[Ex.#1]

Projects	PSI	Cost	Benefit 1	Benefit 2	B1/C	B2/C	DB1/DC	DB2/DC
1-A	2.2	0.5	30	3	60.0	6.0	60.0	6.0
(1-B)	2.2	0.7	30	5	42.9	(7.1)	0.0	10.0
(1-C)	2.2	1.5	30	10	20.0	6.7	0.0	6.3
2-A	2	0.6	45	3	75.0	5.0	75.0	5.0
(2-B)	2	0.9	45	5	50.0	(5.6)	0.0	6.7
(2-C)	2	2.5	45	10	18.0	4.0	0.0	3.1
(3-A)	1.8	0.4	20	3	50.0	7.5	50.0	7.5
(3-B)	1.8	0.8	20	5	25.0	6.3	0.0	5.0
(3-C)	1.8	1.9	20	10	10.5	5.3	0.0	4.5
4-A	2.7	0.3	22	3	73.3	10.0	73.3	10.0
4-B	2.7	0.5	22	5	44.0	10.0	0.0	10.0
4-C	2.7	1.2	22	10	18.3	8.3	0.0	7.1

→ 7.1 (section 1); → 5.6 (section 2); 可略 (section 4)

Network Algorithm

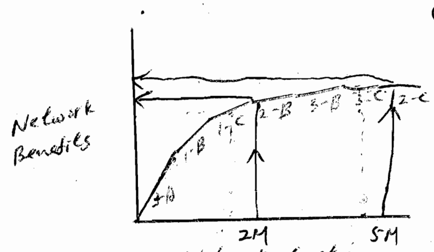
基本原則:

1. Needs 需要 Rehab selection options
   (i.e. Decision Trees, LCC, or Single Rehab)
2. Ranking 亦需要 Rehab Selection Options
   (" " ")
   及 Budget Limits
3. B/C Ratio 亦需要 Rehab Selection options
   (同上) **Benefit options**
4. IB/C 則已全部考慮
5. Section #4 可略，因尚未達PSI門檻值 **(2.5)**

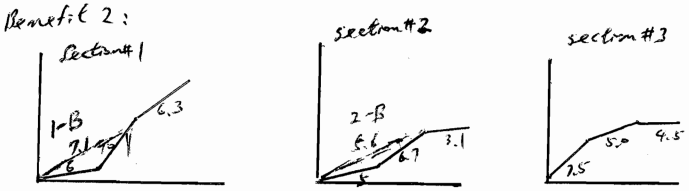
[Sol]:

1. Needs + (Decision Trees or Single Rehab)
   ⇒ 所需之 Costs 與 Benefits 將不同
   eg.: 若選 Rehab "A": Total Cost = 0.5 + 0.6 + 0.4
   Total Benefit₁ = 30 + 45 + 20
   or Benefit₂ = 3 + 3 + 3
2. Ranking + (Decision Trees or Single Rehab)
   ⇒ 優先順序為 3 2 1
   視 Budget Limits 及 Single Rehab 選定而異
   eg. 若選 Rehab "C"，則在 2M# 限制下，僅 3-C 可選
   5M# 〃 下，僅 3-C, 2-C 可選
   Total Benefit 亦隨之而異
3. B/C + (Decision Trees, LCC, or Single Rehab)
   eg. Benefit #1 { Rehab "A": 2-A, 1-A, 3-A 之優先順序
   Rehab "C": 1-C, 2-C, 3-C 〃 〃
   Benefit #2 { Rehab "A": 3-A, 1-A, 2-A 〃 〃
   Rehab "B": 1-B, 3-B, 2-B 〃 〃
4. IB/C
   (a) Benefit 1:
   僅最低 Cost 被選取:
   優先順序: 2-A, 1-A, 3-A.

   (b) Benefit 2:



Budgets
1. 2M#: 3-A, 1-C
2. 5M#: 3-C, 2-B, 1-C



$\frac{\Delta B_1 + \Delta B_2}{\Delta C_1 + \Delta C_2} = \frac{5}{0.7} \approx 7.1$ $\frac{\Delta B_1 + \Delta B_2}{\Delta C_1 + \Delta C_2} = \frac{5}{0.9} = 5.6$

All Possible Rehab options: 優先順序
3-A, 1-B, 1-C, 2-B, 3-B, 3-C, 2-C

1. 假設某一鋪面路網有四個路段，可考慮三種維修方式(A, B, C)，在某一分析期間其 PSI 值、維修成本、與預期效益如下：

Projects	PSI	Cost, 百萬元	Benefit, VMT (1000 延車英哩)	Benefit, Added Life (Years)
1-A	2.2	0.5	30	3
1-B	2.2	0.7	30	5
1-C	2.2	1.5	30	10
2-A	2.0	0.6	45	3
2-B	2.0	0.9	45	5
2-C	2.0	2.5	45	10
3-A	1.8	0.4	20	3
3-B	1.8	0.8	20	5
3-C	1.8	1.9	20	10
4-A	2.7	0.3	22	3
4-B	2.7	0.5	22	5
4-C	2.7	1.2	22	10

(a) 假設可接受之 PSI 門檻值為 2.5，請您依據 Needs 之概念決定在該分析期間所需之維修養護經費。

(b) 假設在可運用經費為二百萬與五百萬元之條件下，並請依據 Ranking, Benefit-Cost Ratio, 與 Incremental Benefit-Cost Ratio 等方法分析各種不同之最佳化路網維修方式與經費運用情形，並請比較在不同之 Benefit 定義下其差異為何？

(c) 此分析方式之重要性與必要性為何？

(d) 請利用 Linear Integer Programming 之 LINDO 程式執行，並比較其差異。

(A.) Benefit 1

```
MAX
  30P1S1+30P1S2+30P1S3
 +45P2S1+45P2S2+45P2S3
 +20P3S1+20P3S2+20P3S3
ST
  P1S1+P1S2+P1S3+P1S0=1
  P2S1+P2S2+P2S3+P2S0=1
  P3S1+P3S2+P3S3+P3S0=1
  0.5P1S1+0.6P2S1+0.4P3S1
 +0.7P1S2+0.9P2S2+0.8P3S2
 +1.5P1S3+2.5P2S3+1.9P3S3<=2
END
```

(B.) Benefit 2

```
MAX
  3P1S1+5P1S2+10P1S3
 +3P2S1+5P2S2+10P2S3
 +3P3S1+5P3S2+10P3S3
ST
  P1S1+P1S2+P1S3+P1S0=1
  P2S1+P2S2+P2S3+P2S0=1
  P3S1+P3S2+P3S3+P3S0=1
  0.5P1S1+0.6P2S1+0.4P3S1
 +0.7P1S2+0.9P2S2+0.8P3S2
 +1.5P1S3+2.5P2S3+1.9P3S3<=2
END
```

Lecture #11:

◎ Example of Working System
- Basic Features of Working Systems
- Network Level Examples of PMS
- The ILLINET (Illinois Interstate Highways Network Management System) Program

◎ Demonstration of ILLINET Program
程式簡介、實際操作、與成果分析

◎ Looking Ahead (LTPP)
- Demo of LTPP Data Request Program
- Analyzing Special Problems
- Application of Expert Systems and New Emerging Technologies
- Institutional Issues and Barriers Related to PMS Implementation
- Future Directions and Need for Innovation in Pavement Management

◎ Brief Demo of the TKUPAV Program
(NSC Project: New Stress Analysis and Thickness Design Procedures for Jointed Concrete Pavements)
(Lee, Y. H., et. al., "Modified PCA Stress Analysis and Thickness Design Procedures")

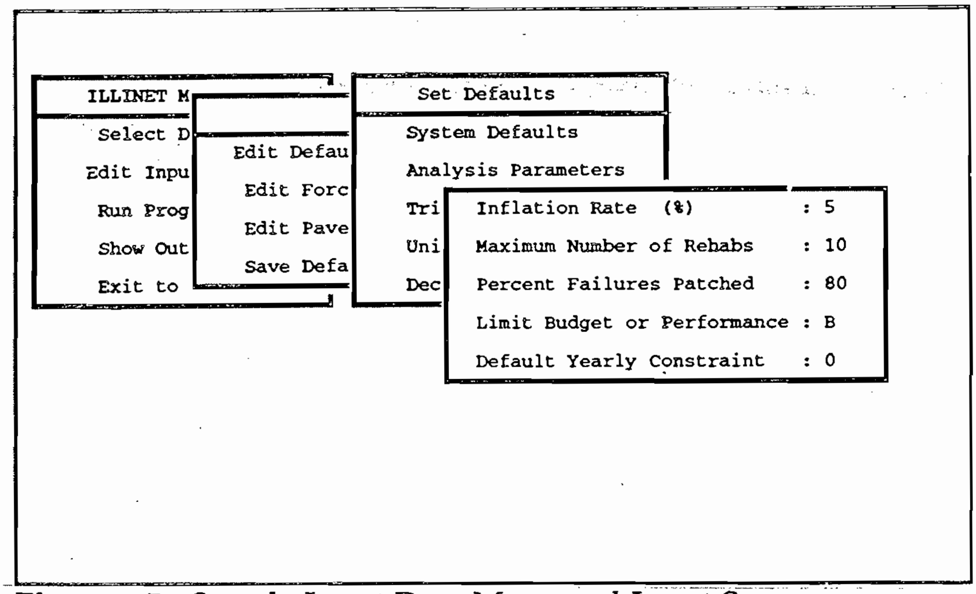


Figure 2.5 - Sample Input Data Menu and Input Screen.

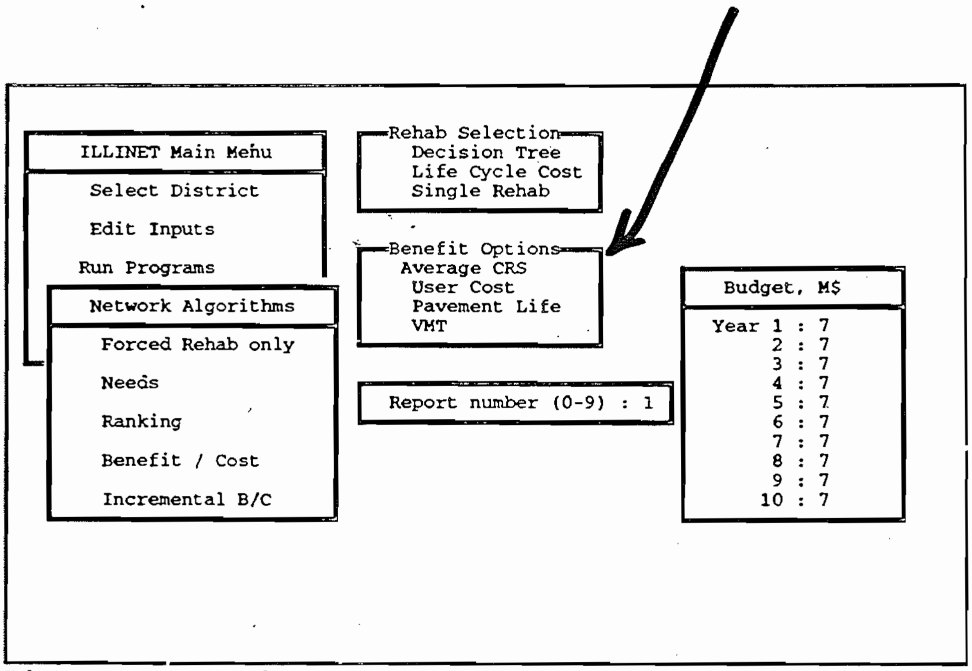


Figure 2.6 - Sample Run Program Menu and Input Screen.

Table 8.2 - Default User Input Values for ILLINET.

Default Parameter	Value	Unit
Analysis Year	1987	
Length of Analysis Period	10	Year
Analysis Interval	1	Year
Trigger for Accruing	6	CRS
Trigger for Backlog	4	CRS
Trigger for Rehabilitation	6	CRS
Inflation	5	Percent
No of Rehabilitations Allowed	1	
Percent Patching	80	Percent
User's Cost for CRS>=6	27	Cents/mi
User's Cost for 6 >CRS> 5	31	Cents/mi
User's Cost for CRS<=5	34	Cents/mi

Table 8.3 - Default Trigger Values for Decision Tree.

	Trigger Values for Rehabilitation			
Rehabilitation Type	BARE JRCP	BARE CRCP	BARE 'D' Cracked	Asphalt Overlays
CPR	6	6	n/a	n/a
3.25-inch Overlay	5	5	6	6
5.0-inch Overlay	4	4	4	4
Reconstruction	3	3	3	3

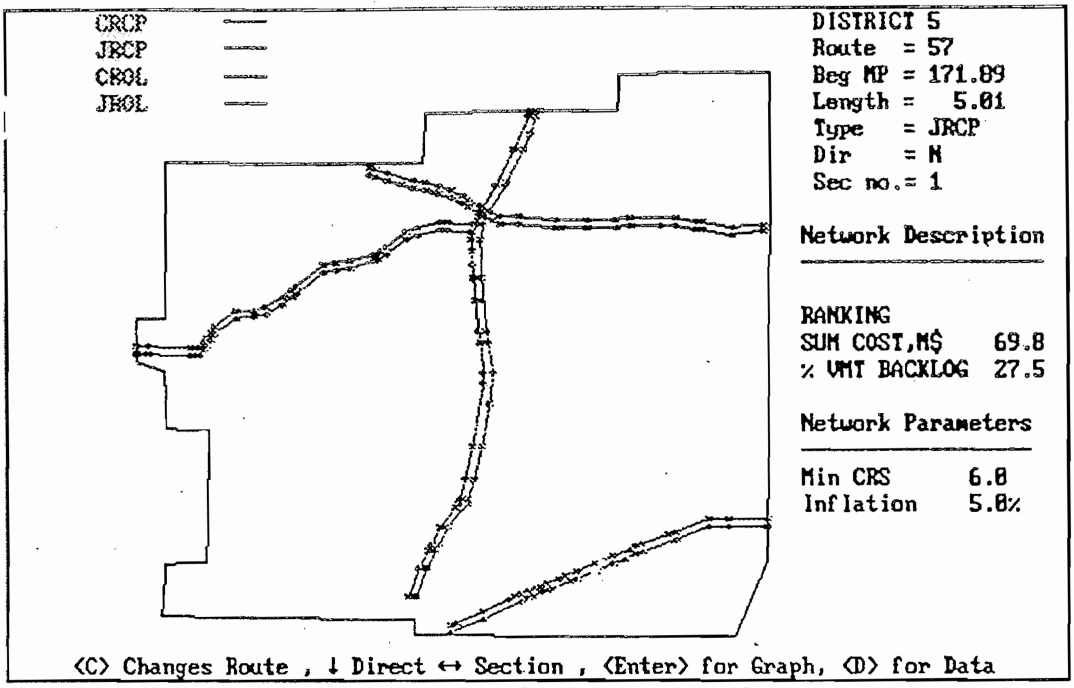


Figure 2.7 - Sample ILLINET Map (IDOT district 5).

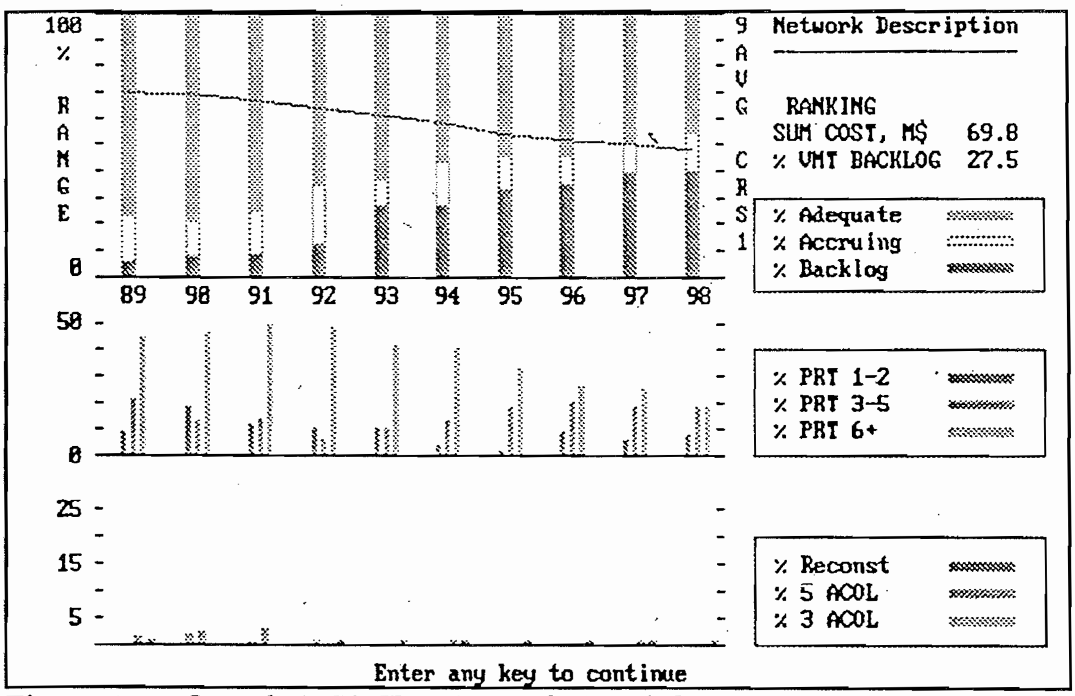


Figure 2.8 - Sample ILLINET Network-Level Graph.

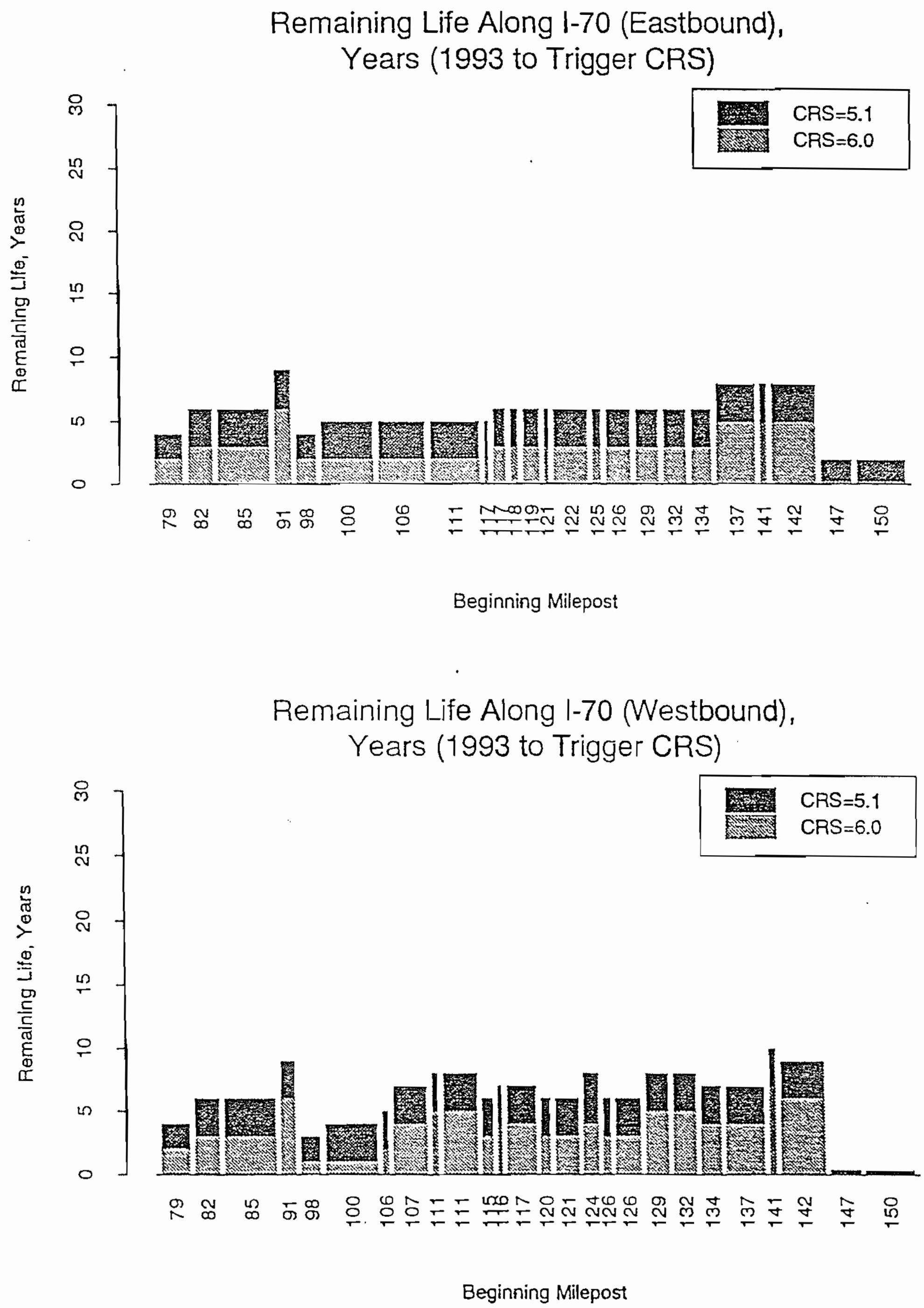
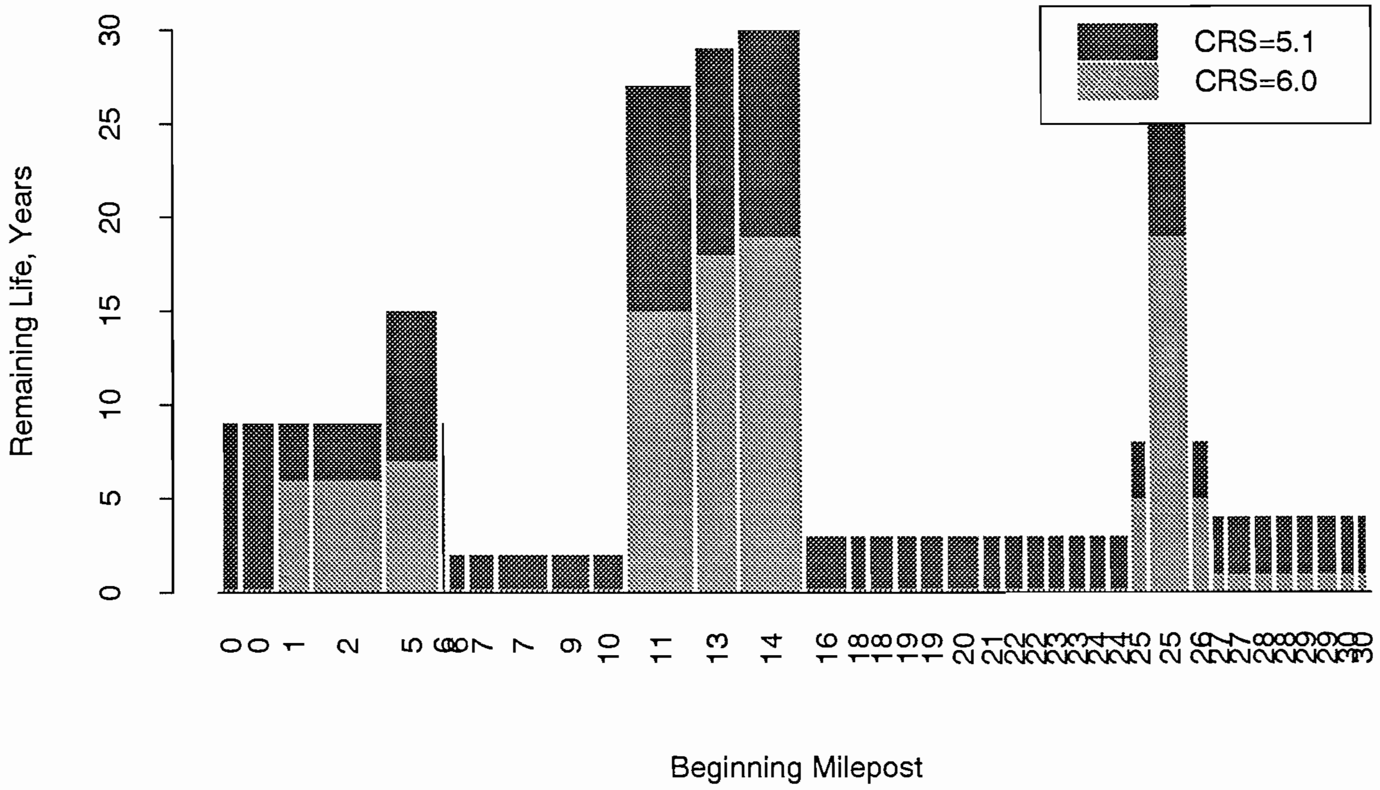
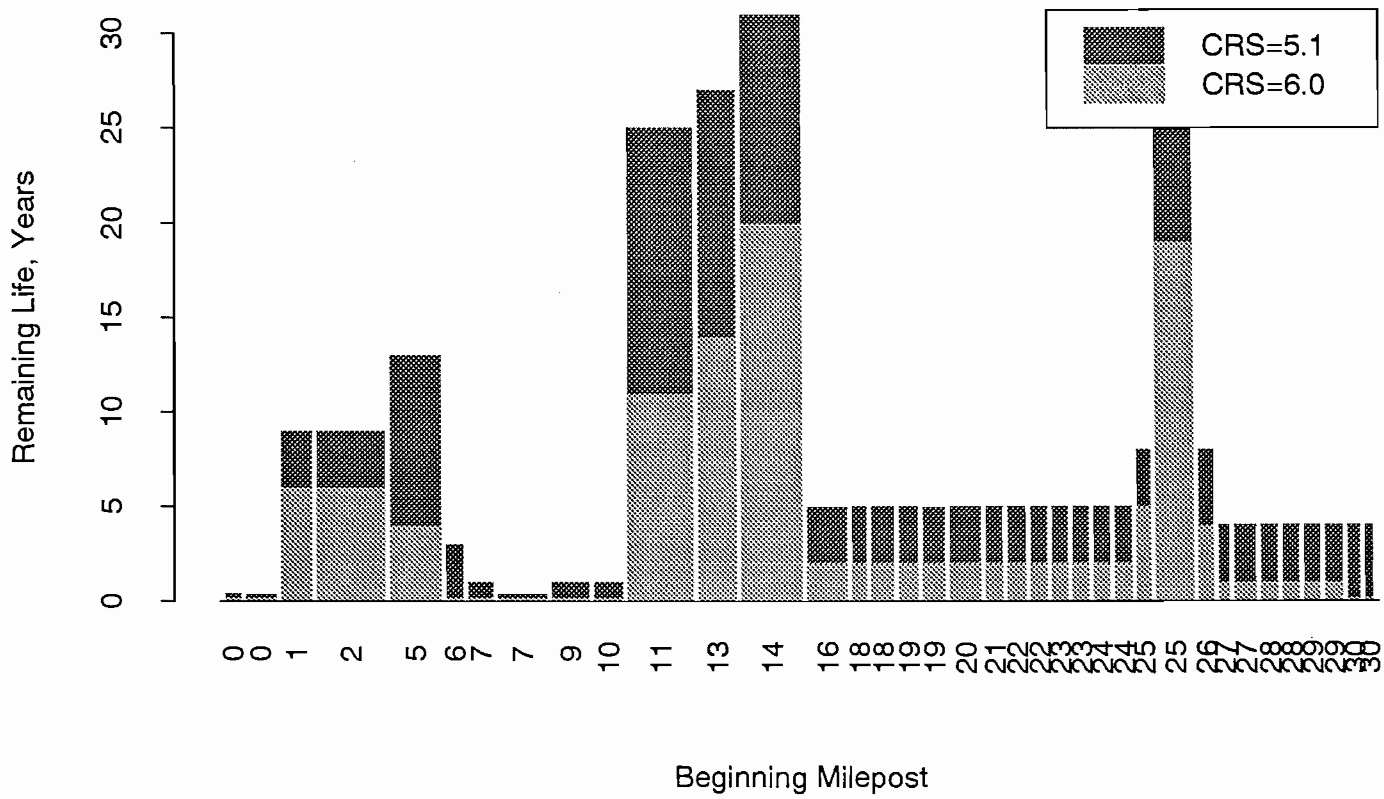


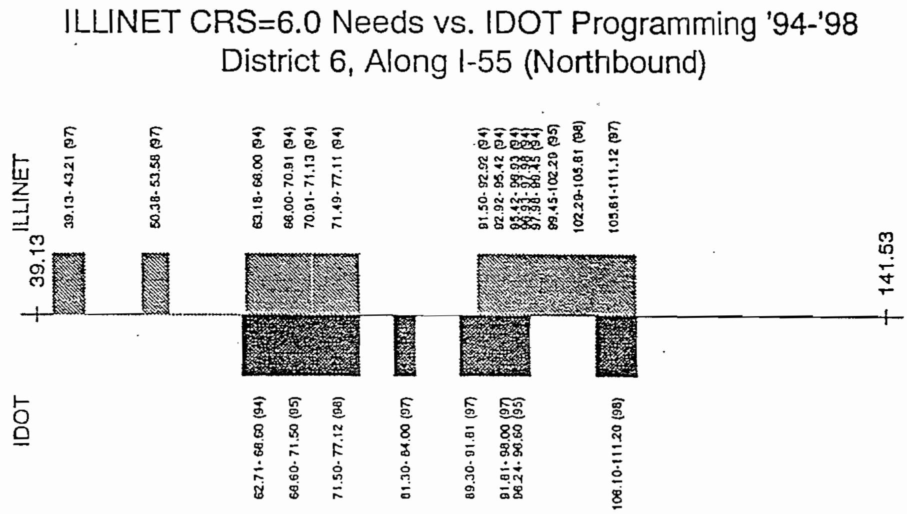
Figure 3. Remaining life of pavement sections along portion of Interstate 70.

Remaining Life Along I-290 (Eastbound), Years (1993 to Trigger CRS)



Remaining Life Along I-290 (Westbound), Years (1993 to Trigger CRS)





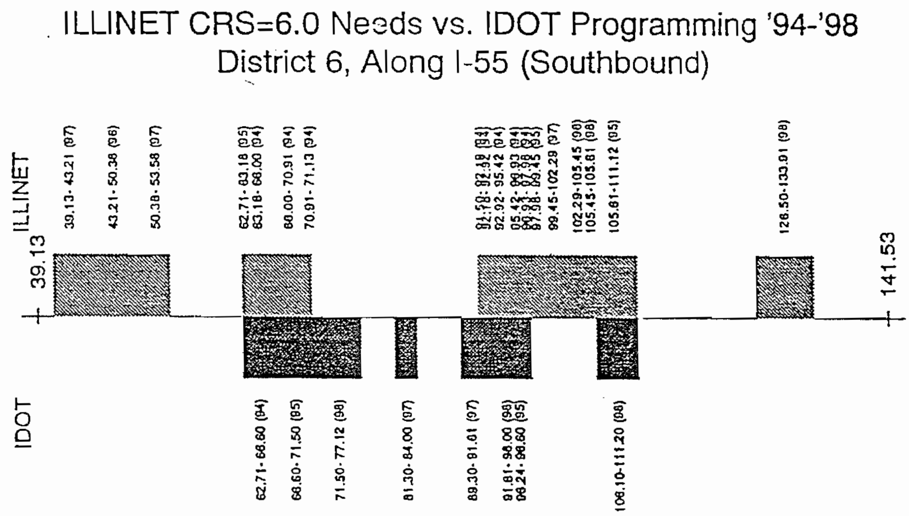
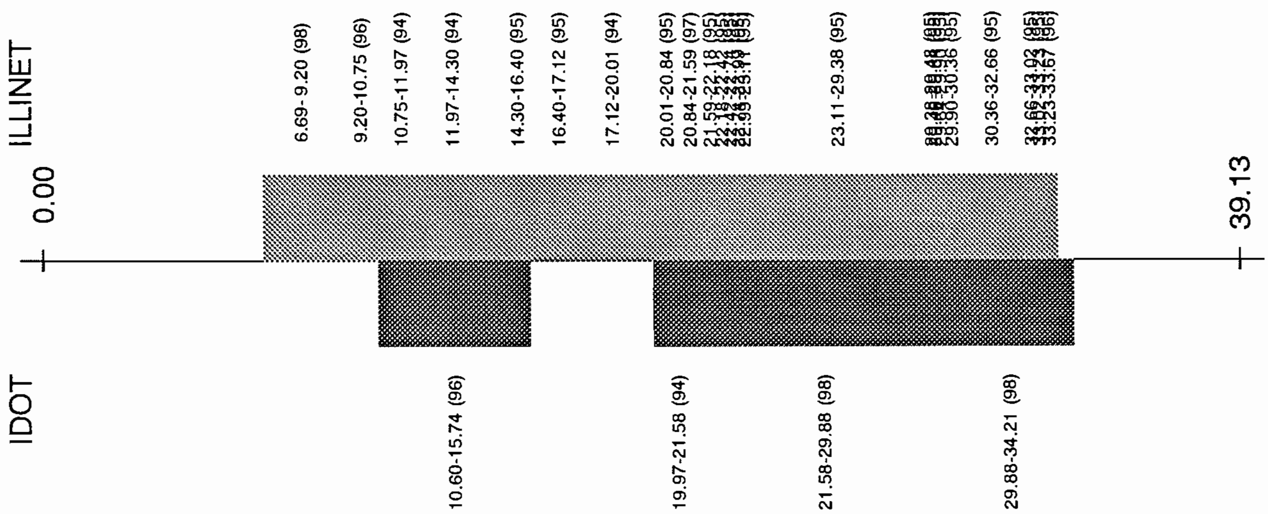
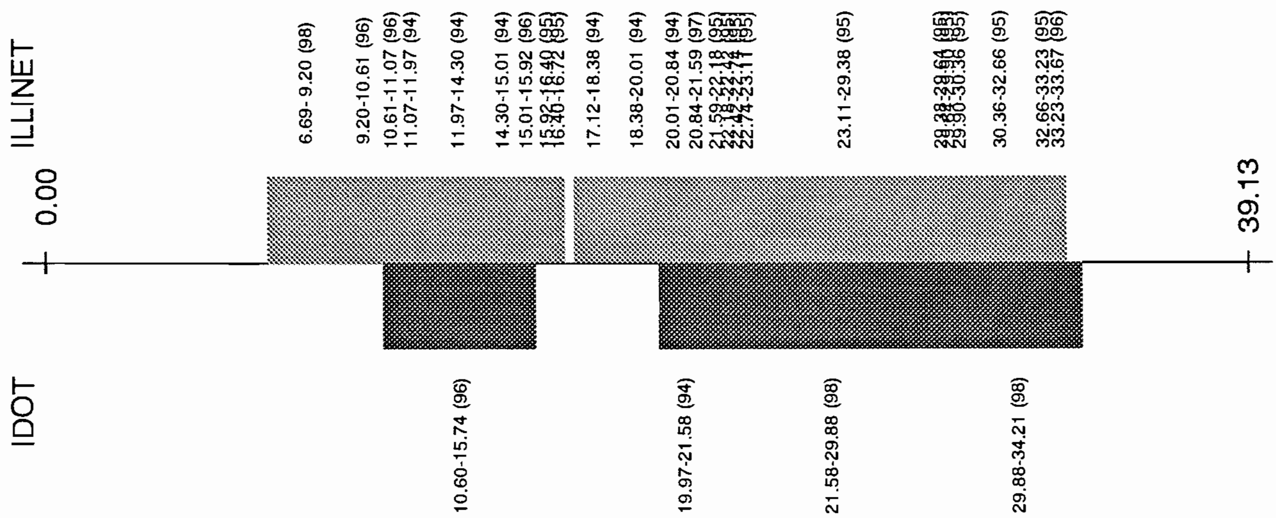


Figure 4. Rehabilitation needs (from ILLINET) versus rehabilitation programmed (from IDOT 1994-1998 program) for portion of Interstate 55.

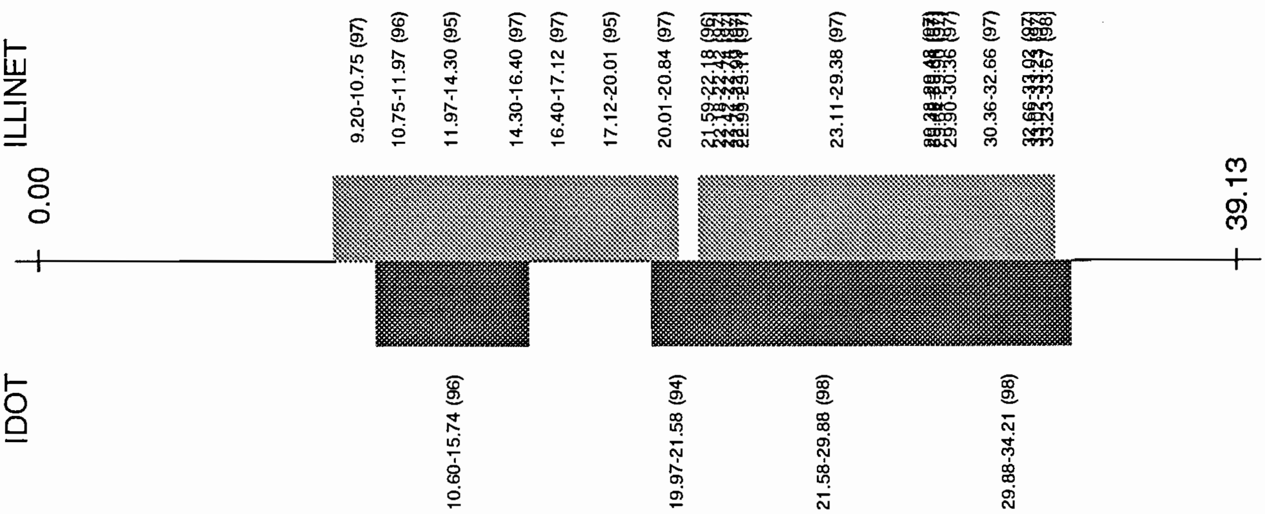
ILLINET CRS=6 Needs vs. IDOT Programming '94-'98
District 8, Along I-55 (Northbound)



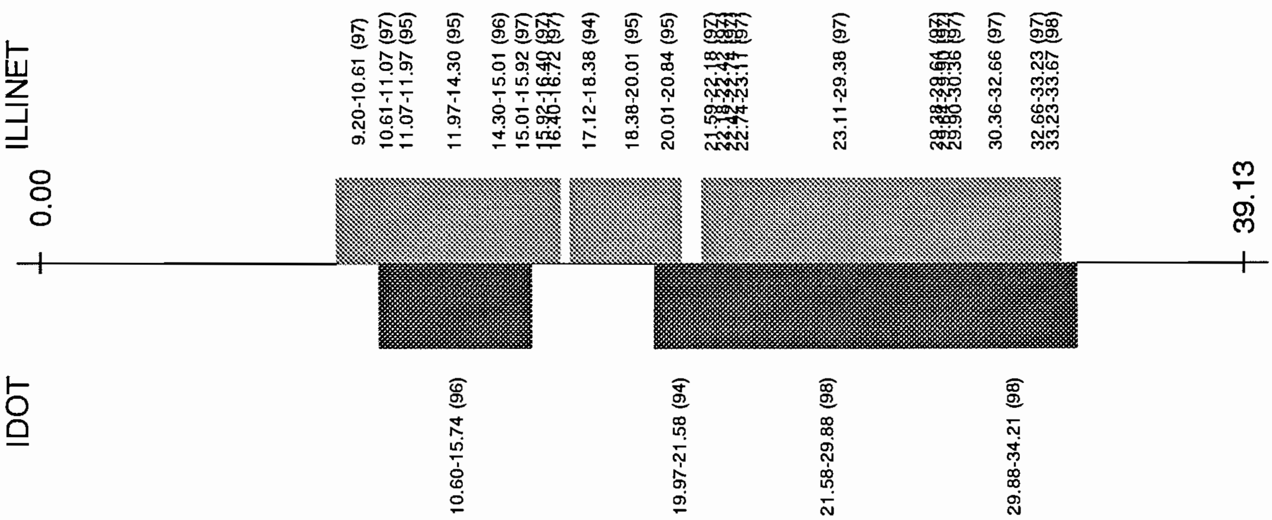
ILLINET CRS=6 Needs vs. IDOT Programming '94-'98
District 8, Along I-55 (Southbound)



ILLINET CRS=5.5 Needs vs. IDOT Programming '94-'98
District 8, Along I-55 (Northbound)



ILLINET CRS=5.5 Needs vs. IDOT Programming '94-'98
District 8, Along I-55 (Southbound)



```
source("summary.s")
> attach(allrpt.dat)
> x1 <- cbind(lngth.6 = tapply(lngth, district, sum), lngth.55 = tapply(
        lngth.55, district, sum), lngth.5 = tapply(lngth.5, district, sum),
        idot = tapply(lngthi, district, sum))
> print(x1)
  lngth.6 lngth.55 lngth.5   idot
1  412.59   170.31  153.14 185.81
2  320.10   114.71   51.55 109.76
3  476.63   123.85   93.73 117.73
4  207.26    91.09   72.90 107.27
5  510.82   146.81  112.90 162.47
6  246.56    43.57   32.78  62.54
7  405.93   143.98  113.28 144.49
8  352.16    86.77   37.62  72.82
9  229.88    53.82    7.91  25.48
> print(sum(x1[, "lngth.6"]))
[1] 3161.93
> print(sum(x1[, "lngth.55"]))
[1] 974.91
> print(sum(x1[, "lngth.5"]))
[1] 675.81
> print(sum(x1[, "idot"]))
[1] 988.37
> detach(2)
sink()
```

Homework:

假設在十年期間每年之維修經費均為八百萬元，請利用ILLINET程式協助分析在不同之路網維修管理選項下之結果，請比較說明各選項之特點與差異，此次分析之結論與心得。

Handouts:

1. Hall, K. T., Y. H. Lee, M. I. Darter, D. L. Lippert (1994), "Forecasting Pavement Rehabilitation Needs for the Illinois Interstate Highway System, " TRR 1455, pp. 116-122.

2. Mohseni, A. (1991), "Alternative Methods for Pavement Network Rehabilitation Management," Ph.D. Thesis, University of Illinois, Urbana. (Appendix B: ILLINET User's Guide)

Table 8.4 - Network Parameters for Six Application Runs for District 5.

Network-Level Opti	RAND	NEEDS	RANK	IBC	OPT	LIN
Project-Level Option	Random	LCC	LCC	All	All	All
Benfit Option	n/a	n/a	n/a	VMT	VMT	VMT
Budget Limit, Million Dollars	75	n/a	75	75	75	75
Cost, Million Dollars	74	90.1	73.8	73.3	75	71.2
Average network CRS 1-9 scale	6.49	7.15	6.74	6.82	6.99	6.81
Average % VMT on Backlog	15.4	2.6	3.5	6.1	4.2	6.2
Remaining Life, Years / mile	3.5	4.7	3.8	4.2	4.4	4.3
% VMT-Backlog @ Year 10	35	10	14	17	14	17
Total CRS Area, CRS-Year / mile	21.5	37.0	26.1	28.4	31.6	29.2
User Benefit, Million Dollars	218	443	287	386	408	383
Total Added Life, Years / mile	2.89	5.9	3.4	4.7	5.2	4.8
VMT on Adequate, Billions	2.98	6.44	3.82	5.64	6.02	5.63
Benefit (VMT-A)/Cost	40	71.5	52	77	80	79

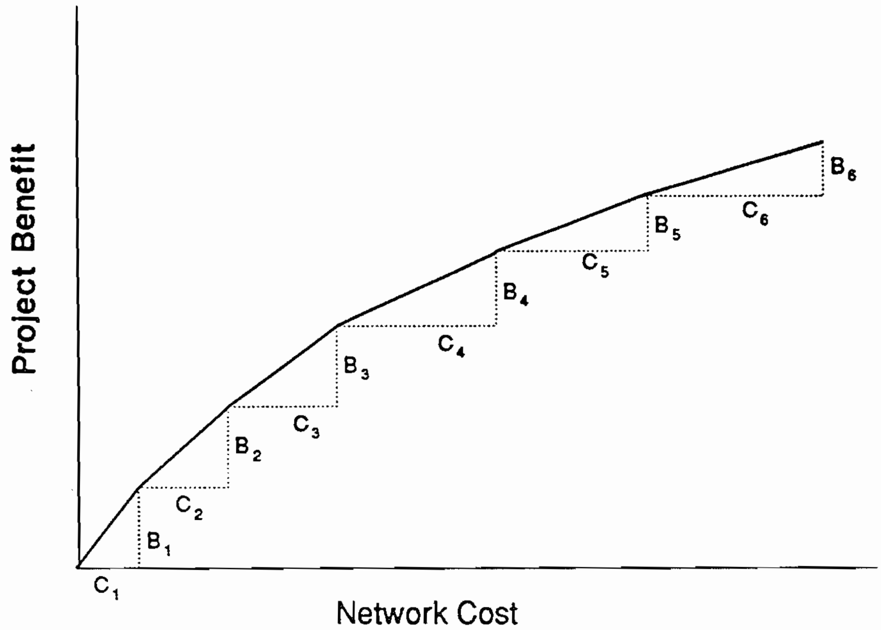


Figure 7.4 - Benefit-Cost Curve for Project Selection for a Given Year.

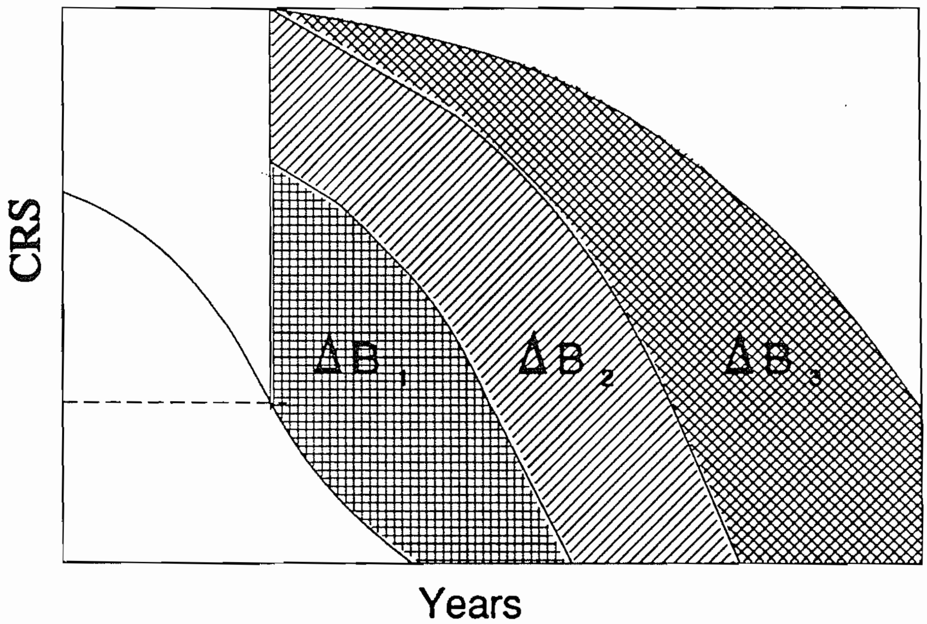


Figure 7.5 - Incremental Benefit and Costs for Different Projects.

After projects for all deficient sections are arranged in the proper order at the project level, all projects for all sections are arranged in descending order of IBC such that the network IBC curve provides the steepest path when moving from low to high cost (see Figure 7.8). This network IBC curve also can be regarded as the steepest benefit path or highest gradient curve. Projects selected from the steepest path curve contribute the most to the network benefit since they provide the highest benefit per cost. The project selection continues on the steepest path until the budget limit is reached. It is evident from figure Figure 7.8 that the resulting network benefit is the maximum possible for the budget limit. When more than one project is selected for a section, the most recent project selected replaces all previous projects. Thus, only one project is selected for each section in the network. All sections that do not receive funding will be maintained (i.e. their rehabilitation is delayed for at least one year). When a project is not selected because its cost of rehabilitation exceeds the budget, other projects with the lower IBC are considered for selection. In this case those projects that were set aside at the project-level because they violated the concave down rule are also considered in selection.

As shown before, the IBC method selects projects such that the resulting network benefit is maximum for a yearly network budget limit. In effect, IBC solves the optimization formulation (to be discussed in the next section) to maximize yearly pavement network benefit for a limited budget.

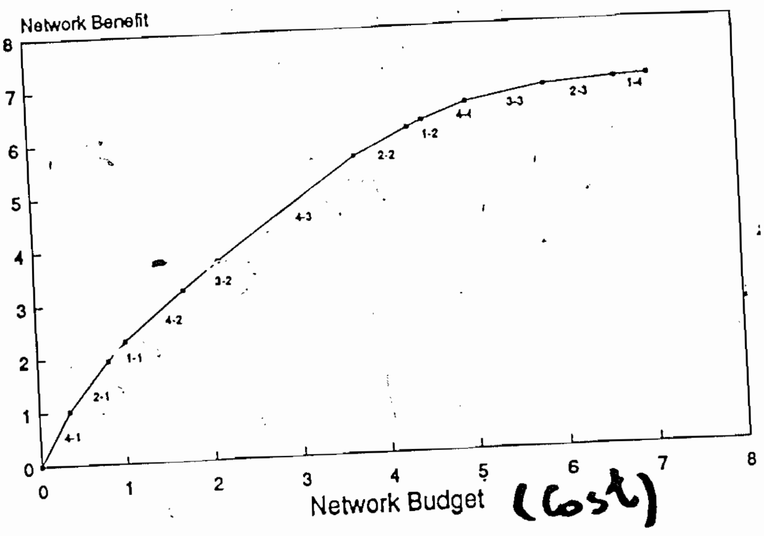


Figure 7.8 - IBC Steepest Benefit Path Curve for Project Selection.

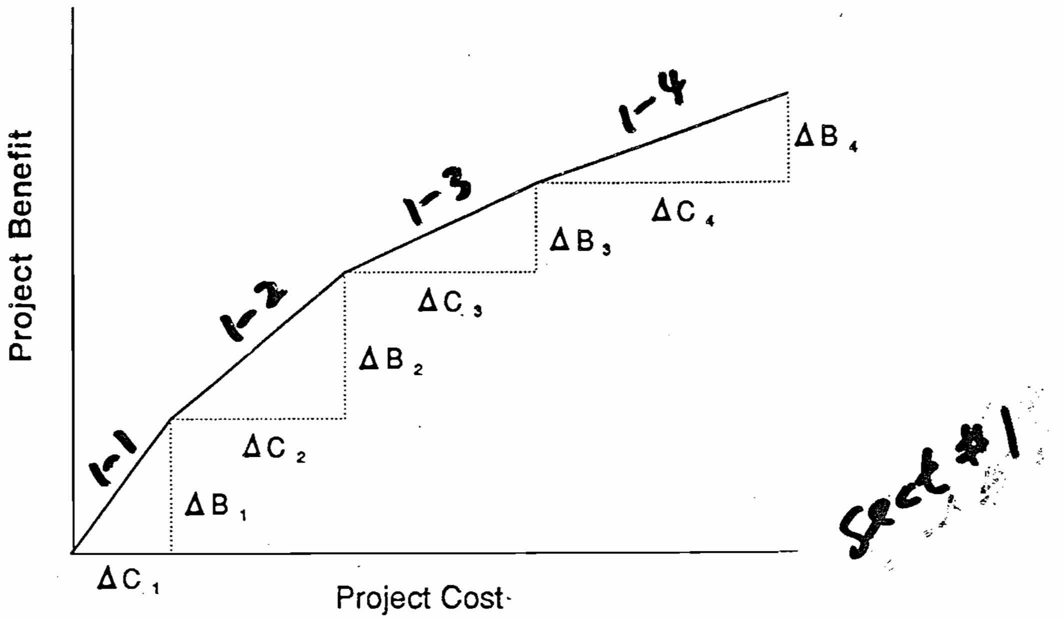


Figure 7.6 - Arranging IBC's for One Section (Concave Situation).

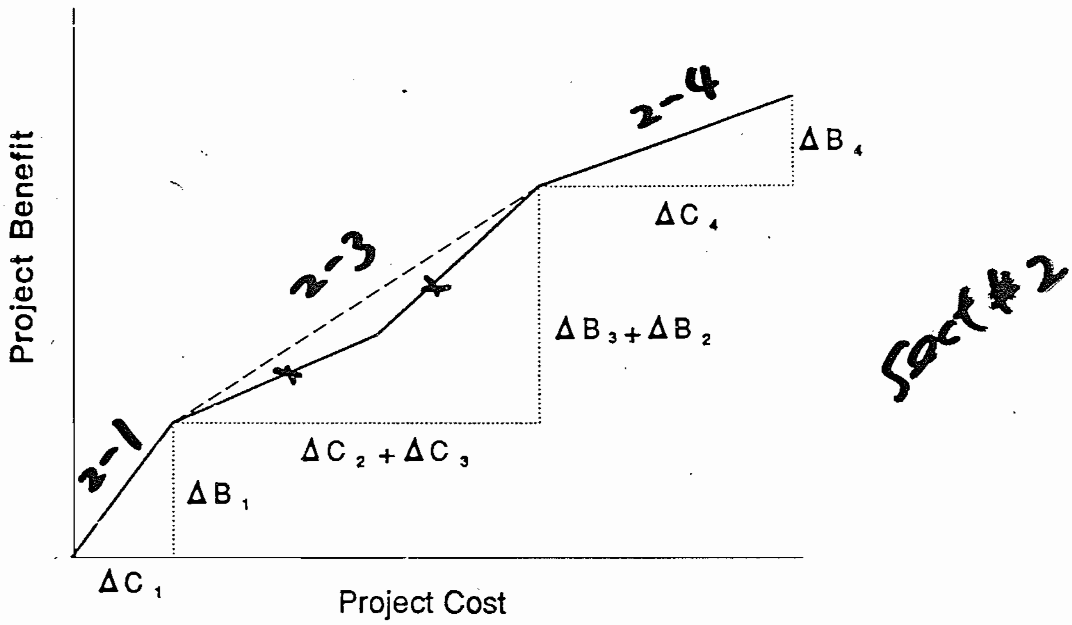


Figure 7.7 - Arranging IBC's for One Section (Non-Concave Situation).