due to lane closures, forcing traffic to travel under stop-and-go conditions. This increases road user travel time, fuel cost and vehicle maintenance costs. An alternative route (Detour) similarly results in increased cost due to increased travel time. In order to reduce road user costs, it is recommended to perform roadway repairs at night. The total transport cost is the addition of the agency and road user costs.

Results indicate that the overlay cost for I-75 in year 2012 is 78.811 million dollars (Table 4). HDM-4 provides a micro surfacing option to be 78.486 million dollars (Sen, 2013). The cost of the two alternatives is nearly identical, however the performance of overlay is far superior depicted on Figures 5 and 6. Similarly, the cost of overlay and micro-surfacing for SR 319 in year 2012 is 182.033 and 180.738 million dollars respectively (Table 5) (Sen, 2013). The cost of micro-surfacing is slightly lower than that of overlay treatment; however the performance of overlay is far superior to micro-surfacing (Figures 5 and 6).

Table 4. *Discounted Road Agency and User Cost on I-75 for Overlay*

Section: I-75 Southbound Direction Hamilton County Sequence 1 Alternative: Overlay							
Section ID: Int 75 M 33 1 0 Road Class: Primary or trunk Length: 4.30 km Width: 14.63 m Rise + Fall: 10.00 m/km Curvature: 5.00 deg/km							
Cost in millions of dollars							
Year	Road Agency Costs (RAC)			Road User Costs (RUC)			Total Transport Cost
	Capital	Recurrent	Total RAC	Motorized Traffic (MT)		Total RUC	
				Vehicle Operation	Travel Time		
2012	0.609	0.000	0.609	48.040	30.162	78.202	78.811
2013	0.586	0.000	0.586	47.156	29.895	77.051	77.636
2014	0.563	0.000	0.563	46.301	29.666	75.967	76.530
2015	0.541	0.000	0.541	45.483	29.476	74.960	75.501
2016	0.521	0.000	0.521	44.702	29.332	74.034	74.555
2017	0.501	0.000	0.501	43.933	29.306	73.239	73.739
2018	0.481	0.000	0.481	43.423	29.715	73.138	73.619
2019	0.463	0.000	0.463	42.789	29.794	72.584	73.046
2020	0.445	0.000	0.445	42.211	29.964	72.175	72.620
2021	0.428	0.000	0.428	41.695	30.242	71.937	72.365
Total	5.137	0.000	5.137	445.734	297.553	743.287	748.423
All costs are discounted at 4.00%							

Table 5. *Discounted Road Agency and User Cost on SR 319 for Overlay*

Section: State Route 319 Northbound Direction Hamilton County Sequence 1 Alternative: Overlay							
Section ID: SR 319 P 33 1 0 Road Class: Secondary or trunk Length: 34.30 km Width: 7.32 m Rise + Fall: 10.00 m/km Curvature: 15.00 deg/km							
Cost in millions of dollars							
Year	Road Agency Costs (RAC)			Road User Costs (RUC)			Total Transport Cost
	Capital	Recurrent	Total RAC	Motorized Traffic (MT)		Total RUC	
				Vehicle Operation	Travel Time		
2012	2.429	0.000	2.429	111.198	68.406	179.604	182.033
2013	2.335	0.000	2.335	108.878	67.018	175.896	178.231
2014	2.246	0.000	2.246	106.604	65.658	172.262	174.508
2015	2.159	0.000	2.159	104.376	64.327	168.704	170.863
2016	2.076	0.000	2.076	102.195	63.025	165.219	167.295
2017	1.996	0.000	1.996	100.058	61.749	161.808	163.804
2018	1.920	0.000	1.920	97.967	60.501	158.468	160.387
2019	1.846	0.000	1.846	95.919	59.279	155.198	157.044
2020	1.775	0.000	1.775	93.911	58.082	151.993	153.768
2021	1.706	0.000	1.706	91.944	56.911	148.855	150.561
Total	20.488	0.000	20.488	1,013.050	624.956	1,638.006	1,658.494
All costs are discounted at 4.00%							

The total user cost for SR 319 is almost double that of I-75 (Table 6) because SR 319 is subjected to stop-and-go traffic motion due to traffic signals and low travel speed limits. Slower traffic speeds result in increased travel time, hence, increased user cost. The road agency cost for SR 319 is about four times higher than the agency cost for I-75. SR 319 is more prone to pavement failures due to slow speeds. When slow heavy vehicles spend more time on a pavement section, they cause more damage on pavement sections. This causes more pavement deterioration that requires frequent maintenance to keep the roadway at acceptable condition. For the micro-surfacing alternative, the total transport cost decrease slightly due to the decrease in agency cost.

Table 6. *Fuel Consumption on I-75 for Passenger Cars*

Gallon per 1000 veh-mi (Liters per 1000 veh-km)					
Year	Period 1	Period 2	Period 3	Period 4	Period 5
2012	50.54 (118.98)	39.63 (93.29)	33.88 (79.77)	35.38 (83.30)	41.30 (97.22)
2013	50.55 (119.00)	40.98 (96.48)	34.31 (80.78)	34.99 (82.37)	41.13 (96.83)
2014	50.55 (119.01)	42.85 (100.87)	34.82 (81.97)	34.62 (81.50)	40.96 (96.43)
2015	50.56 (119.02)	45.10 (106.18)	35.48 (83.52)	34.28 (80.71)	40.78 (96.01)
2016	50.56 (119.03)	47.83 (112.61)	36.26 (85.37)	34.01 (80.06)	40.60 (95.58)
2017	50.56 (119.04)	50.56 (119.04)	36.39 (85.67)	33.66 (79.24)	40.41 (95.14)
2018	50.57 (119.05)	50.57 (119.05)	38.17 (89.87)	33.30 (78.39)	40.22 (94.68)
2019	50.57 (119.06)	50.57 (119.06)	39.48 (92.95)	32.92 (77.51)	40.03 (94.23)
2020	50.58 (119.07)	50.58 (119.07)	41.05 (96.64)	32.66 (76.90)	39.82 (93.75)
2021	50.58 (119.07)	50.58 (119.07)	42.90 (100.99)	32.61 (76.77)	39.62 (93.27)

Fuel Consumption

Vehicle fuel consumption is a function of pavement condition, travel time and speed, and driver characteristics, among other things. Vehicles consume less fuel when a pavement is in a good condition. However, pavement deterioration results in increase in roughness and surface distresses, hence, increase in fuel consumption. Roadway construction/repairs, contributes to increase in fuel consumption. Lane closures during pavement maintenance force traffic to travel under stop-and-go motion, resulting in higher fuel consumption. Fuel consumption may be minimized by performing roadway repairs during off peak periods, traveling at the posted speed limit and reducing idling time. While each vehicle reaches its minimum fuel consumption at a different speed or range of speeds, fuel consumption usually increases rapidly at speeds above 50 mph (U.S. Department of Energy, 2013).

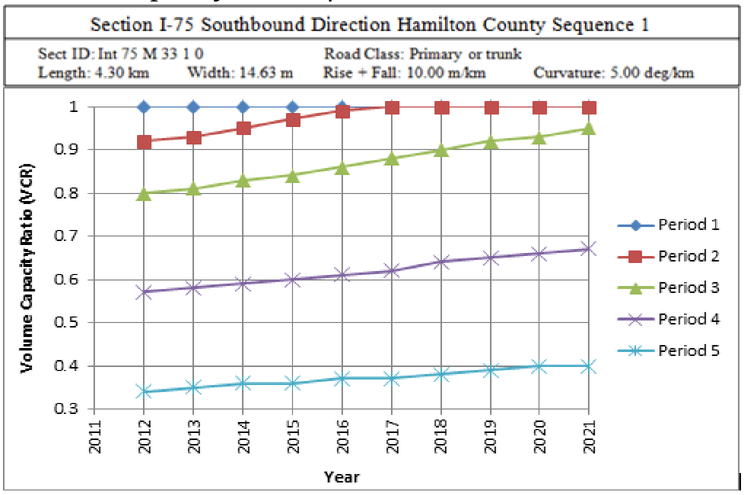
Table 6 shows 10 year fuel consumption in gallon per 1000 vehicle miles (liters per 1000 vehicle-kilometers) for passenger cars on I-75. Both overlay and micro-surfacing alternatives provide very similar results. The fuel consumption in 2012 is estimated to be approximately 50.54 gallons of fuel per 1000 veh-mi for passenger cars during peak hours. This is due to low traffic speeds experienced during peak hours. Periods 2, 3, and 4, provide more free movements that allow vehicles to travel continuously without interruption resulting in lower fuel consumption (Table 6). At night (Period 5) vehicles can travel at higher speeds resulting in higher fuel consumption. Similar trend is observed on other vehicles over the analysis period. Refer to Sen (2013) for more tables on fuel consumption (Sen, 2013).

HDM-4 produces a multi-year optimization results for selected routes/projects. The maximum NPV/cost is used to identify which section requires immediate maintenance attention. Using a budget constraint of one million dollars for interstates and two million dollar for state routes, the optimization results prioritizes each roadway section based on which section needs maintenance prior to other roadway sections. Based on this analysis, among the interstates, I-124 M 33 1 (3.2 km) requires immediate maintenance at a specified cost. The cumulative cost each year is within the budget constraint. The next section requiring maintenance would be I-124 P 33 1 (3.2 km) and then I-75 M 33 1 (2.4 km). As for the state routes, SR 29 P 33 1 (3.34 km) requires immediate maintenance.

Capacity

The AADT growth rate of 1.8 per year was used for the ten years analysis period. The volume/capacity ratio of I-75 during the five flow periods is shown in Figure 7. For I-75, the volume/capacity ratio (VCR) in the flow periods 2, 3, 4, and 5 will increase gradually over the years. The peak volume is defined as the flow rate during the peak 15 minute period (Garber and Hoel, 2009, p. 391).This ratio is used to measure capacity sufficiency. Period 1 or during the peak hours, the results show a maximum of 1 for the volume-capacity ratio. This implies that the volume will equal the capacity during the analysis period while the other flow periods volume equals a fraction of the capacity. The operating characteristics may be improved by changing the roadway geometrics. TDOT Planning Department provided the volume/capacity ratio for 2012 on I-75 Southbound section as 0.73.

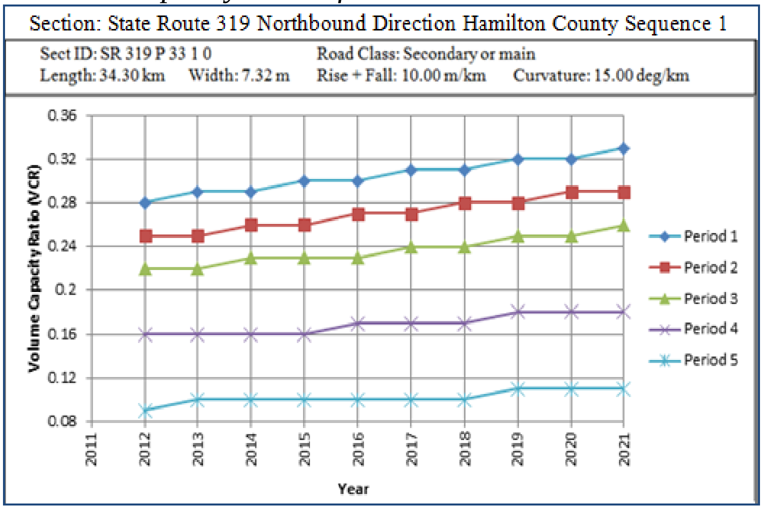
Figure 7. *Volume / Capacity Ratios for I-75*



As for SR 319 (Hixson Pike), the volume/capacity ratio during all five periods will increase gradually over the years as shown in Figure 8. The volume/capacity ratio during the peak period is predicted to be 0.28 in 2012. TDOT Planning Department provides the volume/capacity ratio for SR 319 Northbound in 2012 as 0.2. Both volume/capacity ratio results provided HDM-

4 and TDOT Planning Department imply that travel conditions are completely free flow (LOS A).

Figure 8. *Volume / Capacity Ratios for SR 319*



Conclusions

A cost-effective strategy was used to prioritize each Hamilton County interstate and state route. The immediate maintenance needs for the road sections were considered on the analysis. This study indicated that HDM-4 software is capable of performing pavement analysis depending on the quality of input data. A proper data input and current condition study is recommended for high quality of results.

Most of the results obtained are very close to actual situations on the selected pavement sections, a validation study is required for a solid conclusion.

Although HDM-4 software results may not be comparable to other PMS software available, its ability to capture user cost, agency cost, fuel consumptions, travel time/speed and emissions, among other things can be considered as an added advantage on studies. However input data to accurately reflect unit costs and other input requirement are essential.

Results from the Case Study Show that

From the analysis, a road with higher NPV/cost requires immediate maintenance. After the HDM-4 analysis, sections needing immediate maintenance were: I-124 M 33 1 and I-124 P 33 1 for interstates and SR 29 P 33 1 and SR 320 P 33 1 for state routes.

A detailed analysis was performed for two routes, I-75 (interstate) and SR 319 (state route).

- Based on the pavement condition results for I-75 and SR 319, it can be concluded that micro-surfacing may cost less but it does not necessarily improve all the distresses. Signs of structural cracking, rutting and raveling appear the year following application. Using overlay improves the roadway section significantly throughout the analysis period.

- The fuel consumption results for I-75 and SR 319 indicate that passenger cars during peak hours consume more fuel due to the stop-and-go traffic motion. Periods 2, 3, and 4 experiences less traffic and higher speeds allowing continuous vehicle travel, resulting to lower fuel consumption. In Period 5, when there is no congestion, vehicles travel at higher speeds resulting to slightly higher fuel consumption (Table 5). Single unit vehicles and tractor-trailers behave in a similar manner (Sen, 2013).
- The 4% discounted transport cost for overlay, which includes the road user and agency cost in 2012, for I-75 is approximately 78 million dollars while for SR 319 is 182 million dollars.
- The total user cost for SR 319 is approximately double the values of I-75 because state routes are subjected to stop-and-go traffic due to traffic signals. This motion increases travel time while and fuel consumption and hence road user cost. The road agency cost for SR 319 is about four times higher than that for I-75. The stop-and-go traffic on state routes, results into more loading on pavement sections and hence more pavement deterioration, requiring more maintenance to keep the pavement performance at acceptable levels.
- The volume/capacity ratio for I-75 Southbound (4.3 km) in 2012 is 1.00. The roadway geometrics changes, such as increasing number of lanes, may be required to improve the operating conditions.
- The volume/capacity ratio for SR 319 Northbound (34.30 km) in 2012 is 0.28. This indicates that the travel conditions are completely free flow (Level of Service A).

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