Recommended Criteria in the Decision Process for Paving Unsurfaced Roadways

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by

Scott Shuler
Associate Professor
Department of Construction Management
Colorado State University
Ft. Collins, Colorado

Introduction

Approximately seventy percent of the roadways in Colorado are unpaved (1). Many of these roads evolved from primitive trails that were paths of least resistance used by game, early man and finally the current settlers. As traffic increased these pathways became roads that were gradually improved with crushed stone or sand and gravel surfaces. Usually, engineering was minimal on these early roads since the objective of placing the rock surfaces was simply to keep the residents 'out of the mud'. As traffic, population and dust increased these unsurfaced roads often had liquid asphalt, chlorides or even chip seals applied to improve durability or reduce dust. However, adequate improvements to the foundation support, drainage and alignment were often not done as these surface improvements were made. Then when paving did occur later in the life of the roadway maintenance problems arose due to the inadequate preparation of the foundations.

To Pave or Not to Pave …

What do we mean by a 'paved' road? In this paper we are considering any asphalt bound, all-weather surface a pavement. That means any combination of asphalt and aggregate so that the asphalt provides waterproofing and some adhesive qualities and the aggregates provide structural strength and frictional resistance. So, by this definition the word 'paved' means everything from chip seals to hot mixed asphalt concrete.

Paving an unsurfaced road includes certain tradeoffs. The advantages include waterproofing the subgrade and base course. This reduces potential for load related damage of the surface during wet weather. Paving reduces dust. Most users enjoy the smoother ride qualities that paving produces. And pavements can accommodate more varieties of vehicles than unpaved roads.

However, the initial cost of unsurfaced roads is low. If maintained effectively, aggregate surfaced roads provide an adequate riding surface. And, depending on the structure of

the subgrade and base course the aggregate surfaced road may be easier and less expensive to maintain and require less operator skill. Traffic speeds are usually lower and, although potholes occur more frequently, can be repaired faster.

The information needed to make the decision to pave or not to pave can be synthesized into five steps (2):

1. A Road Management Program
2. Determining Traffic Demands and Geometry
3. Improving Base and Drainage
4. Pavement Life and Costs
5. Public Opinion

A Road Management Program

Paving one gravel road in a network is not a decision made in a vacuum. Instead, a road management system is designed to improve all roads or streets in the network by using the management practices shown below:

Develop a Road Inventory
Determine what roads are the responsibility of the agency. This inventory provides information on what roads are paved and unpaved and where they are located.

Develop a Condition Survey
Adopt a pavement management program. This can be a simple program like Micro PAVER (3) or something more complex depending on the size of the network. A program like this keeps a continuous record of pavement condition over time.

Preventive Maintenance and Rehabilitation Strategies
Select the most appropriate treatment to repair each road, bridge, or problem area.

Determine Needs
Estimate the cost of each repair job using generalized average costs. Establish long-range goals and objectives that in turn will help the agency justify its budget requests.

Establish Priorities

Keep good roads in good shape (preventive maintenance) and establish a separate budget, or request a temporary increase, to reconstruct roads in poor condition.

Determining Traffic Demands and Geometry

Traffic volume and type affects roadway performance. As average daily traffic (ADT) approaches 500 vehicles per day, paving should be considered.

However, the type of traffic should also be considered. For example, a road carrying 500 ADT which is primarily passenger cars and light trucks may be equivalent to another road carrying 250 ADT which are light and medium size trucks.

Unpaved roads are sometimes inadequate with respect to vertical and horizontal alignment. Paving will encourage higher traffic speeds. As speed increases, sight distance must also increase, and obstructions must be removed to maintain safety.

Some engineers recommend 22 feet as the minimum safe width for paved roads (2). If widening is needed bridges may also require widening. In addition to improving width, removing obstructions such as trees, and vertical and horizontal alignment, the surface friction must be improved and superelevation may need to be added to curves.

Improving Base and Drainage

The subgrade soil and base course are the foundation for the pavement structure. If inadequate, premature pavement failure will result. Often, the foundation soil and aggregate surface, which was adequate as the structure for the unpaved road, is not adequate as the foundation for the paved road. This is because the aggregate material used in an unpaved road requires plasticity in the fine aggregate to help bind the matrix. This improved surface drainage, creates a stiffer riding surface and reduces the time between maintenance grading operations. However, this type of material is often an inferior base for a pavement. These higher plasticity materials can trap moisture resulting in a weak substrate for the pavement above. The result is premature fatigue failure resulting in potholes.

Pavement Costs

At least three costs should be considered before paving a gravel road. These are short-term preparation and construction costs, long-term maintenance costs and user costs.

The short-term preparation costs include a host of variations including obstruction removal from nearby shoulders, vertical and horizontal alignment changes, drainage improvements, and new materials for base course. However, initial paving and base costs, long term maintenance costs and user costs can be estimated on an equal basis for paved versus unpaved roads and can be compared. For example, maintenance costs for both road surfaces can be summarized as follows:

Paved

- patching
- seal coats

- crack filling
- striping

Unpaved

- re-graveling
- grading
- stabilization
- dust control

Practical methodologies and models that local road agencies can use to determine when to upgrade road surfaces have been developed (6, 7, 8). These procedures will be used in the following examples to help provide a guide for others involved in the decision process when the question to pave or not to pave arises.

Obtaining reliable cost data is challenging. These costs depend on a large number of variables. Some variables such as road geometry, traffic volume, terrain, subgrade condition, and distance from material suppliers, could be determined for each section of road. However, such data are widely variable making development of deterministic models questionable. This means that developing the future cost of maintenance for a specific road is not feasible given the myriad variables that influence costs. However, it is possible to estimate average costs over a road network with much greater confidence. Therefore, construction, maintenance and user costs will be estimated based on average costs in the example to follow.

Costs to the user of the roadway should be considered in the decision to pave or not to pave. There is a significant difference in cost to the user between driving on a gravel surface and driving on a paved surface.

Vehicles cost more to operate on gravel surfaces than on paved surfaces. There is greater rolling resistance and less traction. This increases fuel consumption. The roughness of the surface contributes to additional tire wear and influences maintenance and repair expenses. Dust causes extra engine wear, oil consumption and maintenance costs.

AASHTO published an important report in 1977 which provides comprehensive life cycle cost analysis of various roadways (4) and shows the impacts of gravel surfaces on user costs. An update of this analysis was completed by NCHRP on Project 7-12, "Microcomputer Evaluation of Highway User Benefits," resulting in an automated means (MicroBENCOST) to evaluate user-benefits (5).

Economic Analysis

Once the decision is made to consider paving a gravel road, an economic analysis should be conducted to determine the difference between the cost of maintaining the gravel and the cost to construct and maintain the asphalt pavement. Relatively rigorous analyses have been presented (10) that make arguments for postponing paving so that capital can

be invested in other assets. And although these analyses may be valid in some circumstances when capital can be reinvested or saved for alternative spending needs, in many cases this is not the case. Therefore, a very simple economic analysis is provided below for how the cost of maintaining an existing gravel road can be compared with the cost of paving and maintaining a new hot mix asphalt pavement.

Example: To Pave or Not to Pave County Road X

Three levels of maintenance are presented below for County Road X per mile.

Low Level - motor grader at $100/hr x 2 hrs/day = $200/day
Assume grader operates two times per month or 26 x $200 = $5200/mi/yr

Med Level – motor grader at $100/hr x 3 hrs = $300/day
+ water truck + water at $75/hr x 3 hrs = $225/day = $525/day
Assume two times per month or 26 x $525/day = $13,650/mi/yr

High Level- motor grader at $100/hr x 8 hrs = $800/day
+ water truck + water at $75/hr x 8 hrs = $600/day
+ chloride at 2000 gals at $0.50/gal = $1000/day
Assume two times per month or 26 x $1400/day= $36,400/mi/yr
+$1000 = $37,400/mi/yr

Assume that $150,000 per mile will be required to pave County Road X. Over the 20 year life of the road, average maintenance costs for the asphalt pavement are estimated in Table 1 using a discount rate of 3 percent. To determine the economic feasibility of paving versus not paving the costs for paving should be compared with the costs of continuing to maintain the road with gravel. Table 2 provides this comparison for agency costs in net present value over twenty years.

Table 1. Average County Road Cost Data

Year	Initial Cost, $	Crack Seal, $	Chip Seal, $	Striping, $	Patching, $	Total, $	Present Value, $
0	150,000					150,000	150,000
1							
2							
3							
4		1,600			500	2,100	1,866
5							
6			7,000	300	500	7,800	6,532
7							
8		1,600			500	2,100	1,658
9							
10			7,000	300	500	7,800	5,804
11							
12		1,600			500	2,100	1,473
13							
14			7,000	300	500	7,800	5,157
15							
16		1,600			500	2,100	1,309
17							
18			7,000	300	500	7,800	4,582
19							
20		1,600			500	2,100	1,163
						Total Present Value >>	179,543

Table 2. Paving vs Maintenance Costs for 20 Years on County Road X

Year	Low Maint	Low Maint NPV	Med Maint	Med Maint NPV	High Maint	High Maint NPV
0	5,200	5,200	13,650	13,650	37,400	37,400
1	5,200	5,049	13,650	13,252	37,400	36,311
2	5,200	4,901	13,650	12,866	37,400	35,253
3	5,200	4,759	13,650	12,492	37,400	34,226
4	5,200	4,620	13,650	12,128	37,400	33,229
5	5,200	4,486	13,650	11,775	37,400	32,262
6	5,200	4,355	13,650	11,432	37,400	31,322
7	5,200	4,228	13,650	11,099	37,400	30,410
8	5,200	4,105	13,650	10,775	37,400	29,524
9	5,200	3,985	13,650	10,462	37,400	28,664
10	5,200	3,869	13,650	10,157	37,400	27,829
11	5,200	3,757	13,650	9,861	37,400	27,019
12	5,200	3,647	13,650	9,574	37,400	26,232
13	5,200	3,541	13,650	9,295	37,400	25,468
14	5,200	3,438	13,650	9,024	37,400	24,726
15	5,200	3,338	13,650	8,761	37,400	24,006
16	5,200	3,240	13,650	8,506	37,400	23,306
17	5,200	3,146	13,650	8,258	37,400	22,628
18	5,200	3,054	13,650	8,018	37,400	21,969
19	5,200	2,965	13,650	7,784	37,400	21,329
20	5,200	2,879	13,650	7,558	37,400	20,707
		82,563		216,728		593,818

There are other ways to look at this analysis, also. For example, if capital expenditures for construction are separate from maintenance funds, a comparison of just maintenance

costs for the two scenarios might be of interest. Then, the cost of maintaining the hot mix asphalt pavement would be $29,543 over twenty years and the cost of maintaining the gravel road at the low medium and high levels would be as shown in Table 2. This represents a savings of $53,020, $187,185, and $564,275 for the low, medium and high-level maintenance alternatives, respectively over twenty years on an original $150,000 investment in the asphalt pavement.

When vehicle operating costs are included the difference becomes more significant. For example a 350 ADT two lane road would cost an estimated $480,000 per mile in vehicle operating costs for gravel and $180,000 for hot mix asphalt according to Zimmerman and Wolters (6) as shown in Figure 1. This represents a net present value of $99,662 using a 3 percent discount rate. When added to the $53,020, $187,185, and $564,275 in maintenance savings the public realizes a total of $152,682, $286,847, $663,937 in net savings, respectively. As Figure 1 shows the operating cost difference between gravel and hot mix asphalt becomes greater as traffic volume increases, as expected. This is a simplified analysis and does not include additional benefits such as safety, dust reduction, and increased property values.

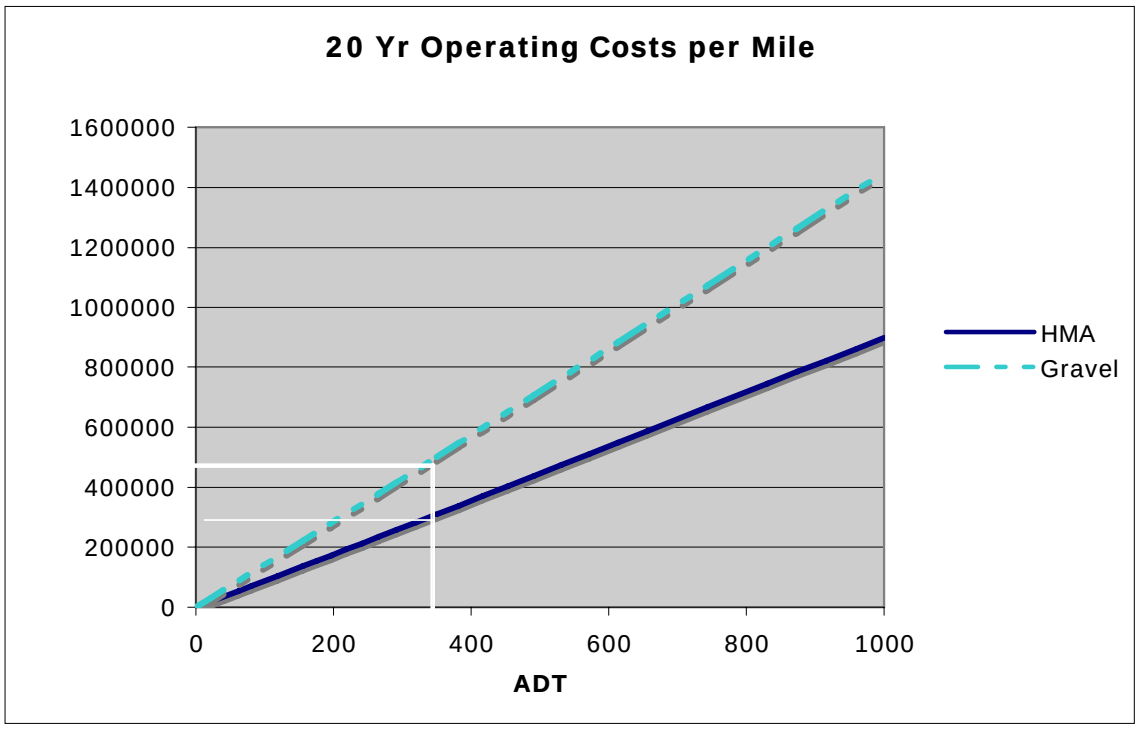

Figure 1. Cumulative 20-year Vehicle Operating Cost per Mile (6)

Public Opinion

The decision to pave an unsurfaced road may affect the public. Consequently, public opinion as to whether this will be accepted should be obtained before proceeding. In

most cases, the public will welcome the smoother riding surface, reduced dust and safer driving environment. However, pavements often encourage higher speeds and traffic volume that may not be desirable to some.

Summary

This report provides a simple outline of the factors to consider when deciding whether to pave a gravel road. These factors include whether a pavement management program exists, determining traffic demands on the road, road structure, economic considerations and public opinion.

The simplest criteria for selecting candidate roads for paving is traffic volume. A correlation exists between traffic volume and maintenance costs for unsurfaced roads (6). Therefore, traffic volume can be utilized as an indicator for roads that may be candidates for paving. In general, as average daily traffic increases beyond 200 vehicles per day, paving begins to become feasible. As ADT reached 350 vehicles per day maintenance costs rise in proportion and the economics of paving begin to match the cost of continued maintenance of the unsurfaced road.

The economic example used in this report provides a very simple guide to those considering paving a gravel road. The values used in the example are hypothetical and should not be considered precise, especially since costs can change significantly over time. However, the outline should provide a useful tool for agencies wishing to determine if paving makes economic sense for specific circumstances when actual agency costs are utilized.

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