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Prototype Road Surface Management System

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Abstract

The Road Surface Management System (RSMS) is a powerful tool that can provide an overview and rough estimate of a roadway system's condition at the network level and the approximate costs for future improvements in towns and small cities. This helps municipalities and local agencies to apply limited budget resources and provide the greatest road quality benefits. To control the cost of roadway surface deterioration, local agencies and municipalities need to make cost-effective decisions regarding the maintenance, rehabilitation, and reconstruction of the roadway network. RSMS can help in assessing the condition of the network, weighing alternatives, and establishing long-term treatment plans and budgets. In this paper, RSMS is used to evaluate a university campus road network in the state of Idaho and to establish the necessary repair methods for 10 selected sections in the campus network.

Keywords

Road Management System, Cost-Effective Alternatives, Inventory Roads

1. Introduction

Pavement preservation and maintenance is a planned system of treating pavements at the optimum time to maximize their useful life, and to enhance pavement longevity at the lowest cost. Pavements perform well under traffic loads until a particular point in their life spans, at which time they deteriorate considerably and rapidly to failure, as shown in **Figure 1**. Municipalities and local agencies are often challenged with the high cost of maintaining a transportation system, and they must control costs by slowing roadway surface deterioration. This requires making cost effective decisions regarding the maintenance, repair, rehabilitation, and reconstruction of the municipal roadway network. Developing a maintenance budget based on cost-effective decisions requires a rational and systematic process. Typically, communities develop budgets using methods such as last year's budget, worst first, and political pressure. Though these decision-making criteria can work if a community has adequate resources and the majority of road surfaces are in good shape, this is often not the case. As such, municipal officials can benefit from a system that enables them to assess the condition of the network, weigh alternatives, and

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establish long-term programs and budgets. Although road systems are built at considerable cost, many roads show signs of major distress. If these problems are not corrected, the cost to bring the road to an acceptable condition can be many times more expensive than the cost of timely repair. As municipal roads worsen maintenance budgets need to increase. There are more deteriorated streets each year, and the cost per mile for maintenance increases disproportionately. According to the American Association of State Highway and Transportation Officials [1] [2], every $1 spent to keep a road in good condition avoids $6 - 14 needed later to rebuild the same road once it has deteriorated significantly. The Road Surface Management System (RSMS) is a useful tool to identify a road system's condition and determine the approximate costs for future improvements. RSMS provides a systematic approach for local officials to assess their road system, and to guide future improvement and investment in line with their budget. The RSMS program provides information on the condition, traffic, and importance of roads in a town to create a long term maintenance program. The general road surface management system (RSMS) processing includes the following tasks for the road network [3]:

- Inventory the road system by driving/or walking on the roads and making visual inspections;
- Determine and document the surface distresses condition and drainage condition of each road and entering that data into the program;
- Assign maintenance or repair methods for each condition strategy produced by the program;
- Determine costs of maintenance and repair methods;
- Assign repair and maintenance methods to each road;
- Establish maintenance and repair priorities;
- Establish long-term financial and budget plans.

2. Methodology

The University of Idaho (UI) road campus is used to apply the RSMS approach that was developed by the Department of Civil Engineering at the University of New Hampshire. The UI is located in the northern City of Moscow, ID. The methodology used in this paper is implemented using a computer based software package RSMS 11 that addresses the fundamental RSMS tasks, including: identifying the sections and roads in the UI campus network and their importance and the associated traffic volume in a scale of (1 - 5) with 1 the lowest and 5 the highest; inventory the road system by making a field survey of the surface distresses and drainage conditions; determining the condition of each road or section, assigning the suitable repair method for each section; determining the cost of each maintenance; rehabilitation or repair method; establishing repair priorities, and planning for long-term budget plans. Further details are shown in the next steps.

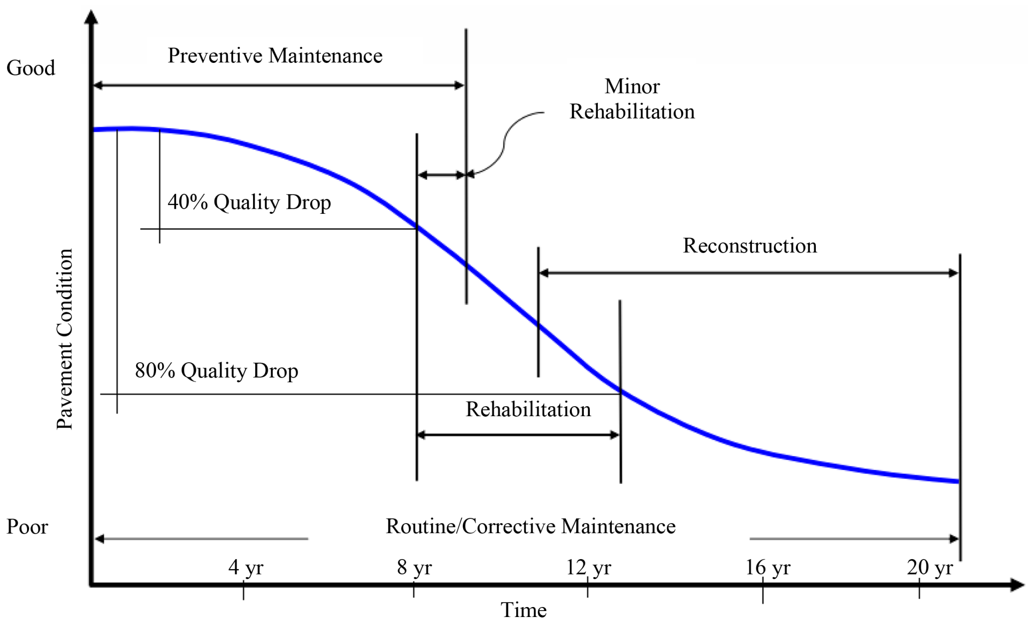

Figure 1. Pavement maintenance, rehabilitation, and construction phases with time.

3. Identifying the Deteriorated Road Sections

The following 10 roads (sections) were selected and identified for evaluation within the UI campus network system (with total length of 5.88 miles):

Section # 1: 6th Street from Deakin Ave to Perimeter Dr (0.695 miles).
Section # 2: Perimeter Dr from Blake Ave to SH8 (1.445 miles).
Section # 3: Stadium Dr from Perimeter Dr to Rayburn Street (0.692 miles).
Section # 4: Rayburn Street from Perimeter Dr to SH8 (0.592 miles).
Section # 5: Line Street from University Ave to SH8 (0.445 miles).
Section # 6: Blake Ave from 6th Street to Taylor Ave (0.502 miles).
Section # 7: Deakin Ave from 6th Street to Blake Ave (0.486 miles).
Section # 8: Idaho Ave from Deakin Ave to Stadium Dr (0.436 miles).
Section # 9: University Ave from Deakin Ave to Line Street (0.329 miles).
Section # 10: Sweet Ave from UI 95 to Blake Ave (0.341 miles).

An accurate road inventory is a very important part of any pavement management system (PMS) and it is considered the foundation of the system. The required data for the UI campus network were obtained from the campus maps and facility services, and from field survey of each section and road, including its length, width, number of lanes, shoulder type and its width, the importance of the section in a scale of (1 - 5) with 1 the lowest and 5 the highest, the traffic volume on each section in a scale of (1 - 5) with 1 the lowest and 5 the highest, the speed limits, right-of-way, and the maintenance division [3]. **Table 1** shows the 2016 inventory of the identified paved sections of the UI campus road network in Moscow, ID.

The importance of each section in a scale of (1 - 5) with 1 the lowest and 5 the highest, and the rank of the existing traffic volume used by each section in a scale of (1 - 5) with 1 being the lowest and 5 the highest were used in the RSMS as shown in **Table 2**.

4. Condition Survey for the Existing Surface Distresses and Drainage Conditions of the Road Sections

The purpose of the condition survey is to determine the condition of each section by visually observing the surface distresses. The condition survey is crucial to the pavement management system since certain distresses are related to certain causes of pavement deterioration [4] [5]. Due to this direct relationship, RSMS links distress types to the Maintenance, Rehabilitation, and Reconstruction (MR & R) strategies [3] [6] [7]. Gathering the inventory and road surface condition and drainage condition for each identified section is done by driving on the roads and/or walking on the roads and collecting visual inspections of the existing distresses and the roadside drainage for each road section, recording the SEVERITY and EXTENT of a distress. The severity is ranked as

Table 1. Inventory of the paved sections in the UI campus road network in Moscow, ID.

Section #	Name	From	To	Length (mile)	Width (ft)	Number of Lanes	Shoulder Width (ft)
1	6th St	Deakin Ave	Perimeter Dr	0.695	25	2	8
2	Perimeter Dr	Blake Ave	SH8	1.445	45	4	3
3	Stadium Dr	Perimeter Dr	Rayburn St	0.692	50	4	5
4	Rayburn St	Perimeter Dr	SH8	0.592	37.5	3	6
5	Line St	SH8	University Ave	0.445	32	2	6
6	Blake Ave	6th St	Taylor Ave	0.502	37.5	3	5
7	Deakin Ave	6th St	Blake Ave	0.486	37.5	3	6
8	Idaho Ave	Deakin Ave	Stadium Dr	0.436	25	2	3
9	University Ave	Deakin Ave	Line St	0.239	25	2	3
10	Sweet Ave	UI 95	Blake Ave	0.341	37.5	3	6

(low, medium, and high) depending on the length, width and the visual shape of the existing cracks and distresses, and the extent is ranked as low for <10% of the road section area, medium for 10% - 30%, and high for >30% as indicated in the RSMS. Decision trees are used to relate the surface distresses of each section with the appropriate strategy. Each distress type (*i.e*. alligator cracking, potholes, etc.) has a link that relates each severity/extent condition with an MR & R strategy. RSMS categorizes each section in term of the strategy repair method and determines its repair options depending on the surface distresses and roadside drainage data input. The type of repair strategies produced by RSMS are the following (No Maintenance, Routine, Preventive, Rehabilitation, and Reconstruction), and each strategy has several repair options. The following types of distresses were inspected and documented by their level of severity and extent:

1) Alligator Cracks
2) Longitudinal/Transverse Cracks
3) Edge Cracking
4) Patches and Potholes
5) Roughness
6) Rutting
7) Roadside Drainage

Table 3 shows the condition survey for each section within the UI campus road network, the different types

Table 2. The importance and traffic volume of the road sections.

Section #	Name	Road surface type	The importance of the section in (1 - 5) scale	Traffic volume on the section in (1 - 5) scale
1	6^{th} St	Paved	1	1
2	Perimeter Dr	Paved	1	1
3	Stadium Dr	Paved	1	1
4	Rayburn St	Paved	3	3
5	Line St	Paved	1	1
6	Blake Ave	Paved	3	3
7	Deakin Ave	Paved	2	2
8	Idaho Ave	Paved	4	4
9	University Ave	Paved	4	4
10	Sweet Ave	Paved	1	1

Table 3. Condition survey of the road sections and RSMS status.

Section #	Name	Alligator Cracks	Long/Tran Cracks	Edge Cracks	Patches and Potholes	Rough-Ness	Rutting	Road Drainage	RSMS Surface Status
1	6^{th} St	Low-med	Low-med	Low-med	Low-low	Low-high	med-low	Low-low	Routine
2	Perimeter Dr	Low-med	Low-high	Low-high	Low-low	Med-med	Med-low	Low-low	Preventive
3	Stadium Dr	Low-med	Med-med	Med-med	Low-med	Med-med	Med-med	Low-low	Preventive
4	Rayburn St	Low-med	Low-med	Med-med	Med-low	Med-med	Med-med	Low-low	Preventive
5	Line St	Low-med	Low-med	Med-med	Low-med	Med-med	Med-low	Low-low	Routine
6	Blake Ave	Med-med	High-med	High-med	Med-med	High-med	Med-med	Low-low	Rehabilitate
7	Deakin Ave	Med-med	Med-med	Med-med	Med-med	High-med	Med-med	Low-low	Rehabilitate
8	Idaho Ave	Med-med	Med-med	Med-med	Med-med	High-med	Med-med	Low-low	Rehabilitate
9	University Ave	Med-med	Med-med	Med-med	Med-low	Med-med	Med-med	Low-low	Rehabilitate
10	Sweet Ave	Low-low	Low-med	Low-med	Low-low	Med-med	Med-med	Low-low	Preventive

of the existing surface distresses and drainage conditions, and the RSMS surface status. **Table 4** identifies the sections by the repair strategy of RSMS. **Table 5** shows the repair strategy in term of the percent of total network length

5. Assigning the Suitable Repair Method and Cost-Effective Alternative

RSMS assigns appropriate repair options for each category [3] whether for maintenance costs depending on the road surface distresses as follows:

- For routine category, RSMS gives the following options (crack seal, and Patching).
- For preventive category, RSMS gives the following options (sand seal, chip seal, thick overlay >1”, thin overlay 3/4” - 1”, shim with 1” overlay, 2” cold mix overlay with 1” HMA, and mill and fill 1.25”).
- For rehabilitation category, RSMS gives the following repair options (reclaim incl 6” - 8” base 2” binder 1.5” surface, shim with 2” overlay, reclaim pavement revert to gravel, and RAP reclamation).

Each repair option has an estimated cost and life expectancy that must be the most cost-effective alternative.

Table 6 shows the cost of each repair option for all repair categories, and from this list, the suitable repair option can be selected in the next step.

The selection of the repair option for each section is based on the utilization and optimization of many factors [6] [8]-[11] such as:

- Repair cost: choose the option with the lowest market price and cost.
- Best technical solution: choose the option that best addresses and cure the current surface distress condition and structural capacity of the section. This is an important weighing factor.
- Life cycle cost: choose the option that allows providing serviceability over the longest possible life cycle of the road.
- User delay cost: choose the option that minimizes the user delay cost of the road and contribute to the public satisfaction.
- Safety and risk minimization: choose the option that increases safety and minimizes the risk to the public.
- Recycling of the materials: choose the option that maximizes the re-use of all materials generated during the rehabilitation process and maximizes the recycling process.
- Environmental effects: choose the option that best fits the environmental/climatic effects surrounding the road.

Comparing the different alternatives of repair options for each section, especially the cost factor and the best

Table 4. RSMS repair strategy of road sections.

Routine strategy			Preventive strategy			Rehabilitation strategy		
Section # 1	6th street	0.695 mile	Section # 2	Perimeter Dr	1.445 mile	Section # 6	Blake Ave	0.5 mile
Section # 5	Line street	0.445 mile	Section # 3	Stadium Dr	0.692 mile	Section # 7	Deakin Ave	0.49 mile
			Section # 4	Rayburn St	0.592 mile	Section # 8	Idaho Ave	0.44 mile
Total length		1.14 mile	Section # 10	Sweet Ave	0.341 mile	Section # 9	University Ave	0.24 mile
			Total length		3.07 mile	Total length		1.67 mile

Table 5. The repair strategy in term of the percent of total network length.

RSMS 11 Repair Strategy	% of Total Network Length
No Maintenance	0%
Routine Strategy	20%
Preventive Strategy	52%
Rehabilitation Strategy	28%
Reconstruction Strategy	0%

Table 6. RSMS estimated cost for the repair options.

Section # and Road Name	Repair Strategy	Repair Options	RSMS Estimated Cost in $
Section # 1 6th street	Routine	Patching	869
		Crack seal	8688
Section # 2 Perimeter Dr	Preventive	Sand seal	52,020
		Chip seal (latex modified)	81,281
		Thin (3/4 - 1 in) overlay	130,050
		Shim with 1 in overlay	211,331
		Thick (>1 in) overlay	234,090
		Overlay w/2 in cold mix, top w/1 in HMA	380,396
		Mill and Fill 1.25 in	406,406
Section # 3 Stadium Dr	Preventive	Sand seal	27,680
		Chip seal (latex modified)	43,250
		Thin (3/4 - 1 in) overlay	69,200
		Shim with 1 in overlay	112,450
		Thick (>1 in) overlay	124,560
		Overlay w/2 in cold mix, top w/1 in HMA	202,410
		Mill and Fill 1.25 in	216,250
Section # 4 Rayburn street	Preventive	Sand seal	17,997
		Chip seal (latex modified)	28,120
		Thin (3/4 - 1 in) overlay	44,992
		Shim with 1 in overlay	73,112
		Thick (>1 in) overlay	80,986
		Overlay w/2 in cold mix, top w/1 in HMA	131,602
		Mill and Fill 1.25 in	140,600
Section # 5 Line street	Routine	Patching	712
		Crack seal	7120
Section # 6 Blake Ave	Rehabilitate	Reclaim pavement, revert to gravel	19,076
		Shim with 2 in overlay	123,994
		Reclaim incl 6 - 8 in base, 2 in binder, 1.5 in surface	190,760
		Reclaim incl 6 - 8 in base, stabilized, 2 in binder, 1.5 in surface	233,681
		PM RAP reclamation	233,681
Section # 7 Deakin Ave	Rehabilitate	Reclaim pavement, revert to gravel	18,468
		Shim with 2 in overlay	120,042
		Reclaim incl 6 - 8 in base, 2 in binder, 1.5 in surface	184,680
		Reclaim incl 6 - 8 in base, stabilized, 2 in binder, 1.5 in surface	226,233
		PM RAP reclamation	226,233
Section # 8 Idaho Ave	Rehabilitate	Reclaim pavement, revert to gravel	10,900
		Shim with 2 in overlay	70,850
		Reclaim incl 6 - 8 in base, 2 in binder, 1.5 in surface	109,000
		Reclaim incl 6 - 8 in base, stabilized, 2 in binder, 1.5 in surface	133,525
		PM RAP reclamation	133,525

Continued

Section # 9 University Ave	Rehabilitate	Reclaim pavement, revert to gravel	5975
		Shim with 2 in overlay	38,838
		Reclaim incl 6 - 8 in base, 2 in binder, 1.5 in surface	59,750
		Reclaim incl 6 - 8 in base, stabilized, 2 in binder, 1.5 in surface	73,194
		PM RAP reclamation	73,194
Section # 10 Sweet Ave	Preventive	Sand seal	10,366
		Chip seal (latex modified)	16,198
		Thin (3/4 - 1 in) overlay	25,916
		Shim with 1 in overlay	42,114
		Thick (>1 in) overlay	46,649
		Overlay w/2 in cold mix, top w/1 in HMA	75,804
		Mill and Fill 1.25 in	80,988

technical solution suitable for each section, and weighing the factors above, the appropriate repair methods and budgets were selected with reasoning of the selection as shown in **Table 7**.

6. Determining the Cost of Each Repair Method

RSMS uses an estimate of the prices and costs of the different repair methods based on 1 mile road length and 20 ft wide road as shown in **Table 8**. The total cost of each section can be determined based on the actual length and width of the section.

The RSMS costs shown above can be modified by each agency to reflect the most recent market prices within its jurisdiction.

7. Establishing Repair Priorities

Repair strategies must be analyzed based on their technical and economical impacts so that priority program at the network level can be identified and later implemented at the project level. RSMS prioritizes the repair of all sections based on the surface distresses and the drainage conditions. RSMS gives the highest priority value to road sections that need routine maintenance and having poor drainage, and gives the lowest priority value to road sections that have good drainage but need major rehabilitation. In the UI Campus network, the priority was given to the sections that need routine maintenance in the financial plan because it costs less than other strategies and to effectively extent the life cycle of these low cost sections. **Table 9** shows the repair priority of the sections depending on the repair strategy.

8. Long-Term Financial and Budget Plans

Long-term financial and budget plans are necessary planning tools for any PMS because it can allocate the required resources and budgets per each year in the future planned period. RSMS can prepare long-term financial and budget plans for up to 15 years if the required data were available and entered into the program regarding the repair costs of each section within any number of future years up to 15. **Table 10** shows the financial budget plan for the UI network repair from 2016 to 2024 using the estimated costs of repair of the RSMS, depending on the estimated repair methods used by the program.

9. Conclusion

The Road Surface Management System (RSMS) is a data-intensive program that uses three categories of data; road network inventory, road surface condition survey, and maintenance, rehabilitation and reconstruction (MR & R) strategies and associated unit costs and life expectancy. RSMS is a powerful tool to assist town managers, road commissioners, public works directors, road committees, and budget committees develop a maintenance

Table 7. Choosing the budget.

Section #	Name	RSMS Repair Strategy	Chosen Repair Option	RSMS Budget ($)	Reason for Selection
1	6th St	Routine	Crack seal	8688	-cost effective -addresses the current long/tran cracks in the section -fits the overall good road surface condition -good typical life cycle performance 3 - 5 years
2	Perimeter Dr	Preventive	Chip seal (Latex modified)	81,281	-can waterproof the surface -can restore surface friction -relatively more cost effective than an overlay -provide sealing to low severity cracks -good typical performance life 4 - 7 years -provide opportunity to apply multiple treatments
3	Stadium Dr	Preventive	Chip seal (Latex modified)	43,250	-can waterproof the surface -can restore surface friction -relatively more cost effective than an overlay -provide sealing to low severity cracks -good typical performance life 4 - 7 years -provide opportunity to apply multiple treatments
4	Rayburn St	Preventive	Chip seal (Latex modified)	28,120	-can waterproof the surface -can restore surface friction -relatively more cost effective than an overlay -provide sealing to low severity cracks -good typical performance life 4 - 7 years -provide opportunity to apply multiple treatments
5	Line St	Routine	Crack seal	9790	-cost effective -addresses the current long/tran cracks in the section -fits the overall good road surface condition -good typical life cycle performance 3 - 5 years
6	Blake Ave	Rehabilitate	Shim w/2" overlay	122,363	-improves road profile, crown, and slopes -corrects rutting and other surface distresses -reworks the AC to depth of 2 in -Typical performance 5 - 10 years -more cost effective than mill and fill 1.25" or overlay w/cold mix 2" and hot mix top 1"
7	Deakin Ave	Rehabilitate	Shim w/2" overlay	140,400	-improves road profile, crown, and slopes -corrects rutting and other surface distresses -reworks the AC to depth of 2 in -Typical performance 5 - 10 years -more cost effective than mill and fill 1.25" or overlay w/cold mix 2" and hot mix top 1"
8	Idaho Ave	Rehabilitate	Shim w/2" overlay	70,850	-improves road profile, crown, and slopes -corrects rutting and other surface distresses -reworks the AC to depth of 2 in -Typical performance 5 - 10 years -more cost effective than other rehab methods like mill and fill 1.25" or overlay w/cold mix 2" and hot mix top 1"
9	University Ave	Rehabilitate	Shim w/2" overlay	38,838	-improves road profile, crown, and slopes -corrects rutting and other surface distresses -reworks the AC to depth of 2 in -Typical performance 5 - 10 years -more cost effective than other rehab methods like mill and fill 1.25" or overlay w/cold mix 2" and hot mix top 1"
10	Sweet Ave	Preventive	Chip seal	16,198	-can waterproof the surface -can restore surface friction -relatively more cost effective than an overlay -provide sealing to low severity cracks -good typical performance life 4 - 7 years -provide opportunity to apply multiple treatments
		Total $ 559,778			

Table 8. The RSMS cost of 1 mile road length and 20 ft wide road.

Repair Description	Cost $/mile
Crack seal	10,000
Patching	1000
Sans seal	16,000
Chip seal	25,000
Thick overlay >1”	72,000
Thin overlay 3/4” - 1”	40,000
Shim with 1” overlay	65,000
2” Cold mix overlay with 1” top HMA	117,000
Mill and fill 1.25”	125,000
Reclaim incl 6” - 8” base 2” binder 1.5” surface	200,000
Reclaim incl 6” - 8” base 2”, stabilized, binder 1.5” surface	245,000
Shim with 2” overlay	130,000
Reclaim pavement revert to gravel	20,000
PM RAP reclamation	245,000
18” New 9.5 mm gravel, 2” binder, 1” surface	225,000
24” New gravel, 2” binder, 2” surface	300,000

Table 9. RSMS repair priority.

Section #	Road Name	RSMS Surface Condition	Repair Priority
1	6th St	Routine	1
5	Line St	Routine	2
4	Rayburn St	Preventive	3
2	Perimeter Dr	Preventive	4
3	Stadium Dr	Preventive	5
10	Sweet Ave	Preventive	6
8	Idaho Ave	Rehabilitate	7
9	University Ave	Rehabilitate	8
6	Blake Ave	Rehabilitate	9
7	Deakin Ave	Rehabilitate	10

Table 10. RSMS long term budget plan.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024
Planned long-term Budget in $	559,778	280,273	334,800	340,331	496,072	481,850	382,891	507,691	310,994

plan for their paved road network. RSMS is intended to provide an estimate of a roadway network level condition for towns and small cities and the approximate costs for their repair methods and future improvements. The University of Idaho campus road network is evaluated using the RSMS process. Inventory conditions are conducted by driving and/or walking on 10 sections that are identified within the UI campus (with total length of 5.88 mile) and their inventory conditions are used. RSMS classifies 20% of the total network length as in need of “Routine repair”, 52% of the total network length as in need of “Preventive repair”, and 28% as in need of “Rehabilitation repair”. The adequate repair option is selected for each section through the optimization of the cost effective factors and the most suitable technical solutions with the associated budget, and the program prioritizes the repair of the roads beginning with the routine strategy, then the preventive, and then the rehabilitation strategies. Appropriate budget plans are established by the program for the long-term work as well.

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