FAC 8511 ROAD, SURFACED

FY24 SUC:	$1.20 / SY
Source:	Inflated from previous FY using ENR labor and material cost indices to measure actual inflation
Original Source:	Based upon study by Purdue School of Civil Engineering, April 2013 and Marshall and Swift Valuation Service\n\nDue to Changes in 2015 RPCS, FAC 8511 currently includes curbs and signage.

FAC 8511, Surfaced Road

Sustainment Unit Cost

FY-14 (V16)

FAC 8511 Road, Surfaced UM = SY

SOURCE	TASK	Given	Units	Conversion		Freq	Cost	
Table 5-4, Assessment Procedure for Paved and Gravel Roads, Purdue School of Civil Eng, April 2013	Asphalt Overlay, Crack Sealing, Chip Sealing, Patching/Annual Maintenance	$ 8,064.00	MI	10560	SY/MI	1	$ 0.76	SY
Marshall and Swift Section 66/1 Dec 2013	Concrete curb 6", no gutter, lin. ft. Assume 20% requiring repair	$ 8.13	FT	2	SY/FT	20	$ 0.03	SY
Marshall and Swift Section 66/1 Dec 2013	Replace Street Sign with Post	$ 120.00	EA	0.00069	SY	10	$ 0.01	SY
	Planning Factor .66 of DoD Roads include Curb			**Sum**			$ 0.80	SY
						SUC	$ 0.80	SY
	Inflated From 2013 to October 2015 using ENR Labor and Material cost indicies to measure actual inflation						$ 0.84	SY

Assessment Procedures for Paved and Gravel Roads

April 15, 2013
SP-28-2013

Indiana Local Technical Assistance Program

Purdue University School of Civil Engineering
Indiana Local Technical Assistance Program
3000 Kent Avenue
West Lafayette, Indiana 47906

Telephone: 765.494.2164
Toll Free in Indiana: 1.800.428.7639
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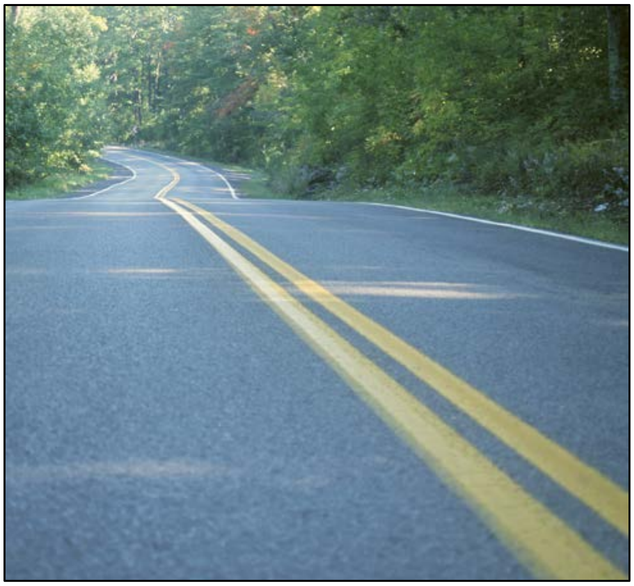
Assessment Procedure for Paved and Gravel Roads



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1.0 Abstract

The funding available to local agencies in Indiana to manage roadways has decreased in recent years, and many agencies cannot provide adequate maintenance with the available resources. Consequently, agencies are doing everything they can to evaluate the least expensive method to maintain their roads that will meet their objectives and needs. In some cases, the most appropriate surface type is a paved road, and in some cases, it is a gravel road. The decision as to the most appropriate surface type depends on a variety of factors, such as cost, traffic volume, development and public input. The purpose of this study was to review the applicable research and develop an assessment procedure that local agencies in Indiana can use to help determine the most appropriate surface type for a given road.

2.0 Introduction

The funding available to manage roadways has decreased in recent years, and many agencies find it challenging to provide adequate maintenance on their roadways with the available resources. Agencies do not have control over the price of materials needed to maintain roads, and most agencies do not get an increase in their budget when costs increase. Furthermore, in Indiana, many local agencies have had decreasing revenues in recent years (Indiana LTAP Center, 2009). When these decreasing revenues are considered in conjunction with increasing material and labor costs, the challenges are exacerbated. Consequently, agencies are doing everything they can to evaluate the least expensive method to maintain their roads that will meet their objectives and needs. While a road with new asphalt overlay is relatively inexpensive to maintain once it has been paved, the cost to pave the road is high, and as the road deteriorates, it gets more expensive to maintain. As budgets become constrained, it is not possible to re-pave all the roads that need to be paved on an appropriate schedule. To address this situation, some agencies in Indiana are converting paved roads back to gravel. On the other hand, as development in an area changes, as traffic on a gravel road increases, and as the vehicles on the road get heavier, the required maintenance on a gravel road increases. In this situation, it may be appropriate to convert a gravel road to a paved road with an overlay of asphalt.

The decision as to the most appropriate surface type, gravel or paved with an asphalt overlay, depends on a variety of factors. This decision has been faced by numerous other agencies and as a result it has been researched by agencies in other states. The purpose of this study was to review the applicable research and develop an assessment procedure that local agencies in Indiana can use to help determine the most appropriate surface type for a given road.

To assure that the proposed assessment procedure reflects the needs of agencies and conditions in Indiana, LTAP surveyed local agencies for information such as the maintenance practices for paved and gravel roads, the costs of these activities, and the factors that affect their decision regarding the most appropriate road surface.

It is also worthwhile to briefly address nomenclature. This report refers to “gravel” throughout the document. The term “gravel” is used as a generic term for simplicity, however, it is acknowledged that some agencies may actually be using “stone” rather than “gravel” for their aggregate surfaced roads. Similarly, this report refers to “asphalt” roads throughout the document. This may encompass both hot-mix asphalt (HMA) and warm-mix asphalt (WMA). Finally, this report refers to “paved roads” as those with an asphalt mixture surface. Chip seals may also be considered paved roads. Although not directly addressed in this report, the assessment procedures presented could be used to evaluate a chip seal road relative to either a gravel road or paved road with an asphalt mixture surface.

3.0 Literature Review

Numerous agencies have conducted research to address the decision as to whether a road should be paved or gravel. This section includes a brief review of some of the documents that were considered most relevant to the decision-making process in Indiana. For additional information, see the annotated bibliographies in the appendices of *Local Road Surfacing Criteria* (Zimmerman & Wolters, 2004) and *Economics of Upgrading an Aggregate Road* (Jahren, et al., 2005).

3.1 A Framework for Selecting the Appropriate Road Surface

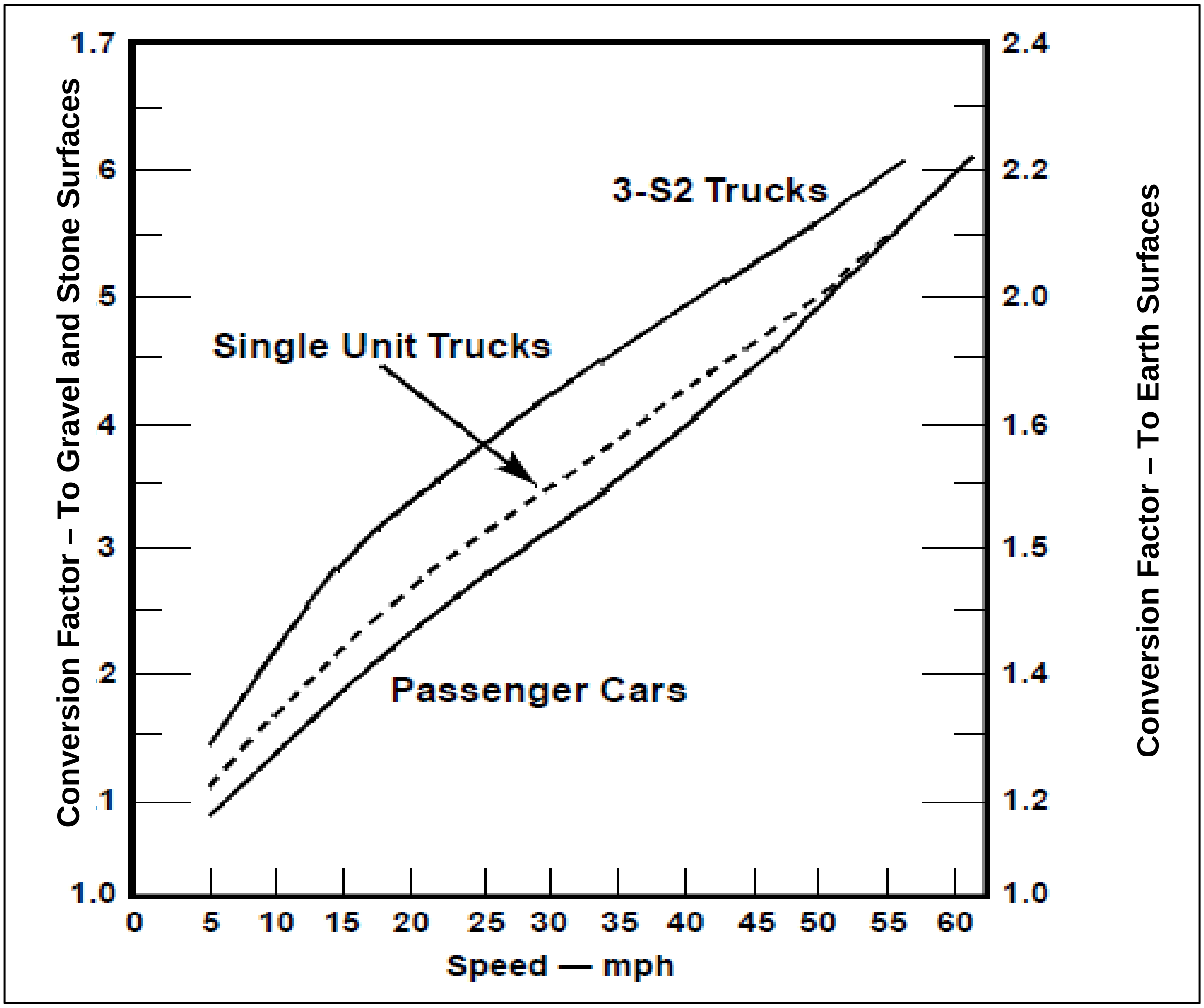
The decision whether a road should be paved or gravel depends on the needs of the local road users, the agency objectives and resources, and the costs and benefits of the alternative surfaces. The costs and benefits of a road surface are strongly influenced by the maintenance practices, which may vary significantly between agencies. There are numerous documents that provide information on recommended maintenance practices for gravel roads (Skorseth & Selim, 2005), (Huntington, 2010), (AASHTO, 2007) and paved roads (AASHTO, 2007), (Johnson, 2000), however, there is limited data regarding the costs associated with maintaining gravel and paved roads. Many agencies do not track this cost closely, and there is limited data in the literature. Moreover, the frequency of maintenance often varies significantly depending on the specific road.

The need for maintenance depends on the physical characteristics of the road (including base, drainage and surface characteristics), the traffic load (including vehicle volume and truck volume), and the environment (including precipitation and snow removal activities). Another challenge is that there may be a substantial discrepancy between the maintenance practices documented in reference material, and the maintenance practices that local agencies typically implement. This discrepancy often stems from local agencies being tasked with maintaining many miles of road using limited resources. A final challenge is that most maintenance and management recommendations presume best design conditions, namely that low-volume rural roads were designed with an adequate base and drainage. In practice, many low-volume rural roads were never "designed" in the conventional sense (e.g., constructed based on a set of plans that includes cross section, drainage, base and surface material to reflect geotechnical considerations and expected traffic volume). Rather, they are the result of unimproved roads evolving to gravel over time. It would be impractical and cost prohibitive to reconstruct all the low-volume local roads according to low-volume pavement design standards. These limitations should be kept in mind as the decision on whether a road should be paved or gravel is contemplated.

Gravel and paved roads differ in many aspects, including construction and maintenance costs, drainage, smoothness and types of vehicle that can be accommodated (Kentucky Transportation Center, 1988). Gravel roads have lower construction and maintenance costs, but also have more dust problems, lower operational speeds, and higher user costs. On the other hand, paved roads are smoother, provide greater protection of the of the base and subgrade material, and may be able to accommodate a wider range of vehicle types, However, these benefits may come at a cost, and may not be appropriate for all roads (Kentucky Transportation Center, 1988).

One of the most concise and comprehensive documents regarding the decision as to whether to pave a gravel road was developed by The Kentucky Transportation Center (Kentucky Transportation Center, 1988), and includes ten factors to consider when deciding whether to pave a gravel road. This document was subsequently included in its entirety in *Gravel Roads Maintenance and Design Manual*, published by the US Department of Transportation (DOT) (Skorseth & Selim, 2005). Key concepts include:

- **Management plan.** Roads should be paved in a systematic manner and reflect a comprehensive management plan. Although beyond the scope of this document, additional information about management plans can be found in documents such as *Asset Management Guide for Local Agencies in Michigan* (Cambridge Systematics, Inc., 2007).
- **Traffic volumes.** Minimum traffic volumes should be met, however, no specific volume threshold is identified.
- **Engineering design standards.** Improvements and their estimated cost must reflect current standards for design, construction and maintenance, including:
    - Safety considerations (such as design speed, sight distance, alignment, and lane width) and adequate pavement width. Some engineers suggest that only roads 22 ft or wider should be paved; this threshold would preclude most county roads in Indiana from being paved, including many roads that are currently paved.
    - Adequate base and drainage design (including grading, plasticity, and optimum moisture content of soil).
- **Life cycle cost analysis, including user costs.** Improvement should compare all costs throughout the road's life cycle, including capital and maintenance costs, as well as user costs.
    - Some costs are common to both surface types (such as roadside maintenance) and other costs vary depending on the surface type. For example, asphalt patching and resealing will be incurred for paved roads, whereas re-graveling, grading and stabilization, and dust control will be incurred for gravel roads. Costs for signs and striping should be considered, but may not vary for paved and gravel road options.
    - User costs are typically higher for gravel roads due to increased fuel consumption, tire wear, maintenance and repair costs. The AASHTO Manual on User Benefit Analysis is referenced for the determination of user costs (AASHTO, 1977), and includes conversion factors for gravel, stone and earth are relative to the cost of travelling on a paved surface. This is shown in Figure 3-1.
- **Public opinion.** Improvement should consider, but not rely exclusively on, public opinion.



Reference (Winfrey, 1968) as referenced in (AASHTO, 1977)

Figure 3-1. User Costs

An underlying principal of this framework is that paving the road is much more significant than merely providing an asphalt overlay, and the decision must be made in a holistic context that considers engineering factors, cost, and the impact to the public.

It is important to emphasize that every agency is different; circumstances and considerations may vary significantly from agency to agency. This is potentially true of technical standards (e.g., desirable design speeds for low-volume roads), costs, and desired maintenance practices. For example, dust control is a significant expense for gravel roads; however, some agencies provide limited or no dust control. If an agency does not utilize dust control, it will reduce costs substantially, but it will also impact public acceptance of gravel roads.

Public acceptance of gravel roads may also vary. In most cases, public opinion favors paved roads, but there are exceptions. It has also been suggested that a gravel road in an agricultural area is preferable to a poorly maintained paved road, since the gravel road can be graded by the nearby farmers when needed, whereas maintenance of an asphalt road in poor condition can only be addressed by the local highway department. In some cases, even residents may prefer gravel, as was reported by Kimley-Horn in a report for a local agency north of Atlanta (Kimley-Horn and Associates, Inc., 2009), where the gravel roads have been described as scenic, pastoral, and peaceful (Nurse, January 24, 2009). Some residents believe gravel roads keep down the speed and volume of traffic, which is desirable from the perspective of local walkers, equestrians and cyclists. Furthermore, it has been suggested that the gravel roads make undesirable development (higher density development) less likely. Public opinion rarely is unanimous, however, and some residents think gravel roads are difficult to maintain and as a result pose a safety hazard.

The costs associated with gravel and paved roads also vary significantly. Many local agencies do not closely track costs, and difficulties in estimating life cycle costs are exacerbated by widely differing maintenance practices, differing maintenance needs for different roads, and a general lack of data for low-volume roads. As noted in *When to Pave a Gravel Road* (Kentucky Transportation Center, 1988), maintenance costs for all options must be determined before any conclusions can be reached. However, in some cases, no data exists upon which to base estimates of maintenance costs on low-volume roads.

Other agencies have taken the basic framework for decision making put forth by Kentucky and expanded it or tailored it to their circumstances. Minnesota has developed a framework for decision making based on a historical cost analysis in Minnesota, a method for estimating the cost of maintaining roads, and an example using economic analysis to support decision making (Jahren, et al., 2005). South Dakota developed a computer program to provide a framework for decision making (Zimmerman & Wolters, 2004). The Excel-based program developed by South Dakota allows local agencies to utilize economic factors (costs), or a combination of economic and non-economic factors in the analysis to determine the most appropriate surface for a local road. Other agencies have also developed computer programs to assist in decision making (Eck, 1987).

Other research has explored not only the decision as to whether the road should be paved, but also the optimal time for paving the road (Bhandari, 1979). There are also a number of papers and reports that assess the relative benefits and costs of gravel and paved roads in other countries (Gannon, 1999), including Africa (Archondo-Callao R. , 1999), Finland (Tervala, 1995), and Nicaragua (Archondo-Callao, Mendez-Talavera, & Cantarero-Zeas, 2003).

3.2 Gravel Road Costs

The appropriate estimation of costs is critical to the analysis of an appropriate surface type. While it is difficult to put forth cost values with confidence, there are some estimates that have been published for maintaining gravel roads. The annual cost of maintaining gravel roads in Kentucky was $3,010 per mile in 1988, equivalent to $5,871 in 2012 when adjusted for inflation (Bureau of Labor Statistics, 2012). Details about this cost are shown in Table 3-1. More recently, the South Dakota Department of Transportation (Zimmerman & Wolters, 2004) estimates that the cost of maintaining a gravel road varies depending on the average daily traffic (ADT), as shown in Table 3-2. Although not shown in the table, an example agency cost for gravel in South Dakota is $6,843 per mile (Zimmerman & Wolters, 2004), equivalent to $8,348 in 2012 when adjusting for inflation.

This South Dakota value is more than one and one-half times higher than the cost estimated by the Minnesota Local Road Research Board of $4,160 per mile in 2005, equivalent to $4,909 in 2012 (Jahren, et al., 2005); Minnesota costs are shown in Table 3-3. South Dakota also makes a distinction between the cost of a gravel road and a stabilized gravel road. The cost for a stabilized gravel road is significantly higher than for gravel, as can be seen by comparing data from Table 3-2 and Table 3-3. Although not shown in the table, an example agency cost for maintaining stabilized gravel roads in South Dakota is $10,297 per mile (Zimmerman & Wolters, 2004), equivalent to $12,138 in 2012 when adjusting for inflation. Additional details about specific elements of the maintenance cost for Kentucky, South Dakota and Minnesota are provided in Table 3-1, Table 3-2, Table 3-3, and Table 3-4.

Table 3-1. Gravel Road Costs in Kentucky

Year	**1 ()**	**2**	**3**	**4**	**5**	**6**	**Total ($/mile)**
Grading	$270	$280	$290	$300	$310	$320	$1,770
Equipment	$90	$100	$110	$120	$130	$140	$690
Labor							
Re-gravel							
Materials			$4,000				
Equipment			$2,500				
Labor			$2,300				
Stabilization/Dust Control							
Materials	$800	$900	$1,200	$920	$950	$975	$5,745
Equipment	$30	$35	$70	$40	$50	$60	$285
Labor	$100	$110	$150	$125	$140	$150	$775
Total	$1,290	$1,425	$10,620	$1,505	$1,580	$1,645	$18,065

Reference: (Kentucky Transportation Center, 1988)

Table 3-2. Gravel Road Costs in South Dakota based on ADT

ADT (vehicles/ day)	**Initial Construction or Major Rehab. Cost ($/mile)**	**Blading**		**Re-gravel**		**Spot Gravel/ Annual Maint. Cost ($/mile)**
		Times per Year	**Cost ($/mile)**	**Years between App.**	**Cost ($/mile)**	
0-99	$3,700	17	$45	8	$3,700	$350
100-199	$3,700	20	$45	8	$3,700	$800
200-299	$4,500	30	$50	6	$4,500	$1,070
> 300	$7,036	50	$65	6	$7,036	$2,420

Reference: (Zimmerman & Wolters, 2004)

Table 3-3. Stabilized Gravel Road Costs in South Dakota based on ADT

ADT (vehicles/ day)	Initial Construction or Major Rehab. Cost ($/mile)	Dust Control[1]		Blading		Re-gravel		Reshape Cross Section		Spot Gravel/ Annual Maint. Cost ($/mile)
		Years between App.	Cost ($/mile)	Times per year	Cost ($/mile)	Years between App.	Cost ($/mile)	Years between App.	Cost ($/mile)	
0-99	$5,000	1	$3,700	4	$40	12	$2,300	--	--	$500
100-199	$8,154	1	$3,300	4	$40	5	$4,854	--	--	$333
200-299	$8,154	1	$3,300	4	$40	5	$4,854	--	--	$333
>300	$19,716	1	$2,300	6	$380	10	$17,416	10	$3,400	$3,635

Reference: (Zimmerman & Wolters, 2004)

Table 3-4. Gravel Road Costs on a Five-Year Cycle in Minnesota (cost per mile)

Year	1	2	3	4	5	6	Total
Grading							
Equipment	$800	$800	$800	$800	$800	$800	$4,800
Labor	$600	$600	$600	$600	$600	$600	$3,600
Resurfacing							
Materials	$7,000					$7,000	$14,000
Equipment	$4,200					$4,200	$8,400
Labor	$2,600					$2,600	$5,200
Annual Total	$15,200	$1,400	$1,400	$1,400	$1,400	$15,200	$36,000
Cumulative Costs		$1,400	$2,800	$4,200	$5,600	$20,800	

Reference: (Jahren, et al., 2005)

The difference in cost to maintain a gravel road in Minnesota and South Dakota is partially attributable to different frequencies for maintenance activities. South Dakota's maintenance program includes "blading" 50 times per year (at $65 per mile) whereas the Minnesota cost reflects "grading" 21 times a year (at $67 per mile). In this case, it is reasonable to assume that "blading" and "grading" are analogous activities. However, it does highlight the fact that different agencies use different vocabulary to describe activities, and it is important to make sure that activities and costs are being appropriately attributed, given these differences in vocabulary.

Differences are also attributable to different costs in different locations. South Dakota's maintenance program includes re-gravelling at $7,036 per mile every six years, whereas Minnesota's program includes re-gravelling at $13,800 per mile every five years when traffic exceeds 100 vehicles per day. The lower cost in South Dakota may be due to varying costs, as well as more frequent blading, and the addition of spot graveling, an activity that is not included in Minnesota.

Neither the South Dakota nor Minnesota costs include dust control, crown and cross section re-shaping, or ditch maintenance in the gravel road maintenance cost. Dust control can be very expensive, and may include a variety of treatments, from calcium chloride (cement stabilization) to emulsion sealants and soybean oil products (Ohio Soybean Council, 2012). Some agencies consider chip and seal or thin asphalt overlays as dust control. Again, this emphasizes the wide range of practices and the difficulties inherent in a lack of common vocabulary. Ironically, while some agencies recommend cement stabilization for dust control, others have cited that a potential disadvantage of cement stabilization is dust problems due to the smaller aggregate size and resulting denser composition, and the fact that the surface may result in a higher vehicle speed and higher traffic volume (Kimley-Horn and Associates, Inc., 2009). Dust control is an important consideration and can represent a substantial cost; agencies should refer to documents such as *Dust Control on Low-Volume Roads* for additional information (Lunsford, 2001).

The impact of different maintenance activities and frequencies is illustrated by the three gravel maintenance scenarios developed for one local agency. The scenarios ranged from $34,000 per mile per year to $16,600 per mile per year, as described below (Kimley-Horn and Associates, Inc., 2009).

- $34,000 per year: blading at $1,500 per mile 21 times a year, re-graveling at $13,000 per mile every six years, and spot graveling at $650 per mile every other year. Note that this scenario does not include dust abatement or ditch-shaping. This high cost was caused by the high frequency of blading.
- $19,000 per year: blading twice a year, re-shaping the cross section and ditch maintenance ($7,400 per mile) once a year, spot graveling once a year, dust abatement ($2,050 per mile) three times a year, and re-graveling every six years.

- $16,600 per year: blading twice a year, re-shaping the cross section and ditch maintenance once a year, spot graveling once a year, and dust abatement three times a year.

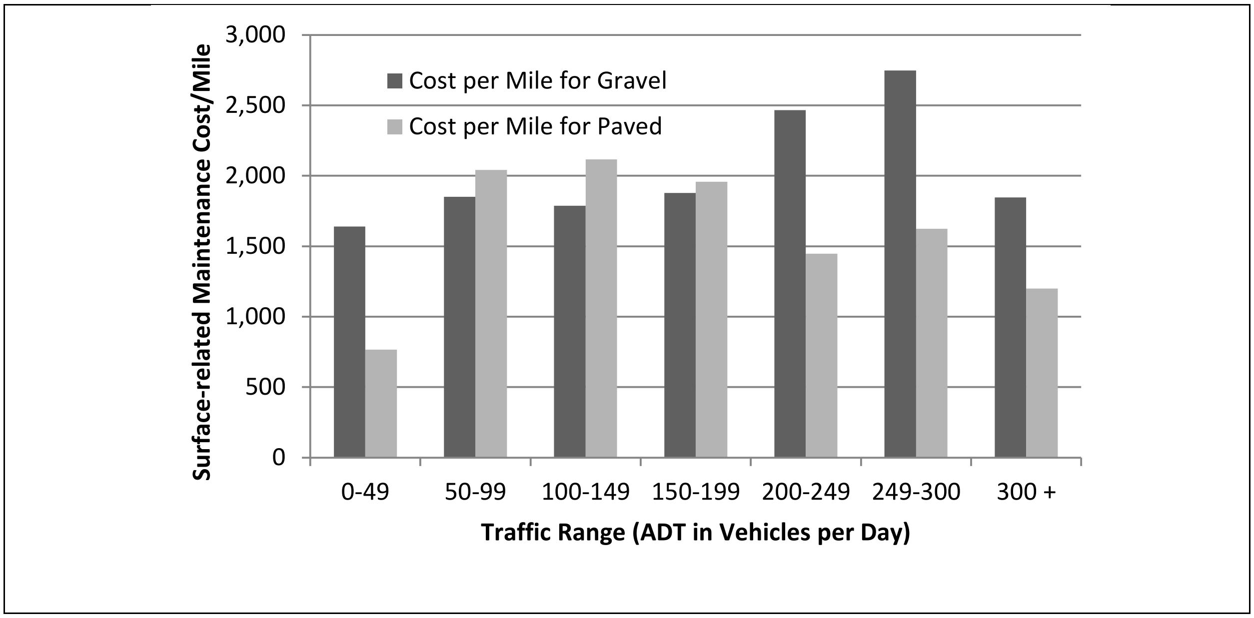
The above scenarios illustrate that from a cost perspective, maintenance is a primary factor affecting the decision of whether a road should be paved or gravel. These findings are confirmed by another report for a local agency, which found that a wide range of costs to maintain a gravel road in Wyoming (BenchMark Engineers, P.C., 2006). Reported annual maintenance cost varied from $584 per mile to $20,348, and estimated maintenance costs were as follows (BenchMark Engineers, P.C., 2006):

- $3,640 per mile per year for typical maintenance.
- $7,280 per mile per year for above average maintenance.
- $13,520 per mile per year for roads requiring a high level of maintenance with water.
- $42,640 per mile per year for roads requiring frequent maintenance with chloride.

3.3 Paved Road Costs

As with gravel road costs, paved road costs can vary significantly, and cost differences may be attributable to different characteristics of each individual road, different maintenance practices, local costs, and traffic. The potential impact of traffic on the cost for both gravel and paved roads is illustrated in Figure 3-2, based on data collected from four counties over a five year period in Minnesota. This chart is based on actual data from multiple agencies. The thickness of the asphalt surface course, the adequacy of the base, the age of the roadway, the drainage, and the maintenance practices vary for different jurisdictions and for different roads. Generally, the cost of maintaining a road would be expected to increase with increasing traffic.

Potential costs associated with maintaining pavement include periodic overlays of asphalt, crack sealing, surface treatments (chip sealing, fog sealing, etc.), and patching. Local practices may vary significantly, and the use of one maintenance practice may affect the need for and cost of other maintenance practices. For example, use of a chip seal may extend the pavement life and increase the intervals between overlays. One maintenance schedule for a seven-year cycle for asphalt is shown in Table 3-5, based on data reported in Minnesota. Costs for asphalt roads for South Dakota are shown in Table 3-6. Although not shown in the table, an example agency cost for asphalt in South Dakota is $4,570 per mile (Zimmerman & Wolters, 2004), equivalent to $5,570 per mile in 2012 when adjusting for inflation. This cost reflects crack sealing every 3 years ($1,200 per mile), seal coating every 4 years ($7,000 per mile), an overlay every 20 years ($37,000 per mile), and striping and marking every 4 years ($280 per mile).



Reference (Jahren, et al., 2005)

Figure 3-2. Surface-Related Maintenance Cost Varies Depending on Traffic Volume

Similarly, the reported average annual cost for asphalt maintenance in Minnesota is $2,460 per mile (includes seal coat every 7 years, but not the initial $130,000 resurfacing cost), equivalent to $2,900 per mile in 2012 when adjusting for inflation. If the expected life of the asphalt resurfacing is 14 years, the equivalent annual cost for asphalt resurfacing would be $9,290 per mile, for a total resurfacing and maintenance cost of $11,750 per mile, equivalent to $13,805 per mile in 2012 when adjusting for inflation.

3.4 Considerations in the Identification of the Appropriate Surface

Cost is a primary consideration in the decision as to the most appropriate surface type. In Minnesota, the report concluded that the maintenance cost savings alone could not justify the investment in an asphalt upgrade (Jahren, et al., 2005). Still, some benefits, like safety, economic development and quality of life, in addition to the reduced maintenance cost, can justify the improvement. Many benefits cannot easily be assigned monetary value. Adding to the complexity of the decision making is the fact that there are a variety of surface treatments that can be considered for implementation. In some cases, an upgrade may be justified based on maintenance cost if the upgrade is minimal. For example, a "lightly-surfaced road", such as a seal coat, may be warranted since it would require a smaller investment compared to asphalt (Jahren, et al., 2005). The term "lightly-surfaced road" again points to the important consideration of vocabulary. The term "paved road" may have different implications for different agencies. Some agencies consider chip seal over gravel a pavement, and others

Table 3-5. Asphalt Road Costs for a Seven-Year Cycle in Minnesota (cost per mile)

Year	1	2	3	4	5	6	7	8	Total
Maintenance	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$12,800
Resurfacing	$130,000							$6,000*	$136,000
Annual Total	$131,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$7,600	$148,800
Summary	$131,600	$133,200	$134,800	$136,400	$138,000	$139,600	$141,200	$148,800	

Reference: (Jahren, et al., 2005)

*Seal coat application

Table 3-6. Asphalt Road Cost in South Dakota based upon ADT levels

ADT (vehicles/ day)	Initial Const. or Major Rehab. Cost ($/mile)	Crack Seal		Seal Coat		Overlay		Stripping and Marking		Patching/ Annual Maint. Cost ($/mile)
		Years between App.	Cost ($/mile)	Years between App.	Cost ($/mile)	Years between App.	Cost ($/mile)	Years between App.	Cost ($/mile)	
0-99	35,000	3	900	5	6,500	21	35,000	5	210	500
100-199	35,000	3	900	5	6,500	17	35,000	4	250	500
200-299	37,000	3	1,200	4	7,000	20	37,000	4	280	500
300-399	37,000	3	1,200	4	7,000	20	37,000	4	280	500
400-499	39,000	5	1,600	4	7,300	20	39,000	4	310	500
500-599	40,000	6	1,600	4	7,300	20	40,000	4	320	500
600-699	43,000	6	1,600	4	7,300	20	50,000	4	360	500
> 700	43,000	6	1,600	4	7,300	20	50,000	4	360	500

Reference: (Zimmerman & Wolters, 2004)

consider it dust control. Similarly, the thickness of an asphalt overlay has a significant impact on cost and durability. One report identified ten different project alternatives that could be used to upgrade an unsealed road (Archondo-Callao R. , 2011). Although the term “unsealed road” was not explicitly defined in the paper, this is a term that is used to describe roads in Australia and New Zealand, and it typically refers to an unimproved road or a gravel road with such low maintenance that it functions as an unimproved road. Alternatives to improve an unsealed road included gravel ($91,732 per mile), double surface treatment ($247,838 per mile), and asphalt with a thickness of 50 mm ($321,868 per mile), 100 mm ($397,507 per mile) or 150 mm ($473,146 per mile). Each alternative was evaluated for zero and full maintenance. Obviously there are multiple options for maintenance between these two extremes, however, only these two scenarios were evaluated. The results indicated that for a low-volume road with an annual average daily traffic (AADT) of 30 vehicles per day or less, gravel is the best option, regardless of whether there is zero or full maintenance. As the volume on a gravel road increases, the frequency of maintenance increases, which ultimately increases the cost of the project. As the volume on a road increases, it is more cost effective to pave the road rather than increase the frequency of maintenance. The minimum volume required to justify each of the improvements is shown in Table 3-7.

Table 3-7. AADT to Justify Alternative Upgrades

Alternative	Zero Maintenance	Full Maintenance
Double surface treatment	70 vehicles per day	97 vehicles per day
Asphalt 50 mm (2 in.)	98 vehicles per day	130 vehicles per day
Asphalt 100 mm (4 in.)	127 vehicles per day	161 vehicles per day
Asphalt 150 mm (6 in.)	156 vehicles per day	193 vehicles per day

Reference: (Archondo-Callao R. , 2011)

Although most reports do not identify a single volume threshold as the catalyst for paving a road, volume is an important consideration. Volumes of 200 vehicles per day (Jahren C. , 2002) to as low as 50 vehicles per day (Paige-Green, 1998) have been suggested. At the other end of the spectrum, one report suggests that an AADT of 500 vehicles is an appropriate threshold for dust control on gravel roads (UMA Engineering Ltd, 1987). Others suggest that it is not the volume but the load that should be considered (Luhr & McCullough, 1983).

Other factors that have an important impact on the economic analysis include the analysis period and assumptions regarding future interest and inflation rates. If the conversion of a gravel road requires substantial stabilization or other work to improve the base and drainage, then the period over which this activity is amortized will have a significant impact on the economic viability of the project. There is no standard life cycle, but the importance of this factor should be carefully considered.

4.0 Methodology

The project reported in this document focused on reviewing procedures developed in other states, identifying appropriate practices for Indiana and surveying local agencies to identify basic costs for Indiana. The result of these activities is two assessment procedures that can be utilized by local agencies. The assessment procedures provide reasonable default maintenance activities, intervals, and costs. Nevertheless, local agencies are encouraged to use their own costs and intervals to more accurately reflect their practices.

Review of existing literature and feedback from local officials was used to generate the proposed assessment procedures. Initial conversations with county engineers provided basic information which was used to develop a multiple choice survey questionnaire. The resulting survey (shown in Appendix A) was administered to local highway superintendents and county engineers who attended the Indiana Association of County Engineers and Supervisors (IACHES) business meeting in December 2012. Approximately 30 engineers and supervisors were present and participated in the survey.

5.0 Assessment Procedures

Two assessment procedures may be used to help determine the most appropriate surface type for a rural road. The first procedure simply compares the cost of each alternative. The second procedure is a ranking procedure that allows agencies to balance the impacts of multiple criteria. In both assessments, two alternatives are considered, a gravel road and a paved road. It would be possible for an agency to consider other alternatives, such as chip and seal over gravel, but for simplicity, this analysis is limited to gravel and paved with an asphalt overlay.

While these procedures focus on the comparison of gravel and paved roads, it is important to note that the decision regarding the most appropriate road surface type should be made in the context of a road management plan. In fact, all road maintenance and improvement activities should be evaluated and implemented in the context of a larger road management plan. A road management plan includes (Cambridge Systematics, Inc., 2007):

- Current inventory of roads and their conditions,
- List of appropriate preservation and maintenance activities, estimated costs and expected benefits.
- Performance measures and performance goals.
- Procedure for evaluating proposed and alternative activities.
- List of priorities and proposed projects over a multi-year period.
- Documentation of results.

A road management plan is a valuable way of quantifying the costs and benefits of all maintenance, reconstruction and construction activities. This information can then be used to help guide future decisions for maintenance and paving. A road management plan also helps assure that all road investments are efficient, improves accountability and provides important information that can be communicated to decision makers and the public. In addition to being part of a road management plan, it is important that all road improvements incorporate appropriate technical considerations. All road improvements should:

- Meet current standards for design, construction and maintenance (AASHTO, 2011).
- Reflect an adequate level of service (Transportation Research Board, 2010).
- Consider safety, both of the road itself, and of nearby developments. Safety components of the road that must be considered include design speed, sight distance, alignment and lane width (AASHTO, 2010), (AASHTO, 2011), (AASHTO, 2001). Recognize that changing the surface type may have unintended safety consequences. For example, paving a road may increase speeds on the road, increasing the needed sight distance. Alternately, converting a road to gravel may change the path of emergency response vehicles, increasing the response times for some rural areas.

It is also important to note that the surface of the road is just one component, and the life cycle cost and the serviceability of the road are strongly influenced by many features other than the surface material. Merely adding an asphalt overlay to a road with an inadequate base or improper drainage is never an appropriate or cost effective solution in the long term.

5.1 Cost Assessment

The cost of each alternative must be quantified and should include all costs, both capital and maintenance. Costs include, but are not limited to, costs to prepare the roadway (such as grinding up the existing roadway), costs to improve the roadway if needed (such as base stabilization or drainage), capital and or reconstruction costs (such as an overlay or re-graveling), and on-going maintenance costs.

The examples used in this analysis do not include costs for signs, drainage, vegetation management, or snow removal, because it is presumed that both alternatives would incur similar costs. Similarly, the cost does not include the cost for pavement marking, because most low-volume paved roads do not have pavement markings, nor do gravel roads. According to the Manual of Uniform Traffic Control Devices (MUTCD), centerlines should be placed on rural arterials and collectors that are 18 feet or more in width and with an ADT of 3,000 vehicles per day or greater (Federal Highway Administration, 2011). Most local roads that will be evaluated with this assessment technique are two lane roads with substantially less traffic, generally with an ADT of under 500 vehicles per day, and thus would not be required to have pavement markings. The procedure could easily be expanded to include these costs, if desired.

A framework for the inclusion of user costs (costs to drivers) is also provided; this may be included or omitted, at the discretion of the local agency. Another possibility would be to include user costs as a weighted cost (BenchMark Engineers, P.C., 2006).

Another consideration is the time value of money. The analysis presented here considers all prices in 2012 dollars. It would also be possible to index the values to consider projected inflation and interest rates. However, for simplicity constant 2012 dollars were used in this analysis. This assumption can be justified due to the relatively low interest and inflation rates in recent history, the uncertainty associated with forecasting future interest rates and inflation rates, and previous research that suggests that a good case can be made for letting interest and inflation cancel completely and simplify the resulting life cycle cost calculations (Eisenberger, Remer, & Lorden, 1978).

5.1.1. Gravel Road Cost

It is important to recognize that there is no one best maintenance practice, since local resources and priorities may vary significantly. In this assessment, minimal, moderate and high maintenance levels have been identified to illustrate a range of potential practices that may be appropriate for different agencies and on different roads.

Activities for each of the three maintenance levels and the equivalent annual cost for each are shown in Table 5-1. The concept was developed based on the literature (Archondo-Callao R. , 2007), (Jahren, et al., 2005) (Zimmerman & Wolters, 2004), and with input from engineers and highway superintendents in local Indiana county agencies.

Table 5-1. Schedule for Maintenance on Gravel Roads (cost per mile)

Activity	Cost per Mile or Frequency	Maintenance Level		
		Minimal	Moderate	High
Dust Control	Frequency (applications per year)	None	2	4
	Cost per application	$500	$500	$500
	Equivalent annual cost	$0	$1,000	$2,000
Blade	Frequency (per year)	2	5	9 (once a month, March through November)
	Cost per blading	$150	$150	$150
	Equivalent annual cost	$300	$750	$1,350
Re-gravel	Frequency (years that re-gravel will last)	8	5	4
	Cost per re-graveling	$12,000	$12,000	$12,000
	Equivalent Annual Cost	$1,500	$2,400	$3,000
Reshape/Crown	Frequency (per year)	None	1	2
	Cost per reshaping	$300	$300	$300
	Equivalent annual cost	$0	$300	$600
Spot Gravel/ Annual Maintenance	Cost for spot graveling (per year)	$200	$500	$700
Total		$2,000	$4,950	$7,650

The appropriate level of maintenance on a road will also vary depending on the adjacent development, the resources available, and the weather (e.g., frequent rains or excessively dry weather may alter the maintenance needed). The proposed assessment procedure is flexible, and local agencies can modify the schedule and costs to reflect their practices, costs and the specific activities for a given road. Costs vary significantly from agency to agency within Indiana. Table 5-2 illustrates the range in the cost of #53/#73 stone, which varies from $12.05 in Hancock County to $16.85 in Fayette County, a difference of over 30 percent. Another factor that affects cost is the cost to transport materials from the plant to the agency jurisdiction and within the jurisdiction to the road.

Table 5-2. Aggregate Prices Vary Throughout Indiana

2012 Gross Price per Ton	Hancock County	Madison County	Henry County	Wayne County	Fayette County	Madison County
#53/#73 Stone	$12.05	$12.25	$16.25	$16.35	$16.85	$14.75

5.1.2. Conversion from Gravel to Asphalt and from Asphalt to Gravel

Conversion costs are an important consideration and include all costs to prepare and convert the existing road to a new surface type. These costs may vary depending on the specific practices of each agency and the condition of the existing road. Estimated conversion costs for Indiana counties are shown in Table 5-3. The cost for conversion from gravel to asphalt includes the cost to stabilize the base in preparation for an asphalt overlay (the cost to grind the asphalt and stabilize the base is $30,000 per mile). The cost for conversion from asphalt to gravel includes the cost to grind up the existing asphalt, which is presumably in poor condition, and stabilize the base. This stabilized base is then ready for a new asphalt overlay, or for a surface coat of gravel. Ideally, similar base preparation and stabilization would be necessary for a road in very poor condition, regardless of whether a gravel or asphalt surface is used. In practice, however, few agencies do extensive base improvements or stabilization on roads that will remain gravel. For this reason, there is typically no capital cost to maintain a road as gravel. In this case, the cost for re-gravelling a gravel road is included as a maintenance cost.

5.1.3. Paved Road Costs

Maintenance of asphalt roads is necessary to increase the expected life of the road and ensure the performance, safety, and overall quality of the road. Maintenance activities that may occur include asphalt overlay, crack sealing, chip sealing, and patching, as shown in Table 5-4, which is based on input from local agencies. This schedule should be used as a guideline to help local agencies create their own maintenance schedule.

Table 5-3. Estimated Costs Associated with Surface Conversions

Conversion Activity	Cost per Mile
Estimated Costs for Existing Asphalt Road in Poor Condition	
Convert to gravel: Grind asphalt, stabilize base and add new gravel surface	$42,000
Maintain asphalt: Grind asphalt, stabilize base and add new asphalt overlay	$112,000
Estimated Costs for Existing Gravel Road	
Convert to asphalt	$150,000
Maintain as Gravel Road	$0

Table 5-4. Schedule for Maintenance on Asphalt Roads

<table>
<tr><th colspan="2">Activity</th><th>Cost per Mile or Frequency</th><th>Equivalent Annual Cost per Mile</th></tr>
<tr><td rowspan="3">Asphalt Overlay</td><td>Frequency
(years between overlay)</td><td>14 years</td><td rowspan="3">$5,857</td></tr>
<tr><td>Cost per overlay</td><td>$82,000</td></tr>
<tr><td>Equivalent Annual Cost</td><td></td></tr>
<tr><td rowspan="5">Crack Sealing</td><td>Frequency
(years between crack seal)[1]</td><td>2 to 3 years</td><td rowspan="5">$536</td></tr>
<tr><td>Cost per application</td><td>$2,500</td></tr>
<tr><td>Applications in life of overlay[2]</td><td>3</td></tr>
<tr><td>Total Cost for Crack Sealing in 14 Year Life of Asphalt Overlay</td><td>$7,500</td></tr>
<tr><td>Equivalent Annual Cost</td><td></td></tr>
<tr><td rowspan="5">Chip Seal</td><td>Frequency
(years between chip seal)</td><td>7 years</td><td rowspan="5">$1,071</td></tr>
<tr><td>Applications in life of overlay</td><td>1</td></tr>
<tr><td>Cost per resurfacing</td><td>$15,000</td></tr>
<tr><td>Total Cost for Chip Seal in 14 Year Life of Asphalt Overlay</td><td>$15,000</td></tr>
<tr><td>Equivalent Annual Cost</td><td></td></tr>
<tr><td>Patching / Annual Maintenance</td><td>Annual cost per patching</td><td>$600</td><td>$600</td></tr>
<tr><td>Total</td><td></td><td></td><td>$8,064</td></tr>
</table>

[1] Reference on interval for crack sealing: (Johnson, 2000)

[2] Assume crack sealing occurs at years 3, 10, and 12; and chip seal occurs at year 7, and new asphalt overlay occurs at year 14.

5.1.4. User Costs

In addition to construction and maintenance costs, it may also be appropriate to consider user costs. Vehicle costs are higher for gravel surfaces due to increased operating and maintenance costs. Vehicle maintenance increases significantly due to tire and engine wear, and oil consumption. With an average speed of 35 mph, user costs on gravel roads are almost 35 percent greater than paved roads, as was shown in Figure 3-1.

One estimate for user operating expenses is shown in Table 5-5. These costs are generally consistent with reimbursement rates of $0.44 per mile in Indiana (State of Indiana, 2011). Combined with the conversion factor from Figure 3-1, the estimated cost for operating a vehicle on a gravel road is 14.33 cents per mile higher than on a paved road. For a road with a traffic volume of 100 vehicles per day, the difference in vehicle operating cost is $14.33 per day, or $5,229 per year. Although this cost is significant, it is borne by vehicle owners and not the agency. User costs may be included at the discretion of the local agency. Note that this analysis does not consider the value of any time savings that may accrue from higher speeds on a paved road, nor does it consider the cost savings from a reduced trip length that may result if a road is paved and consequently vehicles shift their preferred route. User costs may also be scaled and included with a weighting factor (BenchMark Engineers, P.C., 2006), although doing so is beyond the scope of this document.

Table 5-5. User Costs per Mile

Element	Cost per Mile (cents)
Paved	
Gas	17.29
Oil	0.67
Maintenance and Repair	4.54
Tires	0.83
Vehicle Depreciation	17.60
Total Cost for Paved per Mile	40.93
Gravel	
Conversion Factor for Gravel is 1.35 (see Figure 2-1)	
Total Cost for Gravel per Mile (40.93 * 1.35)	55.26
Difference in Cost Between Paved and Gravel per Mile	14.33

References: (Enterprise, 2012), (Pierce Transit, 2012), (Internal Revenue Service, 2012).

Example 1- Cost Assessment

Compare the cost of converting one mile of an asphalt road in poor condition to a gravel road maintained at a high maintenance level, without considering user costs, for a 14 year analysis period. The ADT for the road is 100 vehicles per day.

Solution

The estimated costs for converting to asphalt and maintaining a gravel road at a moderate maintenance level are based on the information in Table 5-1, Table 5-3 and Table 5-4. The resulting estimated equivalent annual costs for asphalt and gravel are shown in Table 5-6 and Table 5-7.

Table 5-6. Example 1. Cost for Asphalt (14-year analysis period)

Activity	Cost per Mile	Equivalent Annual Cost per Mile
Grind asphalt in poor condition and stabilize base	$30,000	$2,143
Asphalt overlay	$82,000	$5,857
Crack seal		$536
Chip seal		$1,071
Patching/Annual Maintenance		$600
Total		$10,207

Table 5-7. Example 1. Cost for Gravel Maintained at Moderate Level (14-year analysis period)

Activity	Cost per Mile	Equivalent Annual Cost per Mile
Grind asphalt in poor condition and stabilize base	$30,000	$2,143
Initial gravel surface and re-gravel every 5 years	$12,000	$2,400
Dust control		$1,000
Blade		$750
Reshape/Crown		$300
Spot Gravel/Annual Maintenance		$500
Total		$7,093

Comparing the costs for the two options, the gravel road option is the preferred option since it has a lower equivalent annual cost ($7,093 for gravel vs. $10,207 for paved).

Example 2 - Cost Assessment

Compare the cost of converting one mile of an asphalt road in poor condition to a gravel road maintained at a moderate maintenance level, considering user costs for a 14 year analysis period. The ADT for the road is 100 vehicles per day.

Solution

The estimated costs for converting to asphalt and maintaining a gravel road at a moderate maintenance level are based on the information in Table 5-1, Table 5-3 and Table 5-4 as calculated in *Example 1*. User cost information is based on information in Table 5-5. The resulting estimated equivalent annual costs for asphalt and gravel considering user costs are shown in Table 5-8 and Table 5-9.

Table 5-8. Example 2. Cost for Asphalt (14-year analysis period)

Activity	Cost per mile	Equivalent Annual Cost per Mile
Road Cost from Table 5-6		$10,207
User Cost		
Cost per vehicle	$0.41	
Cost for 100 vehicles per day	$41	
Cost for 100 vehicles per day for a year		$14,965
Total		$25,172

Table 5-9. Example 2. Cost for Gravel Maintained at Moderate Level (14-year analysis period)

Activity	Cost per mile	Equivalent Annual Cost per Mile
Road Cost from Table 5-7		$7,093
User Cost		
Cost per vehicle	$0.55	
Cost for 100 vehicles per day	$55	
Cost for 100 vehicles per day for a year		$20,075
Total		$27,168

Comparing the costs for the two options, the paved road option is the preferred option since it has a lower annual cost ($25,135 for paved vs. $27,168 for gravel). As can be seen by comparing *Examples 1* and *2*, including the user costs in the cost assessment makes a significant difference in the cost and the preferred option.

5.2 Multi-objective Assessment

Cost is an important consideration, however, in many cases it is not the only factor that should be considered when evaluating whether a road should be paved. In some cases, cost may not even be the most important consideration for a given agency. For this reason, a second assessment procedure is presented based on multi-objective assessment. In this document, the alternatives are a gravel road and a paved road. However, it would be possible for an agency to use this procedure to consider other alternatives, such as chip and seal over gravel. In this assessment procedure, each alternative (paved and gravel) is rated according to the following attributes:

- Cost
- Traffic volume
- Development and expected growth rate
- Public preference.

This procedure is flexible, and can be expanded to consider additional attributes. Similarly, attributes that are not a priority can be removed from consideration. Each attribute is briefly discussed below.

5.2.1 Cost

Minimizing cost is an important objective for most agencies. Costs include conversion costs, maintenance costs, and possibly user costs, as discussed in the previous section.

5.2.2 Traffic Volume

Traffic volume is an important consideration for many agencies. Higher volume roads are generally a higher priority for most agencies. In many cases, roads that carry higher traffic volumes also require more maintenance, particularly for gravel roads. A reasonable threshold to justify paving based on volume would be in the range of 100 vehicles per day (the most frequently cited value in the survey) to 200 vehicles per day (the average value in the survey), based on the survey responses in Indiana.

5.2.3 Development and Expected Growth Rate

The density and type of development on and near a road affect the functional classification of the road and the importance of the road’s contribution to the transportation network. Generally speaking, paved roads typically serve areas with dense residential, commercial and industrial development, whereas gravel roads may adequately serve low-density residential and agricultural land.

5.2.4 Public Preference

Public preference and political considerations can be an important consideration in many jurisdictions. Responses from county agencies in Indiana suggest the public generally prefers paved roads to gravel roads. Paved roads are generally smoother, allow higher operating speeds, generate less dust and result in lower user costs.

5.2.5 Assessment Procedure

The multi-objective assessment procedure requires that the merits of each alternative be compared based on the chosen attributes. This is accomplished by calculating a score for each alternative. The score is based on a weighting factor for each attribute, and a scaled value for each alternative.

- **Weighting Factor.** Each of the four attributes is assigned a weighting factor to indicate its importance relative to the other attributes. Weighting refers to "how decision makers attach relative levels of important to these criteria" (Sinha & Labi, 2007). The weighting factors presented in this procedure are based on input from the Indiana engineers and surveyors.
- **Scaled Value.** Each alternative is given a scaled value to indicate its score for each attribute. Scaling converts a measurement of each attribute from its original dimension to a scale that is "uniform and commensurate across all performance criteria" (Sinha & Labi, 2007).
- **Total Score.** A total score for each alternative can then be determined based on the weighting factors and the scaled values for each attribute.

5.2.6 Weighting Factors

There are many ways to establish weights for the attributes. In this procedure, the weighting factors were determined based on the results of the survey and were assigned in a range from 0 to 1, as shown in Table 5-10. The weighting factors for all the attributes must sum to 1.0, and the attributes with higher values reflect greater importance. Weighting factors can be adjusted to reflect local priorities. For example, if development and public preference were considered to be equally important, each could be assigned a weight of 0.15.

Table 5-10. Weighting Factor for Each Attribute

Attribute	Weight
Cost	0.35
Traffic Volume	0.35
Development	0.20
Public Preference	0.10

5.2.7 Scaled Value

Scaling is important to allow all attributes to be expressed in comparable units. A scale of 0 to 100 is used, with 100 being highly favorable. Since reducing costs is an objective for local agencies, the scaled value for cost, S_{cost}, for the least cost alternative, $C_{minimum}$, is considered highly favorable and is rated at 100. The scaled value for the second alternative, $C_{alternative}$, is calculated based on the percent difference between the two alternatives, as shown below.

$$S_{cost} = 100 - 100\left[\frac{C_{alternative} - C_{minimum}}{\left(\frac{C_{alternative} + C_{minimum}}{2}\right)}\right] \qquad \textbf{Eq. 1}$$

If the costs are relatively close, than the scaled values for cost are relatively close. If the costs vary dramatically, there will be a larger difference between the scaled cost values. Example 3 provides an example calculation of the scaled values for cost.

Example 3. Calculation of Scaled Value for Cost

Determine the scaled value for Alternative A with a cost of $10,170 and Alternative B with a cost of $7,093.

Solution

The scaled cost for both alternatives can be calculated using Eq. 1. In this example, the minimum cost is $7,093.

$$S_{cost} = 100 - 100\left[\frac{C_{alternative} - C_{minimum}}{\left(\frac{C_{alternative} + C_{minimum}}{2}\right)}\right] \qquad \textbf{Eq. 2}$$

$$S_A = 100 - 100\left[\frac{10{,}207 - 7{,}093}{\left(\frac{10{,}207 + 7{,}093}{2}\right)}\right] \qquad \textbf{Eq. 3}$$

$$S_A = 64 \qquad \textbf{Eq. 4}$$

$$S_B = 100 - 100\left[\frac{7{,}093 - 7{,}093}{\left(\frac{7{,}093 + 7{,}093}{2}\right)}\right] \qquad \textbf{Eq. 5}$$

$$S_B = 100 \qquad \textbf{Eq. 6}$$

The scaled values for traffic volume, development and public preference are shown in Table 5-11, Table 5-12, and Table 5-13. The scaled values in Table 5-11 are based on survey responses. In all cases, local agencies can adjust the scaled values to reflect local perspectives.

Table 5-11. Scaled Value for Traffic Volume

Traffic Volume (veh/day)	**< 50**	**50 to 99**	**100 to 149**	**150 to 199**	**200 to 249**	**250 to 299**	**300 to 374**	**375 to 449**	**≥ 450**
Scaled Value Gravel	90	75	60	55	40	30	15	10	0
Scaled Value Paved	10	25	40	45	60	70	85	90	100

Table 5-12. Scaled Value for Development

Development	**Agriculture**	**Low Density Residential**	**Industrial, Commercial, Moderate or High Density Residential**
Scaled Value – Gravel	50	50	0
Scaled Value – Asphalt	50	50	100

Table 5-13. Scaled Value for Public Preference

Public Preference	**Gravel Road Low Maintenance**	**Gravel Road Moderate Maintenance**	**Gravel Road High Maintenance**	**Paved Road**
Scaled Value	0	5	10	100

5.2.8 Total Score

Calculation of the total score combines the weighting factors and scaled values into a single score to allow the best alternative to be selected. The total score is calculated for each alternative as the sum of the product of the weighting factor (W_i) and its scale value (S_i) for all attributes. The alternative with the highest total score is presumed to be the best alternative, based on the priorities expressed through the weighting factors and the relative benefits expressed through the scaled values for each alternative as shown in Eq. 4 and Eq. 5.

$$Score_{Total} = \sum_{i=0}^{4} W_i S_i \qquad \textbf{Eq. 7}$$

$$Score_{Total} = 0.35\, S_{Cost} + 0.35\, S_{\substack{Traffic\\Volume}} + 0.20\, S_{Development} + 0.10\, S_{\substack{Public\\Preference}} \qquad \textbf{Eq. 8}$$

The application of this multi-objective assessment procedure is illustrated in the following examples.

Example 4 - Multi-objective Assessment

Using the multi-objective assessment procedure, compare the cost of converting one mile of an asphalt road in poor condition to a gravel road maintained at a moderate level, without considering user costs, for a 14 year analysis period. The road, which is in a low density residential area, has an ADT of 50 vehicles per day.

Solution

The alternatives are:

- Alternative A – Grind asphalt road in poor condition, stabilize base and overlay with asphalt.
- Alternative B – Grind asphalt road in poor condition, stabilize base, and convert to a gravel road and maintain at a moderate maintenance level.

The estimated costs for converting to asphalt and maintaining a gravel road at a moderate and high maintenance level are based on the information in Table 5-3, and Table 5-4. The resulting estimated equivalent annual costs for asphalt and gravel maintained at a moderate level are shown in Table 5-14 and Table 5-15.

Table 5-14. Example 4. Cost for Alternative A, Asphalt (14-year analysis period)

Activity	Cost per Mile	Equivalent Annual Cost per Mile
Grind asphalt in poor condition and stabilize base	$30,000	$2,142
Asphalt overlay	$82,000	$5,857
Crack seal		$536
Chip seal		$1,071
Patching/Annual Maintenance		$600
Total		$10,207

Table 5-15. Example 4. Cost for Alternative B, Gravel Maintained at Moderate Level (14-year analysis period)

Activity	Cost per Mile	Equivalent Annual Cost per Mile
Grind asphalt in poor condition and stabilize base	$30,000	$2,142
Gravel at conversion and re-gravel every 5 years	$12,000	$2,400
Dust control		$1,000
Blade		$750
Reshape/Crown		$300
Spot Gravel/Annual Maintenance		$500
Total		$7,093

The scaled value for cost must be calculated based on the cost of the Alternative A, the asphalt with a cost of $10,170, and the minimum cost, which is $7,093 for Alternative B, the gravel road with moderate maintenance, as shown in Example 3.

$$S_A = 100 - 100\left[\frac{10{,}207\ - 7{,}093}{\left(\frac{10{,}207 + 7{,}093}{2}\right)}\right] \quad \textbf{Eq. 9}$$

$$S_A = 64 \quad \textbf{Eq. 10}$$

$$S_B = 100 \quad \textbf{Eq. 11}$$

The scaled values for traffic volume, development and public preference can be found by referring to Table 5-11, Table 5-12, and Table 5-13.

For Alternative A, $S_{Traffic\ Volume}$ = 40, $S_{Development}$ = 50, and $S_{Public\ Preference}$ = 100

For Alternative B, $S_{Traffic\ Volume}$ = 60, $S_{Development}$ = 50, and $S_{Public\ Preference}$ = 5

The score for each alternative can now be calculated based on the weighting factors and scaled values.

$$Score_{Total} = 0.35\ S_{Cost} + 0.35\ S_{\substack{Traffic\\Volume}} + 0.20\ S_{Development} + 0.10\ S_{\substack{Public\\Preference}} \quad \textbf{Eq. 12}$$

$$Score_A = 0.35(64) + 0.35(25) + 0.20(50) + 0.10\ (100) = 51 \quad \textbf{Eq. 13}$$

$$Score_B = 0.35\ (100) + 0.35\ () + 0.20(50) + 0.10\ (5) = 72 \quad \textbf{Eq. 14}$$

On the basis of the total score, Alternative B, the gravel road with moderate maintenance, has a higher score and is therefore the preferred alternative.

Example 5 - Multi-objective Assessment

Using the multi-objective assessment procedure, compare the cost of converting one mile of an asphalt road in poor condition to a gravel road maintained at a moderate level, without considering user costs, for a 14 year analysis period. The road, which is in a low density residential area, has an ADT of 250 vehicles per day.

Solution

The alternatives are:

- Alternative A – Grind asphalt road in poor condition, stabilize base and overlay with asphalt.
- Alternative B – Grind asphalt road in poor condition, stabilize base, and convert to a gravel road and maintain at a moderate maintenance level.

The estimated costs for converting to asphalt and maintaining a gravel road at a moderate and high maintenance level are based on the information in Table 5-3, and Table 5-4. The resulting estimated equivalent annual costs for asphalt and gravel maintained at a moderate level are shown in Table 5-14 and Table 5-15.

The cost ratio for each alternative must be calculated using based on the cost of the alternative and the minimum cost, which is $7,093 for Alternative B, the gravel road with moderate maintenance, as shown in Example 3.

$$S_A = 100 - 100\left[\frac{10{,}207 - 7{,}093}{\left(\frac{10{,}207 + 7{,}093}{2}\right)}\right] \quad \textbf{Eq. 15}$$

$$S_A = 64 \quad \textbf{Eq. 16}$$

$$S_B = 100 \quad \textbf{Eq. 17}$$

The scaled values for traffic volume, development and public preference can be found by referring to Table 5-11, Table 5-12, and Table 5-13.

For Alternative A, $S_{Traffic\ Volume}$ = 70, $S_{Development}$ = 50, and $S_{Public\ Preference}$ = 100

For Alternative B, $S_{Traffic\ Volume}$ = 30, $S_{Development}$ = 50, and $S_{Public\ Preference}$ = 5

The score for each alternative can now be calculated based on the weighting factors and scaled values.

$$Score_{Total} = 0.35\ S_{Cost} + 0.35\ S_{\substack{Traffic \\ Volume}} + 0.20\ S_{Development} + 0.10\ S_{\substack{Public \\ Preference}}$$ **Eq. 18**

$$Score_A = 0.35(64) + 0.35(70) + 0.20(50) + 0.10\ (100) = 67$$ **Eq. 19**

$$Score_B = 0.35\ (100) + 0.35\ (30) + 0.20(50) + 0.10\ (5) = 56$$ **Eq. 20**

On the basis of the total score, Alternative A, the asphalt road, has a higher score and is the preferred alternative. Notice that the increase in volume affected the preferred alternative.

Example 6 - Multi-objective Assessment

Using the multi-objective assessment procedure, compare the cost of converting one mile of an asphalt road in poor condition to a gravel road maintained at a moderate level, without considering user costs, for a 14 year analysis period. The road, which is in a low density residential area, has an ADT of 200 vehicles per day.

Input from the community stakeholders indicates that public preference should not be directly considered, and the weighting values for cost and traffic volume should be weighted higher. The revised weighting factors are shown in Table 5-16. Input from the community stakeholders also indicates that gravel is not an acceptable alternative for any residential development, so the scaled values for development are adjusted as shown in Table 5-17.

Table 5-16. Example 6. Revised Weighting Factors Reflecting Local Input

Attribute	Cost	Traffic Volume	Development	Preference
Weight	0.40	0.40	0.20	0

Table 5-17. Example 6. Revised Scaled Values Reflecting Local Input

Development	Agriculture	Low Density Residential	Industrial, Commercial, Moderate or High Density Residential
Scaled Value – Gravel	50	0	0
Scaled Value – Asphalt	50	100	100

Solution

The alternatives are:

- Alternative A – Grind asphalt road in poor condition, stabilize base and overlay with asphalt.
- Alternative B – Grind asphalt road in poor condition, stabilize base, and convert to a gravel road and maintain at a moderate maintenance level.

The estimated costs for converting to asphalt and maintaining a gravel road at a moderate and high maintenance level are based on the information in Table 5-3, and Table 5-4. The resulting estimated equivalent annual costs for asphalt and gravel maintained at a moderate level are shown in Table 5-14 and Table 5-15.

The cost ratio for each alternative must be calculated using Equation 1 based on the cost of each alternative and the minimum cost, which is $7,093 for Alternative B, the gravel road with moderate maintenance.

$$S_A = 100 - 100\left[\frac{10{,}207\ - 7{,}093}{\left(\frac{10{,}207 + 7{,}093}{2}\right)}\right] \quad \textbf{Eq. 21}$$

$$S_A = 64 \quad \textbf{Eq. 22}$$

$$S_B = 100 \quad \textbf{Eq. 23}$$

The scaled values for traffic volume and development can be found by referring to Table 5-11 and Table 5-17.

For Alternative A, $S_{Traffic\ Volume}$ = 60, $S_{Development}$ = 100

For Alternative B, $S_{Traffic\ Volume}$ = 40, $S_{Development}$ = 0

The score for each alternative can now be calculated using Equation 3 based on the weighting factors and scaled values.

$$Score_{Total} = 0.40\, S_{Cost} + 0.40\, S_{\substack{Traffic \\ Volume}} + 0.20\, S_{Development} + 0.0\, S_{\substack{Public \\ Preference}} \qquad \textbf{Eq. 24}$$

$$Score_A = 0.40(64) + 0.40(60) + 0.20(100) + 0 = 70 \qquad \textbf{Eq. 25}$$

$$Score_B = 0.40\ (100) + 0.40\ (40) + 0.20(0) + 0 = 56 \qquad \textbf{Eq. 26}$$

On the basis of the total score, Alternative A, the asphalt road, has the higher score and is the preferred alternative.

6.0 Conclusion

This report provides two assessment methodologies to provide guidance for a local agency in deciding whether a road should be paved or gravel. The report includes estimated costs for maintaining local roads based on information provided by local agencies in Indiana. The first assessment procedure provides a basic framework for comparing the cost of each alternative. The second procedure is a multi-objective assessment procedure that allows agencies to estimate a score for each alternative based on multiple attributes, such as cost, traffic volume, development and public preference.

It is recommended that the assessment procedures in this report be used as one tool in the decision-making process. In all cases, the local agency can modify the procedure to fit local needs. Local agencies can utilize the maintenance procedures and costs associated with their practices; similarly, for the multi-objective assessment procedure, the local agency can modify the weighting factors and the scaled values to reflect local priorities.

The decision to upgrade a gravel road to paved, or alternately, to convert a paved road back to gravel is not always easy. The decision may encompass not only cost, but also user preferences, community needs and preferences, economic development, and overall quality of life. While important considerations, these factors are inherently challenging to quantify. This report provides one tool, and it is intended to support local agencies in their decision making, rather than constrain them.

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Appendix A. Survey of Indiana Highway Engineers and Supervisors

This appendix provides the results of a survey of local highway superintendents and county engineers who attended the Indiana Association of County Engineers and Supervisors (IACHES) business meeting in December 2012.

1.) Which factor do you think has the greatest impact when deciding whether a road should be paved or gravel?

	Responses (percent)	Responses (count)
Cost (capital and maintenance)	40.62%	13
Traffic volume	40.62%	13
Percent trucks	0%	0
Development / expected growth rate	9.38%	3
Public preference (dust) / political considerations	9.38%	3
Totals	100%	32

2.) Which factor do you think has the second greatest impact when deciding whether a road should be paved or gravel?

	Responses (percent)	Responses (count)
Cost (capital and maintenance)	25.81%	8
Traffic volume	45.16%	14
Percent trucks	3.23%	1
Development / expected growth rate	9.68%	3
Public preference (dust) / political considerations	16.13%	5
Totals	100%	31

3.) Which factor do you think has the third greatest impact when deciding whether a road should be paved or gravel?

	Responses (percent)	Responses (count)
Cost (capital and maintenance)	12.50%	4
Traffic volume	9.38%	3
Percent trucks	9.38%	3
Development / expected growth rate	46.88%	15
Public preference (dust) / political considerations	21.88%	7
Totals	100%	32

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4.) What traffic volume (ADT) generally warrants a paved road?

	Responses (percent)	Responses (count)
There is not a specific volume	18.75%	6
≤ 50 vehicles a day	6.25%	2
100 vehicles a day	28.12%	9
150 vehicles a day	3.12%	1
200 vehicles a day	12.50%	4
250 vehicles a day	6.25%	2
300 vehicles a day	12.50%	4
350 vehicles a day	3.12%	1
400 vehicles a day	3.12%	1
≥ 450 vehicles a day	6.25%	2
Totals	100%	32

5.) What is the average cost for one of your highway department workers? (hourly cost for salary only)

	Responses (percent)	Responses (count)
≤ $12	7.69%	2
$14	23.08%	6
$16	57.69%	15
$18	11.54%	3
$20	0%	0
$22	0%	0
$24	0%	0
$26	0%	0
≥ $28	0%	0
Totals	100%	26

6.) How many miles of gravel have you converted to HMA in the past 10 years?

	Responses (percent)	Responses (count)
Zero, we have not converted any gravel roads to HMA	32.26%	10
≤ 10 miles	38.71%	12
15 miles	3.23%	1
20 miles	16.13%	5
25 miles	0%	0
30 miles	0%	0
40 miles	3.23%	1
50 miles	0%	0
60 miles	0%	0
≥ 70 miles	6.45%	2
Totals	100%	31

7.) How many miles of HMA have you converted to gravel in the past 10 years?

	Responses (percent)	Responses (count)
Zero, we have not converted any HMA roads to gravel	74.19%	23
≤ 10 miles	16.13%	5
15 miles	0%	0
20 miles	6.45%	2
25 miles	0%	0
30 miles	0%	0
40 miles	0%	0
50 miles	0%	0
60 miles	0%	0
≥ 70 miles	3.23%	1
Totals	100%	31

8.) What is the cost for an HMA overlay per mile? (contract price or materials, labor and equipment)

	Responses (percent)	Responses (count)
≤ $50,000	13.33%	4
$65,000	40%	12
$80,000	6.67%	2
$95,000	20%	6
$110,000	10%	3
$125,000	6.67%	2
$140,000	0%	0
$165,000	3.33%	1
≥ $180,000	0%	0
Totals	100%	30

An HMA overlay provides a better driving surface but does not address structural problems with the road.

9.) How thick is the HMA overlay you typically use to improve the driving surface on a county road?

	Responses (percent)	Responses (count)
1 inch	12.90%	4
1.5 inches	38.71%	12
2 inches	29.03%	9
2.5 inches	6.45%	2
≥ 3 inches	12.90%	4
Totals	100%	31

An HMA overlay provides a better driving surface but does not address structural problems with the road.

10.) What is the ideal interval between HMA overlays?

	Responses (percent)	Responses (count)
< 10 years	12.50%	4
10 years	15.62%	5
12 years	12.50%	4
15 years	31.25%	10
18 years	9.38%	3
20 years	12.50%	4
25 years	3.12%	1
30 years	3.12%	1
≥ 35 years	0%	0
Totals	100%	32

An HMA overlay provides a better driving surface but does not address structural problems with the road.

11.) How much does it cost to crack seal a mile of HMA road? (one application, materials, labor and equipment, ideal overlay cycle)

	Responses (percent)	Responses (count)
We do not do this activity	16.67%	5
≤ $1,000	10%	3
$1,500	20%	6
$2,000	13.33%	4
$2,500	10%	3
$3,000	6.67%	2
$3,500	10%	3
$4,000	3.33%	1
$4,500	3.33%	1
≥ $5,000	6.67%	2
Totals	100%	30

Crack seal: A localized treatment method used to prevent water and debris from entering a crack, which might include routing to clean the entire crack and to create a reservoir to hold the sealing.

12.) What is the annual cost to patch HMA road per mile? (material, labor and equipment cost, ideal overlay cycle)

	Responses (percent)	Responses (count)
We do not do this activity	0%	0
≤ $100	6.45%	2
$200	12.90%	4
$300	12.90%	4
$400	19.35%	6
$500	9.68%	3
$750	16.13%	5
$1,000	6.45%	2
$1,250	3.23%	1
≥ $1,500	12.90%	4
Totals	100%	31

Patching: Repair distress and improve ride quality

13.) How much does it cost for a chip seal, seal coat or surface treatment on an HMA road? (include material, labor and equipment cost)

	Responses (percent)	Responses (count)
We do not use a chip seal, seal coat or surface treatment on an HMA road	12.50%	4
≤ $2,500	3.12%	1
$5,000	9.38%	3
$7,500	3.12%	1
$10,000	15.62%	5
$12,500	9.38%	3
$15,000	21.88%	7
$20,000	15.62%	5
$25,000	9.38%	3
≥ $30,000	0%	0
Totals	100%	32

Surface treatments: Used to waterproof the surface, seal small cracks, reduce oxidation of the pavement surface, and improve friction.

14.) Ideally, how often would you apply a chip seal, seal coat or surface treatment on an HMA road?

	Responses (percent)	Responses (count)
We do not typically chip seal an HMA road	12.50%	4
≤ 3 years	3.12%	1
5 years	18.75%	6
6 years	9.38%	3
7 years	34.38%	11
8 years	3.12%	1
9 years	9.38%	3
10 years	6.25%	2
11 years	0%	0
≥ 12 years	3.12%	1
Totals	100%	32

Surface treatments: Used to waterproof the surface, seal small cracks, reduce oxidation of the pavement surface, and improve friction.

15.) What is typically the basis for maintenance on your HMA roads (e.g., overlay, chip seal)?

	Responses (percent)	Responses (count)
On a defined schedule (e.g., every 30 years for an overlay, every 7 years for chip seal, etc.)	3.23%	1
As needed, based on road condition, public comments and/or agency observations	61.29%	19
Combination of a defined schedule and as needed	35.48%	11
Totals	100%	31

16.) How much does it cost to grind the surface and stabilize the base of an existing HMA road in very poor condition? (per mile, material, labor and equipment)

	Responses (percent)	Responses (count)
We do not do this activity	22.58%	7
≤ $5,000	3.23%	1
$10,000	3.23%	1
$15,000	25.81%	8
$20,000	9.68%	3
$25,000	9.68%	3
$30,000	3.23%	1
$40,000	3.23%	1
$50,000	6.45%	2
≥ $60,000	12.90%	4
Totals	100%	31

17.) How much does it cost for one application of dust control on a mile of gravel road? (material, labor and equipment cost)

	Responses (percent)	Responses (count)
We do not do this activity	51.85%	14
≤ $500	18.52%	5
$1,000	11.11%	3
$1,500	7.41%	2
$2,000	3.70%	1
$2,500	0%	0
$3,000	0%	0
$3,500	0%	0
≥ $4,000	7.41%	2
Totals	100%	27

Dust Control: Reduce emanation of fugitive dust

18.) How much does it cost to blade a gravel road? (per mile, materials, labor and equipment)

	Responses (percent)	(count)
We do not do this activity	9.38%	3
≤ $40	18.75%	6
$60	3.12%	1
$80	6.25%	2
$100	21.88%	7
$125	3.12%	1
$150	6.25%	2
$200	6.25%	2
$250	6.25%	2
≥ $300	18.75%	6
Totals	100%	32

Blading: Remove surface defects; minor crown restoration

19.) How much does it cost for gravel to gravel a gravel road? (per mile, MATERIALS ONLY)

	Responses (percent)	(count)
We do not do this activity	10.34%	3
≤ $250	6.90%	2
$500	6.90%	2
$750	3.45%	1
$1,000	0%	0
$2,500	24.14%	7
$5,000	17.24%	5
≥ $7,500	31.03%	9
Totals	100%	29

Re-gravel: Restore structural capacity; improve quality of surfacing gravel; replace lost gravel. Some agencies add a couple of inches every few years to re-gravel a road.

20.) How much does it cost to re-gravel a gravel road? (per mile, MATERIALS, LABOR AND EQUIPMENT)

	Responses (percent)	(count)
We do not do this activity	17.24%	5
≤ $1,000	3.45%	1
$2,000	6.90%	2
$3,000	0%	0
$4,000	0%	0
$5,000	13.79%	4
$6,000	6.90%	2
$8,000	13.79%	4
$10,000	6.90%	2
≥ $12,000	31.03%	9
Totals	100%	29

Re-gravel: Restore structural capacity; improve quality of surfacing gravel; replace lost gravel. Some agencies add a couple of inches every few years to re-gravel a road.

21.) How frequently do you re-gravel a gravel road?

	Responses (percent)	(count)
We do not do this activity	23.33%	7
≤ 2 years	26.67%	8
3 years	10%	3
5 years	26.67%	8
7 years	3.33%	1
10 years	3.33%	1
12 years	3.33%	1
≥ 15 years	3.33%	1
Totals	100%	30

Re-gravel: Restore structural capacity; improve quality of surfacing gravel; replace lost gravel. Some agencies add a couple of inches every few years to re-gravel a road.

22.) How much does it cost to reshape/crown a mile of gravel road? (materials, labor and equipment)

		Responses	
		(percent)	**(count)**
We do not do this activity		17.24%	5
≤ $50		6.90%	2
$100		10.34%	3
$150		3.45%	1
$200		10.34%	3
$250		6.90%	2
$300		6.90%	2
$400		17.24%	5
$500		10.34%	3
≥ $600		10.34%	3
	Totals	100%	29

Reshape/Crown: Change the cross section to improve drainage; recover material from the foreslope or ditch; blend surface gravel; restore crown; remove surface defects and correct defects in the cross section.

23.) How much does it cost to spot gravel/patch and conduct other annual maintenance on a gravel road? (per mile for materials, labor and equipment)

		Responses	
		(percent)	**(count)**
We do not do this activity		9.68%	3
≤ $100		9.68%	3
$150		3.23%	1
$200		12.90%	4
$250		9.68%	3
$300		9.68%	3
$400		6.45%	2
$500		12.90%	4
$750		12.90%	4
≥ $1000		12.90%	4
	Totals	100%	31

Spot gravel / patching: correct isolated defects in the roadway

24.) What is typically the basis for maintenance activities on your gravel roads?

	Responses (percent)	(count)
On a defined schedule (e.g., every month or twice a year depending on the activity)	3.45%	1
As needed, based on road condition, public comments and/or agency observations	65.52%	19
Combination of a defined schedule and as needed	31.03%	9
Totals	100%	29

25.) How much does it cost to improve the base of a gravel road and overlay with HMA (per mile, material, labor and equipment)

	Responses (percent)	(count)
We do not do this activity	3.45%	1
≤ $50,000	3.45%	1
$75,000	10.34%	3
$100,000	6.90%	2
$125,000	24.14%	7
$150,000	20.69%	6
$175,000	3.45%	1
$200,000	13.79%	4
$225,000	6.90%	2
≥ $250,000	6.90%	2
Totals	100%	29

Summary of Survey Results

Question #	Description	Average	Minimum	Maximum	Mode
4	ADT	204	50	450	100
5	Hourly Worker Salary	$15	$12	$18	$16
6	Gravel to HMA Road Conversions (miles)	26	10	70	10
7	HMA to Gravel Road Conversions (miles)	23	10	70	10
8	Asphalt Overlay Cost	$81,833	$50,000	$165,000	$65,000
9	Overlay Thickness (inches)	2	1	3	2
10	Overlay Frequency (years)	14	8	30	15
-	Estimated Overlay Annual Cost	$6,002	$2,778	$15,625	$4,333
11	Crack Seal Cost	$2,500	$1,000	$5,000	$1,500
12	Patching/Annual Maintenance Cost	$616	$100	$1,250	$750
13	Chip Seal Cost	$14,018	$2,500	$25,000	$15,000
14	Chip Seal Frequency (years)	7	3	11	7
-	Estimated Chip Seal Annual Cost	$2,218	$556	$5,000	$3,333
16	Stabilize Base of Asphalt Cost	$28,333	$5,000	$60,000	$15,000
17	Dust Control Cost	$1,423	$500	$4,000	$500
18	Blading Cost	$148	$40	$300	$100
19	Re-gravel Cost (Materials Only)	$4,317	$250	$7,500	$7,500
20	Re-gravel Cost	$8,208	$2,000	$12,000	$12,000
21	Re-gravel Frequency (years)	5	2	15	5
-	Estimated Re-gravel Annual Cost	$2,019	$417	$5,000	$2,000
22	Reshaping Cost	$315	$50	$600	$400
23	Spot Gravel Cost	$454	$100	$1,000	$200
25	Improve Base of Gravel Road and Overlay with Asphalt	$149,107	$50,000	$250,000	$125,000

Note: All costs are per mile.
Average values were typically used except for dust control and re-gravel cost, in which case the mode was used.
The mode was used for dust control since some agencies may have considered chip seal as a form of dust control; chip seal is considerably more expensive.
The mode was used for re-gravel cost because the range of possible answers may not have been high enough since the highest category ($12,000 or more) was the most frequent answer.