Investment Analysis by Computer Methods for the State Trunk Highway System in Wisconsin

Part I: Methodology for Computing Remaining Investments

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•THE MAIN purpose of a highway needs study is to determine the magnitude and costs of a program needed to overcome deficiencies in a particular highway system and attain adequacy within a desired period of years.

The so-called "investment analysis approach" establishes needs from the relationship that exists between highway investments remaining in service and travel requirements (1).

One of the major tasks in estimating needs using the investment analysis approach is the determination of investments remaining in service. Road life and cost records have been the general source of such computations. Difficulties, however, have been encountered in the past mainly because of the inadaptability of existing procedures to modern computer techniques.

Outdated methods of record-keeping and analysis have prevented new developments in the field of road life and investment studies and have led to the belief that such studies are cumbersome and of little value to the highway administrators.

It is believed that the first step towards the overall revival of road life and investment studies as a whole is the reevaluation of existing techniques for their proper incorporation into new computer operations.

This paper constitutes Part I of a two-part investment analysis for the State Trunk Highway System in Wisconsin, undertaken, for the first time, with computer methods.

Part I of the analysis covers the methodology developed for the automatic computation of remaining investments, and Part II, which is not included in this paper, comprises actual needs estimates using the investment analysis approach.

The developed procedure given here is an introduction to the computer approach in estimating remaining costs in highways, and is intended to replace tedious computations now done manually. It is also hoped that this new technique will pave the way for further developments.

Providing that records are properly organized and updated, remaining investments can be computed with this new method in a relatively short period of time and with a minimum of manpower.

Using this new procedure, Wisconsin's backlog of more than twenty years in remaining cost records for the State Trunk Highway System has been eliminated, and possibilities have been created for the evaluation of highway needs on a 100% sample basis, which otherwise would have been impossible.

OUTLINE OF METHOD

The new method mainly calls for the following:

1. Reorganization of construction and retirement data to include all construction cost items dealing with a specific project on a single construction card, and all pertinent

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remaining costs after a retirement on a single retirement card. (The old procedure required the filling of separate construction and retirement cards for each cost item.)

2. Automatic grouping of related construction and retirement cards into "road life units" which incorporate all original projects and their retirements, and all replacement projects and their retirements, arranged in a chronological order between each construction and corresponding retirements.

3. Machine computation of remaining costs using average salvage values based on the method of retirement.

DETAILED PROCEDURE[1]

Reorganization of Old Records

The following steps are taken in reorganizing old road life and cost records:

1. Old records, including construction cards and primary[2] retirement cards, are corrected and missing data completed as a preparation for their transfer to new Cards #8 and 9. (Appendix A shows layout of Cards #8 and 9.)

2. Old construction and primary retirement data are then transferred to new construction Cards #8 and retirement Cards #9. At this transfer stage:

(a) All construction cost items dealing with a specific project are automatically computed on a single Card #8, grouped under five categories and expressed as follows:

Construction Costs

(1)	Total	(in dollars)
(2)	Surface & Base	(as a percentage of the total)
(3)	Grading	(as a percentage of the total)
(4)	Right-of-Way	(as a percentage of the total)
(5)	Other[3]	(as a percentage of the total)

(b) A single retirement Card #9 is coded for each primary retirement of a specific project reported on a construction Card #8.

Provision is made on each Card #9 to show the "remaining costs" after each retirement, grouped in a similar manner as for construction cards and expressed as follows:

Remaining Costs

(1)	Total	(in dollars)
(2)	Surface & Base	(as a percentage of the construction total)
(3)	Grading	(as a percentage of the construction total)
(4)	Right-of-Way	(as a percentage of the construction total)
(5)	Other[3]	(as a percentage of the construction total)

The computation of these "remaining costs" is discussed later.

Exception: Only total construction costs are reported for bridges and miscellaneous construction ("X" or "Y" types), and total remaining costs for bridges ("X" types).

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[1]The details outlined in this chapter are worded for punched-card handling machines. Where tape-oriented machines are used, certain operations given here can be simplified and some of the duplication in data on various cards can be eliminated.

[2]A primary retirement is a direct retirement of a construction which generally involves the retirement of mileages and costs.

[3]Includes traffic services, landscape, detours, administration, engineering, and miscellaneous costs.

3. Construction Cards #8 and primary retirement Cards #9 are then organized to form "road life units and sub-units," which are obtained by grouping all cards pertaining to the same improvement in a chronological order as follows:

Road Life Unit #1

Sub-Unit #1: Original improvement "A" and its retirements
Sub-Unit #2: First replacement of "A" and its retirements
Sub-Unit #3: Second replacement of "A" and its retirements
etc.

Road Life Unit #2

Sub-Unit #1: Original improvement "B" and its retirements
Sub-Unit #2: First replacement of "B" and its retirements
Sub-Unit #3: Second replacement of "B" and its retirements
etc.

At this stage all construction and primary retirement cards are assigned "serial and sequence Nos." in order to keep them in this "road life unit and sub-unit" order permanently. Also, as a temporary measure, "secondary letters" are coded on matching construction and primary retirement cards so as to avoid further artificial breakdowns of units and enable the automatic computation of secondary retirement Cards #9, which is dicussed below.

Automatic Computation of Secondary Retirements[4]

The following method is used for the automatic computation of secondary[5] retirement Cards #9, which do not exist in old records:

1. (a) All construction Cards #8 and primary retirement Cards #9 are sorted in the following order:

Sequence No.	(cc 77-80)	(reverse sort)
Serial No.	(cc 4-6)	(regular sort)
County	(cc 2-3)	(regular sort)

(b) All construction cards are then matched with corresponding primary retirement cards, Cards #8 followed by Cards #9 having identical total construction costs reported in cc 70-75 #8, and cc 23-28 #9.

This operation should bring all "sub-units" within "road life units" in the reverse order, from latest to earliest years. The main reason is to deal with lengthier units, and possibly avoid the handling of small breakdowns throughout the computation, if units were arranged in the regular ascending chronological order.

2. Using cards as organized above:

(a) Within each "road life unit" (same codes in cc 2-3 & 4-6 for County & Serial No.), and after each primary Card #9, secondary Cards #9 are automatically punched, which will have the following information:

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[4]This section is intended to cover the automatic creation of secondary retirement Cards #9 for roadways (excl. bridges), in cases where no such data exists (Wisconsin 1912-1961 records). Once the basic secondary retirement records are established, future secondary retirements can be handled manually, if so desired, and the procedures outlined here (incl. assignment of "secondary letters") are not needed.

[5]A secondary retirement is an indirect retirement of a construction, caused by a primary retirement of a superseding replacement construction. This type involves the retirement of costs only.

(1) Transferred from each preceding primary Card #9, and as many times as there are preceding Cards #9, retirement values for:

Length Retired	(cc 42-45)
Year Retired	(cc 46-47)
Reason for Retirement	(cc 48-49)
Method of Retirement	(cc 50-51)

Note: Where the "length retired" is greater than the construction length, it is transferred from the corresponding Card #8, and equals the "length constructed" (cc 26-29 #8).

(2) Transferred from each Card #8 in the succeeding "sub-units," and as many times as there are succeeding "sub-units," construction values for:

County	(cc 2-3)	Administ. Group	(cc 12)
Serial No.	(cc 4-6)	Length	(cc 13-16)
Highway Syst.	(cc 7-8)	Type Code	(cc 17-20)
Highway No.	(cc 9-11)	Year Completed	(cc 21-22)
		Total Cost	(cc 23-28)

The above transfers are made providing that each set of primary Cards #9 and construction Cards #8, from which secondary retirement Cards #9 are computed, have the same "secondary letters" (cc 75 #9, cc 50-54 or cc 38-41 #8). If these "secondary letters" are not matched, no secondary retirement card is punched. (This is a temporary measure devised in order to avoid further artificial breakdown of units and expedite the computation procedure.)

(b) Also at this stage, all established secondary retirement Cards #9 are punched with:

Code "9" in cc 1, denoting Card Type #9
Code "2" in cc 29, denoting a secondary Retirement Type
(a primary retirement is coded "1" in this column)

3. (a) After step 2, all retirement Cards #9 (primary and secondary) are sorted in the following order:

Retirement Type	(cc 29)
Year Retired	(cc 46-47)
Total Cost (Constr.)	(cc 23-28)
Serial No.	(cc 4-6)
County	(cc 2-3)

(b) Then all secondary Cards #9 (code "2" in cc 29) are punched with a permanent Sequence No. (cc 77-80) which will be equal to:
(Preceding Card #9 Sequence No.) + 3

4. (a) After step 3, all retirement Cards #9 (primary and secondary) are sorted in the order of:

Sequence No.	(cc 77-80)
Serial No.	(cc 4-6)
County	(cc 2-3)

which will put them in the regular ascending chronological order by "road life units and sub-units."

(b) Within each "sub-unit" (same values in cc 23-28 for total construction cost) a Retirement Factor[6] (cc 30-31) is computed and punched on each Card #9 as follows:

(1) For retirement Cards #9 (primary and secondary) not preceded by prior abandonments or transfers (codes "3" or "4" in cc 50):

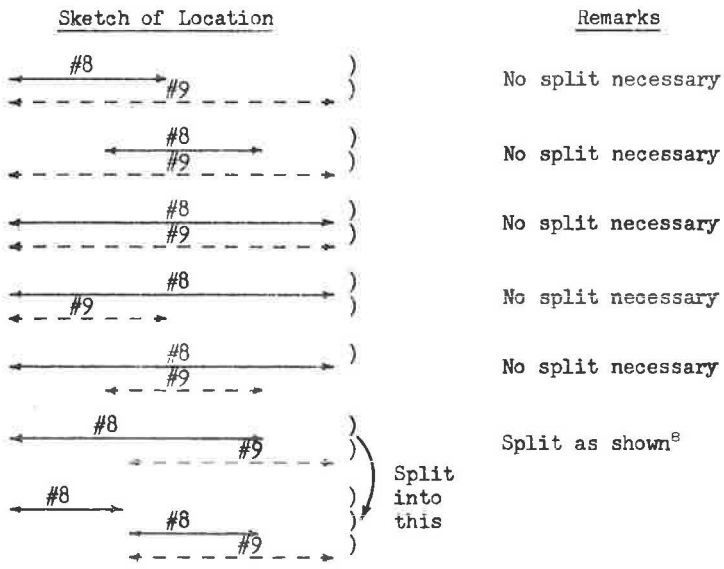
$$\text{Retirement Factor} = \frac{\text{Length Retired (cc 42-45)}}{\text{Length Constructed (cc 13-16)}}$$

(2) For retirement Cards #9 (primary or secondary) preceded by prior abandonments or transfers (codes "3" or "4" in cc 50):

$$\text{Ret. Factor} = \frac{\text{Length Retired (cc 42-45)}}{\text{Length Const. (cc 13-16)} - \text{Lengths Ret. (cc 42-45)}^{7}}$$

Note: If the denominator above is "zero," the retirement Card #9 should be disregarded entirely. If the retirement factor computed is more than 1.00, it should be treated as 1.00.

General Notes for the Splitting of Cards. —In certain cases, corresponding construction Cards #8 and primary retirement Cards #9, as they exist in the records, have to be split in order to make possible the automatic computation of secondary retirement cards outlined above. Below is a sketch showing the general procedure followed, as applied to cards organized in reverse, descending chronological order:



[6] A retirement factor is generally the ratio between the mileage retired and the mileage constructed, with the exception that if a portion of the original construction mileage has been previously abandoned or transferred out, the denominator in such cases is the mileage remaining after such abandonment or transfer, rather than the original construction mileage.

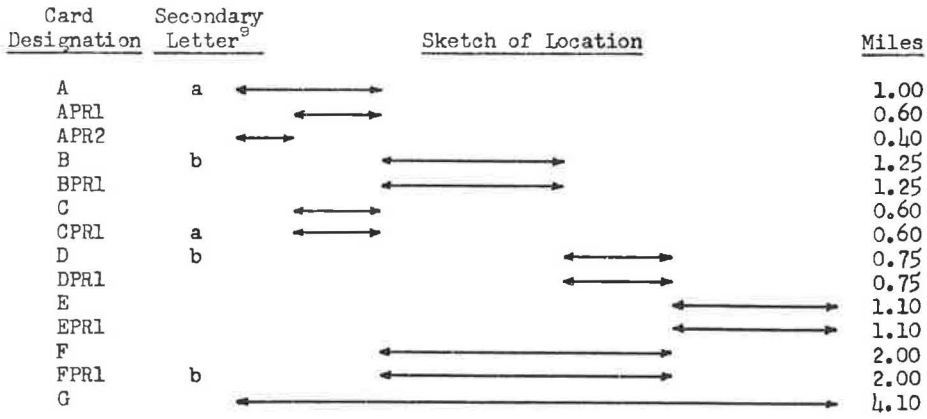
[7] Cumulative total of all preceding Cards #9 (primary or secondary) with codes "3" or "4" in cc 50.

[8] Cards split into two equal portions should have at least $100 difference in total construction costs, to avoid possible duplications in sorting.

Illustrative Example. —The following is an illustrative example for the automatic computation of secondary retirement Cards #9.

The table and sketch below show hypothetical Cards #8 & 9 as organized in the regular sequence of "road life unit and sub-units," in an ascending chronological order:

	Subject	Card Designation	Card Type	Total Constr. Cost ($100)	Year Completed	Year Retired	Sequence No.
Unit / Sub-Units	Construction A	A	8	1000	1912	-	0010
	1st Primary Ret. of A	APR1	9	1000	1912	1915	0030
	2nd Primary Ret. of A	APR2	9	1000	1912	1950	0050
	Construction B	B	8	1500	1913	-	0070
	1st Primary Ret. of B	BPR1	9	1500	1913	1930	0090
	Construction C	C	8	600	1915	-	0110
	1st Primary Ret. of C	CPR1	9	600	1915	1950	0130
	Construction D	D	8	800	1920	-	0150
	1st Primary Ret. of D	DPR1	9	800	1920	1930	0170
	Construction E	E	8	1200	1921	-	0190
	1st Primary Ret. of E	EPR1	9	1200	1921	1950	0210
	Construction F	F	8	2000	1930	-	0230
	1st Primary Ret. of F	FPR1	9	2000	1930	1950	0250
	Construction G	G	8	3000	1950	-	0270



1. After the reverse sort and matching of Cards #8 & 9, as explained in step 1 of the computation procedure, all cards are arranged in the following manner, in descending chronological order:

[9]No "secondary letter" is assigned to cards not involved in a secondary retirement.

Card Designation	Secondary Letter	Sequence No.
G		0270
F		0230
FPR1	b	0250
E		0190
EPR1		0210
D	b	0150
DPR1		0170
C		0110
CPR1	a	0130
B	b	0070
BPR1		0090
A	a	0010
APR2		0050
APR1		0030

2. In accordance with step 2a of the computation procedure, and starting with the first primary retirement card FPR1, secondary retirement cards are computed and punched as follows:

Subject	Card Designation	Cards #9 Referred to 1/		Cards #8 Referred to 2/		Remarks
		Designation	Secon. Letter	Designation	Secon. Letter	
No Secondary Card		FPR1	b	E		Second. letters not matched
1st Second. Ret. of D	DSR1	FPR1	b	D	b	Secondary letters matched
No Secondary Card		FPR1	b	C		Second. letters not matched
1st Second. Ret. of B	BSR1	FPR1	b	B	b	Secondary letters matched
No Secondary Card		FPR1	b	A	a	Second. letters not matched
" " "		EPR1		D	b	" " " "
" " "		EPR1		C		" " " "
" " "		EPR1		B	b	" " " "
" " "		EPR1		A	a	" " " "
" " "		DPR1		C		" " " "
" " "		DPR1		B	b	" " " "
" " "		DPR1		A	a	" " " "
" " "		CPR1	a	B	b	" " " "
1st Second. Ret. of A	ASR1	CPR1	a	A	a	Secondary letters matched
No Secondary Card		BPR1		A	a	Second. letters not matched
" " "		APR2		-		No Card #8 following
" " "		APR1		-		No Card #8 following

1/ Codes for cc 42-51 transferred from preceding primary Cards #9
2/ Codes for cc 2-28 transferred from succeeding Cards #8

Major Data Punched on Secondary Cards #9

Card Designation	Construction Data				Retirement Data	
	Tot. Cost ($100)	Length	Year		Length	Year
ASR1	1000	1.00	1912		0.60	1950
BSR1	1500	1.25	1913	2-00[10]	1.25	1950
DSR1	800	0.75	1920	2-00[10]	0.75	1950

[10]Length retired is reduced to match length constructed.

3. All retirement Cards #9 are then sorted as explained in step 3a of the computation procedure, which organizes them in the following order:

Card Designation	Retirement Type	Retirement Year	Tot. Constr. Cost ($100)	Sequence No.
CPR1	1	1950	600	0130
DPR1	1	1930	800	0170
DSR1	2	1950	800	Blank
APR1	1	1915	1000	0030
APR2	1	1950	1000	0050
ASR1	2	1950	1000	Blank
EPR1	1	1950	1200	0210
BPR1	1	1930	1500	0090
BSR1	2	1950	1500	Blank
FPR1	1	1950	2000	0250

Then, proper Sequence Nos. for the secondary Cards #9 are computed as follows:

For DSR1 = preceding Sequence No. + 3 = 0170 + 3 = 0173
For ASR1 = preceding Sequence No. + 3 = 0050 + 3 = 0053
For BSR1 = preceding Sequence No. + 3 = 0090 + 3 = 0093

4. Finally, in accordance with step 4 of the computation procedure, all retirement Cards #9 are sorted in regular sequence by "sub-units" within the given "unit," in an ascending chronological order, and then the "retirement factor" for each card is computed as follows:

Card Designation	Sequence No.	Length		Retirement		Computed Retirement Factor
		Constructed	Retired	Type	Method	
APR1	0030	1.00	0.60	1	Reconst.	0.60 ÷ 1.00 = 0.60
APR2	0050	1.00	0.40	1	Reconst.	0.40 ÷ 1.00 = 0.40
ASR1	0053	1.00	0.60	2	Resurf.	0.60 ÷ 1.00 = 0.60
BPR1	0090	1.25	1.25	1	Aband.	1.25 ÷ 1.25 = 1.00
BSR1	0093	1.25	1.25	2		1.25 ÷(1.25-1.25)[11]
CPR1	0130	0.60	0.60	1	Resurf.	0.60 ÷ 0.60 = 1.00
DPR1	0170	0.75	0.75	1	Resurf.	0.75 ÷ 0.75 = 1.00
DSR1	0173	0.75	0.75	2	Resurf.	0.75 ÷ 0.75 = 1.00
EPR1	0210	1.10	1.10	1	Reconst.	1.10 ÷ 1.10 = 1.00
FPR1	0250	2.00	2.00	1	Resurf.	2.00 ÷ 2.00 = 1.00

[11]The denominator here being "zero," card BSR1 should be entirely disregarded as a secondary retirement card.

Automatic Computation of Remaining Costs

1. All construction Cards #8 and retirement Cards #9 (roadways and bridges) are sorted by order of:

Sequence No.	(cc 77-80)
Serial No.	(cc 4-6)
County No.	(cc 2-3)

(This operation should group all construction and retirement cards within "road life units.")

2. It should be made certain that the following have been properly coded:

Construction Cards #8		Retirement Cards #9	
Subject	Card Columns	Subject	Card Columns
Length Constructed	26-29	Length Constructed	13-16
Year Completed	57-58	Total Const. Cost ($100)	23-28
Surf. & Base Cost %	61-63	Retirement Type	29
Grading Cost %	64-65	Retirement Factor	30-31
R.O.W. Cost %	66-67	Length Retired	42-45
Other Cost %	68-69	Year Retired	46-47
Total Cost ($100)	70-75	Method of Retirement[12]	50-51

3. Keeping all construction and retirement cards as organized in item 1 above, remaining cost values derived as follows are automatically computed and punched on retirement cards:

a) ROADWAYS:

Cost Item	Remaining Cost Preceding Card #8 or 9	% Retired From Table App. B	Retirement Factor	Remaining Cost (This Card) (%)	Remaining Cost (This Card) ($100)
Surf.& Base %	(%) X	[1-(%) X ( )] =		% 1/	—
Grading (%)	(%) X	[1-(%) X ( )] =		% 2/	—
R.O.W. (%)	(%) X	[1-(%) X ( )] =		% 3/	—
Other (%)	(%) X	[1-(%) X ( )] =		% 4/	—
Total ($100)	(Corresponding Construction) ($) X (%) = $				5/

1/ To be punched on Card #9 cc 52-54
2/ To be punched on Card #9 cc 55-56
3/ To be punched on Card #9 cc 57-58
4/ To be punched on Card #9 cc 59-60
5/ To be punched on Card #9 cc 61-66

Note: All construction and remaining costs given in percentages are expressed in terms of the total construction cost.

[12]Refer to Appendix B for average values used in retiring costs and various methods of retirement.

b) BRIDGES:

Cost Item	Remaining Total Cost Preceding Card #8 or 9	% Retired From Table App. B	Remaining Tot. Cost (This Card) ($100)
Total ($100)	($) X	[1-(%)] =	$ 5/

5/ To be punched on Card #9 cc 61-66

The following is an illustrative example for a roadway dealing with construction and retirement cards grouped in one "unit":

	Item	Subject	Card Type	Year Completed	Year Retired
Unit / Sub-Unit	1	Original Constr. A	8	1941	-
	2	Primary Ret. of A	9	1941	1945
	3	Secondary Ret. of A (Caused by Item 5)	9	1941	1950
Sub-Unit	4	Replacement Constr. A1 (Caused by Item 2)	8	1945	-
	5	Primary Ret. of A1	9	1945	1950
Sub-Unit	6	Replacement Constr. A2 (Caused by Item 5) (Still Living)	8	1950	-

Item	Sketch of Location		
1	Original Construction A	10.00 Mi.	Card #8
2	Primary Retirement of A	9.00 Mi.	Card #9
3	Secondary Retirement of A	8.00 Mi.	Card #9
4	Replacement Construction A1	9.00 Mi.	Card #8
5	Primary Retirement of A1	8.00 Mi.	Card #9
6	Replacement Construction A2	8.00 Mi.	Card #8

Illustrative Example for Remaining Costs Computation

	Subject \ Item No.→	1 (Card #8)	2 (Card #9)	3 (Card #9)	4 (Card #8)	5 (Card #9)	6 (Card #8)
Construction Data	Length	10.00	10.00	10.00	9.00	9.00	8.00
	Year	1941	1941	1941	1945	1945	1950
	S.B. Cost %	30	-	-	80	-	40
	Gr. Cost %	40	-	-	15	-	50
	R.O.W. Cost %	10	-	-	0	-	5
	Other Cost %	20	-	-	5	-	5
	Total Cost ($100)	10,000	10,000	10,000	5,000	5,000	8,000
Retirement Data	Ret. Type	-	1(Prim.)	2(Sec.)	-	1(Prim.)	-
	Ret. Factor	-	$\frac{9.00}{10.00}$=0.90	$\frac{8.00}{10.00}$=0.80	-	$\frac{8.00}{9.00}$=0.89	-
	Length Ret.	-	9.00	8.00	-	8.00	-
	Year Ret.	-	1945	1950	-	1950	-
	Meth. Ret.	-	01 (Reg.)	27	-	27	-
% Retired Costs (Table App. B)	Surf. & B.	-	30	100	-	100	-
	Grading	-	0	100	-	100	-
	R.O.W.	-	0	50	-	50	-
	Other	-	10	95	-	95	-
Computed Rem. Costs*	S.B. Cost Rem. %	(30)	22	4	(80)	9	(40)
	Gr.Cost Rem. %	(40)	40	8	(15)	2	(50)
	R.O.W. Cost Rem. %	(10)	10	6	(0)	0	(5)
	Other Cost Rem. %	(20)	18	4	(5)	1	(5)
	Tot.Cost Rem.($100)	(10,000)	9,000	2,200	(5,000)	600	(8,000)

* Remaining costs are separately computed for retirement cards within each "sub-unit". (Figures in parentheses are not computed, but show the ones punched on construction cards prior to retirements) Refer to next page for computations).

Computation of Remaining Costs for Item 2:

Cost Item	Remaining Cost Preceding Card #8 (Item 1)		% Retired From Table App. B		Retirement Factor		Remaining Cost (This Card) %	Remaining Cost (This Card) ($100)
Surf. & Base (%)	(30%)	x	[1-(30%	x	(0.90)]	=	22%	—
Grading (%)	(40%)	x	[1- (0%	x	(0.90)]	=	40%	—
R.O.W. (%)	(10%)	x	[1- (0%	x	(0.90)]	=	10%	—
Other (%)	(20%)	x	[1-(10%	x	(0.90)]	=	18%	—
Total ($100)(Corresponding Construction)					($10,000)	x	(90%) =	$9,000

Computation of Remaining Costs for Item 3:

Cost Item	Remaining Cost Preceding Card #9(Item 2)		% Retired From Table App. B		Retirement Factor		Remaining Cost (This Card) %	Remaining Cost (This Card) ($100)
Surf & Base (%)	(22%)	x	[1-(100%	x	(0.80)]	=	4%	—
Grading (%)	(40%)	x	[1-(100%	x	(0.80)]	=	8%	—
R.O.W. (%)	(10%)	x	[1-(50%	x	(0.80)]	=	6%	—
Other (%)	(18%)	x	[1-(95%	x	(0.80)]	=	4%	—
Total ($100) (Corresponding Construction)					($10,000)	x	(22%) =	$2,200

Computation of Remaining Costs for Item 5:

Cost Item	Remaining Cost Preceding Card #3 (Item 4)		% Retired From Table App. B		Retirement Factor		Remaining Cost (This Card) %	Remaining Cost (This Card) ($100)
Surf. & Base (%)	(80%)	x	[1-(100%	x	(0.89)]	=	9%	—
Grading (%)	(15%)	x	[1-(100%	x	(0.89)]	=	2%	—
R.O.W. (%)	(0%)	x	[1-(50%	x	(0.89)]	=	0%	—
Other (%)	(5%)	x	[1-(95%	x	(0.89)]	=	1%	—
Total ($100)(Corresponding Construction)					($5,000)	x	(12%) =	$600

The following summarizes the results obtained for the illustrative example:

Item	Project	Year Const.	Total Constr. Cost ($100,000)	Remaining Total Costs ($100,000) Jan. 1 of Each Year 1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1-3	A	1941	10.0	10.0	10.0	10.0	10.0	9.0	9.0	9.0	9.0	9.0	2.2
4-5	A 1	1945	5.0	-	-	-	-	5.0	5.0	5.0	5.0	5.0	0.6
6	A 2	1950	8.0	-	-	-	-	-	-	-	-	-	8.0
	Total for Unit			10.0	10.0	10.0	10.0	14.0	14.0	14.0	14.0	14.0	10.8

Note: The computation is started at each construction Card #8 and followed through corresponding retirement Cards #9. Underlined figures are obtained from Cards #8 & 9, and others are automatic repetitions of preceding values.

4. Total remaining costs for any specific type of road or structure can be computed by machine utilizing all "units" involved within that specific type, and totaling by years remaining values obtained within each "unit."

If an analysis is to be made for a particular cost item (surface & base, grading, R. O. W., or other), all costs have to be converted from percentages into dollars, within each "sub-unit," before the totaling of remaining values for that particular cost item. The table below shows this procedure dealing with grading costs applied to the illustrative example given above:

Existing Data on Cards #8 & 9:

Item	Project	Year Const.	Grading Cost %	Remaining Grading Costs (%) Jan. 1 of Each Year 1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1-3	A	1941	40	40	40	40	40	40	40	40	40	40	8
4-5	A 1	1945	15	-	-	-	-	15	15	15	15	15	2
6	A 2	1950	50	-	-	-	-	-	-	-	-	-	50

Conversion Into Dollars:

Item	Project	Year Const.	Grading Cost ($100,000)	Remaining Grading Costs ($100,000) Jan. 1 of Each Year 1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1-3	A	1941	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.8
4-5	A 1	1945	0.75	-	-	-	-	0.75	0.75	0.75	0.75	0.75	0.1
6	A 2	1950	4.0	-	-	-	-	-	-	-	-	-	4.0
	Total for Unit			4.0	4.0	4.0	4.0	4.75	4.75	4.75	4.75	4.75	4.9

CONCLUSIONS

Wisconsin has reorganized its road life and cost records for the State Trunk Highway System in accordance with the new procedures outlined here and will be in a position to analyze needs from the standpoint of highway investments remaining in service, as soon as work now under way for computer programming is completed.

The following conclusions can be drawn, however, based on over two years' experience in dealing with the new techniques:

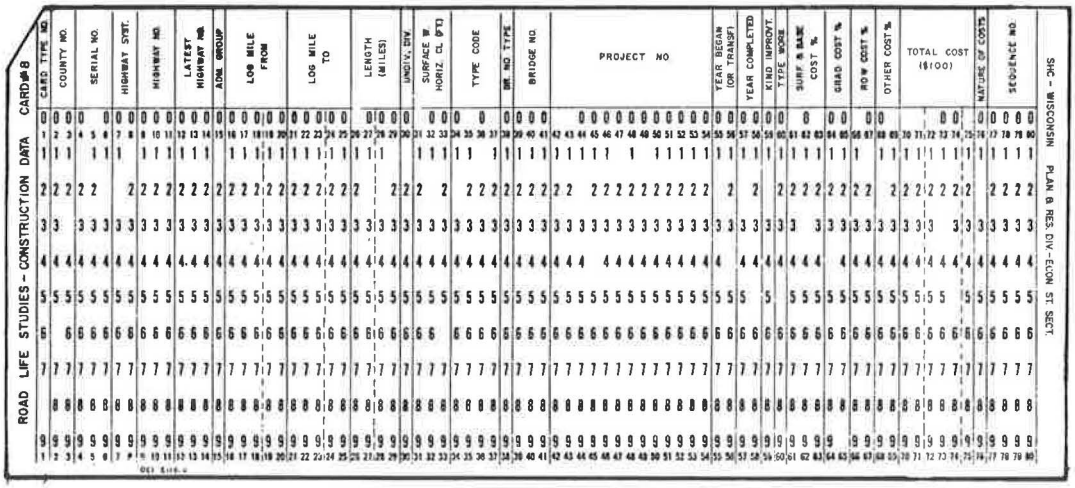
1. The methods outlined in this paper have been proved satisfactory, and it is hoped that they will pave the way for the revival of road life and investment studies, abandoned by many states due to the high volume of manual work involved.
2. The procedures given here are adaptable to regular electronic data processing machines (accounting type) as well as high-speed tape-oriented computers.
3. The new techniques will eventually lead to the development of electronic computer methods for the calculation of survivor curves (service and dollar life).
4. With these new procedures, providing that road life and cost records are updated on a continuous basis, investment analyses can readily be made as often as needed by highway planners and administrators.
5. Further research is required for the expansion of the general retirement table given in Appendix B, in order to meet the specific needs of various states and yield more accurate results. If such a system is developed, retired costs can be expressed as a percentage of individual cases rather than over-all averages.
6. Further research is also needed in order to incorporate depreciation factors into the automatic computation of remaining investments as presented in this paper.

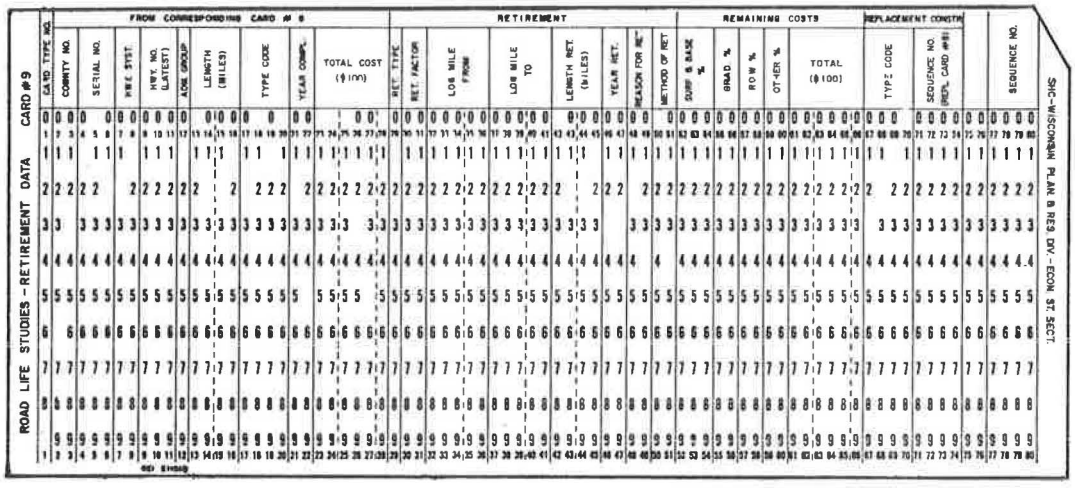
REFERENCE

1. Farrell, F. B. The Investment Analysis Approach to Estimating Highway Needs. Proc. HRB, Vol. 35, pp. 9-13, 1956.

Appendix A

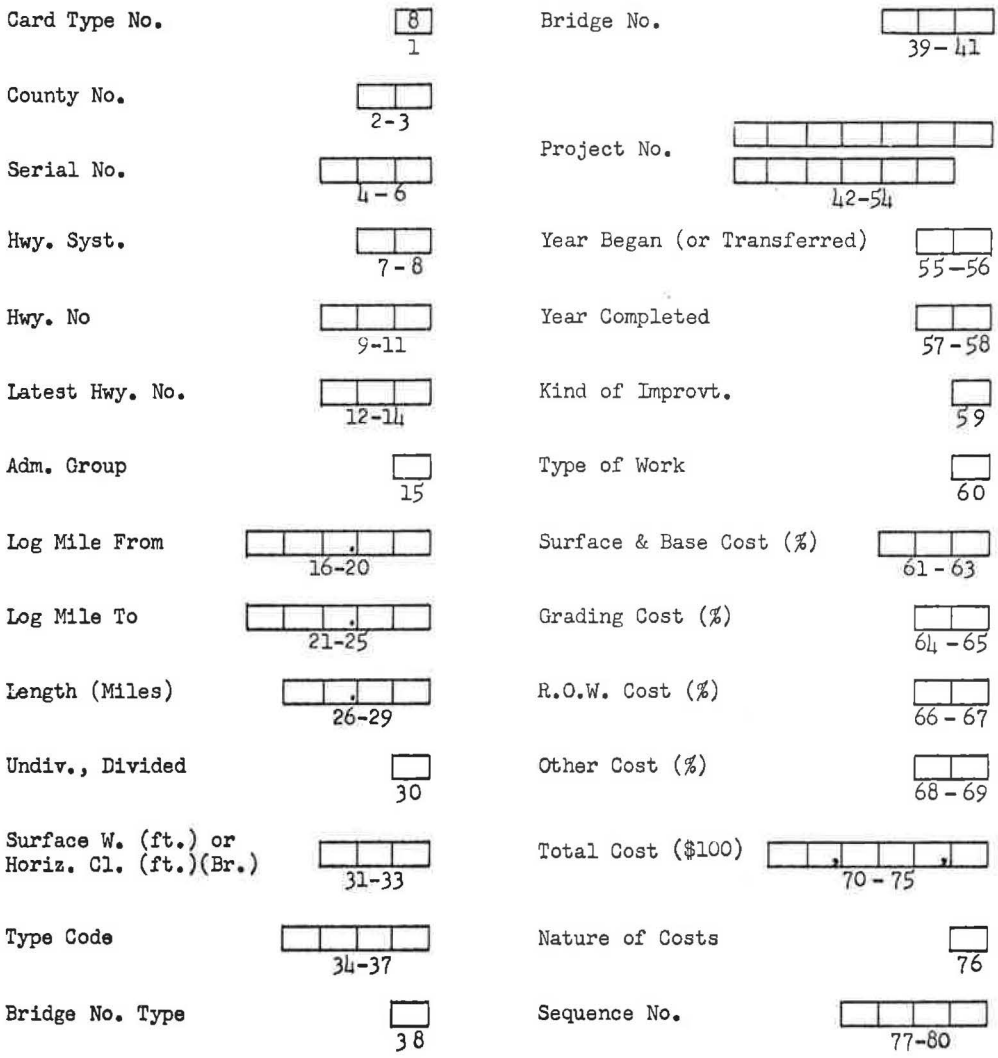
LAYOUT OF CARDS #8 & 9





CODE SHEET - CARD #8

ROAD LIFE STUDIES - CONSTRUCTION DATA



Remarks: cc 50-54 and 38-41 are temporarily used for coding "secondary letters" (1912-1961 records)

CODE SHEET - CARD #9

ROAD LIFE STUDIES - RETIREMENT DATA

Card Type No. [9] 1

From Corresponding Card #8

County No. [ ] 2-3

Serial No. [ ] 4-6

Hwy. System [ ] 7-8

Hwy. No. (or Latest Hwy. No.) [ ] 9-11

Adm. Group [ ] 12

Length (Miles) [.] 13-16

Type Code [ ] 17-20

Year Completed [ ] 21-22

Total Cost ($100) [,] 23-28

Retirement

Retirement Type [ ] 29

Retirement Factor [ ] 30-31

Log Mile From [,] 32-36

Log Mile To [.] 37-41

Length Retired (Miles) [.] 42-45

Year Retired [ ] 46-47

Reason for Retirement [ ] 48-49

Method of Retirement [ ] 50-51

Remaining Costs

Surface & Base (%) [ ] 52-54

Grading (%) [ ] 55-56

R.O.W. (%) [ ] 57-58

Other (%) [ ] 59-60

Total ($100) [,] 61-66

Replacement Construction (if any)

Type Code [ ] 67-70

Sequence No. (Repl. Card #8) [ ] 71-74

Sequence No.(This Card) [ ] 77-80

Remarks: cc 75 is temporarily used for coding "secondary letters" (1912-1961 records)

(Columns 75-76 are reserved for future use)

Appendix B

TABLE SHOWING
AVERAGE RETIRED COSTS ACCORDING TO METHOD OF RETIREMENT

Method of Retirement	Code (#9 cc50-51)	Cost Retired % *				
		Surf. & Base	Grad.	R.O.W.	Other	Total
ROADWAYS						
1. Resurfacing:						
Old wearing course not altered, new course added	01-02	10 1/ 30 60 2/	10 1/ 0 10 2/	0 1/ 0 0 2/	25 1/ 10 5 2/	—
Old wearing course scarified or reworked, new course added	03-04	65	10	0	25	—
2. Reconstruction (Same Line & Grade):						
Old wearing course and base reworked and reused	11-12, 15-18	70	20	0	35	—
Old wearing course and base torn out, not reused	13-14,19-22	100	20	0	40	—
3. Reconstruction (Same Line, New Grade):						
Old wearing course and base torn up and reused	23-24	75	75	0	70	—
Old wearing course and base torn out, not reused	25-26	100	75	0	75	—
4. Reconstruction (New Line & Grade):						
Old R.O.W. partially used, roadway rebuilt	27-28	100	100	50	95	—
Old roadway abandoned or transferred	31-32,41-44	100	100	100	100	—
5. No New Construction As Replacement:						
Old roadway abandoned or transferred	33, 45-46	100	100	100	100	—
BRIDGES						
1. Partial Rebuilding	51-53	-	-	-	-	50
2. Replacement:						
Old structure salvaged and re-used at new location	61	-	-	-	-	75
Old structure demolished, abandoned or transferred	62-63 71, 81-82	-	-	-	-	100
3. No New Construction as Replacement:						
Old structure demolished, abandoned or transferred	72-73 83-84	-	-	-	-	100

1/ P.C. Concrete capped with new concrete or resurfaced with bituminous material.
2/ Resurfacing of gravel and stone to similar type.
* Percentages given here are within each cost item and reflect over-all estimated averages, excluding depreciation.

LIST OF RETIREMENT CODES
(Card #9 cc 50-51)

Method of Retirement of Roadways	Code (Replacement Same Major Type)	Code (Replacement Different Major Type)
1. Resurfacing:		
Old wearing course not altered and new wearing course added	01	02
Old wearing course scarified or partially reworked and new wearing course added.	03	04
2. Reconstruction along same line and same grade which retires a single course road type (gravel, concrete, etc.):		
Old course completely reworked and reused	11	12
Old course torn out and not reused	13	14
3. Reconstruction along same line and same grade which retires a multiple course road type (surface treated gravel, bituminous concrete on gravel or concrete, etc.)		
Old wearing course completely reworked and reused	15	16
Old wearing course and old base completely reworked and reused	17	18
Old wearing course torn out and not reused	19	20
Old wearing course and old base torn out and not reused	21	22
4. Reconstruction along same line but on new grades:		
Old wearing course and base (if any) torn up and reused	23	24
Old wearing course and base (if any) torn out and not reused	25	26
5. Reconstruction along new line and new grades:		
Old right-of-way partially used, but roadway completely rebuilt	27	28
Old roadway abandoned	31	32
Old roadway transferred to local road systems	41	42
Interstate highway transferred to STH system, or vice-versa	43	44
6. No new construction which can be considered as replacing the old roadway:		
Old roadway abandoned		33
Old roadway transferred to local road systems		45
Interstate highway transferred to STH system, or vice-versa		46

LIST OF RETIREMENT CODES (Cont'd)
(Card #9 cc 50-51)

Method of Retirement of Bridges	Code
1. Partially rebuilt:	
New superstructure	51
New substructure	52
Widened	53
2. Replacement at same location:	
Old structure replaced but salvaged by removal to new location and reused	61
Old structure demolished	62
3. Replacement at new location:	
Old structure demolished	63
Old structure abandoned	71
Old structure transferred to local road systems	81
Interstate bridge transferred to STH system, or vice-versa	82
4. No new construction which can be considered as replacing the old structure:	
Old structure demolished	72
Old structure abandoned	73
Old structure transferred to local road systems	83
Interstate bridge transferred to STH system, or vice-versa	84

Grouping of "Method of Retirement" Codes:

Roadways	Codes in Col. 50
Resurfacing	0
Reconstruction	1,2
Abandonment	3
Transfer	4
Bridges	
Partial Rebuilding	5
Replacement	6
Abandonment	7
Transfer	8