PREDICTION OF ROAD CONSTRUCTION COST QUANTITIES AND THEIR UNIT PRICES FOR TURKEY

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By

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ABSTRACT

PREDICTION OF ROAD CONSTRUCTION
COST QUANTITIES AND THEIR UNIT PRICES FOR TURKEY

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The main aim of this thesis is to develope a model which help to predict road construction costs and to provide the values required for either selecting the best alternative or investment planning , with the minimal information for Turkey .

As known , in road construction costs , earthwork , drainage , bridge and pavement are the major costs which include the greater amount of total cost . For this reason , when developing the model , these main cost components have been taken as a base .

In road constructions , geometric standard and terrain type which are the most important factors have been used like basic variables . But , for example , for geometric standard road's vertical rises plus falls - in longitudinal direction - per kilometer of roadway (RF) , for terrain type ground's vertical rises plus falls per kilometer (GRF) which helps not to fall in hesitation when determining the type of terrain (from flat to rolling or from rolling to mountainous terrains) have been used as variables .

By means of this model , in the point of its easy use (after the first stage of a project - preparing ground and grade lines in longitudinal profile of the road -) , its helps on selecting the best alternative and its simplification of making a decision on investment planning views , it is important .

Key Words : road construction cost , cost predicting model , terrain type - ground rise plus fall - , geometric standard - road rise plus fall , roadway width.

ÖZET

TÜRKİYE İÇİN YOL MALİYET MİKTARLARINI VE BİRİM FİATLARINI ÖNCEDEN TAHMİN İÇİN BİR MODEL

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Bu tezin esas amacı,Türkiye'de yol yapım miktar ve maliyetlerini en az bilgi ile tahmin etmeye yarayacak bir model geliştirmek ve gerek alternatif seçiminde gerekse yatırım planlamasında ihtıyacı duyulacak değerleri sağlamaktır .

Bilindiği gibi yol yapım maliyetlerinde,toprak işleri ,drenaj , köprü ve kaplama toplam maliyetin büyük kısmını oluştururlar . Bu sebeple , model geliştirilirken bu esas bileşenler alınmıştır .

Yol inşaatlarında , geometrik standardın ve zemin türünün en önemli faktörler olması nedeniyle modelin tahmın bölümlerinde temel değişkenler olarak alınmışlardır . Ama , örneğin geometrik standart için kilometre başına

yol'daki boyuna iniş ve çıkışlar toplamı (RF) ve yol genişligi (şeritler ve banketler toplamı),zemin türü için düz ile dalgalı , dalgalı ile dağlık arazi arasında tereddütü ortadan kaldırmaya yarayacak zemindeki kilometre başına boyuna iniş ve çıkışlar toplamı (GRF) kullanılmıştır.

Bu model yardımıyla ,projenin ilk aşamasında (yolun boy profilinin hazırlanmasından sonra) kolaylıkla kullanılması , alternatif seçiminde yardım edebilmesi yatırım konusunda karar vermeyi basitleştirmesi açısından önemlidir .

Anahtar kelimeler : yol yapım maliyeti ,maliyet tahmın modeli , arazi tipi - kilometre başına zemin iniş ve çıkışları - , geometrik standart - kilometre başına yol iniş çıkışları , yol genişlığı .

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ABBREVIATIONS

#	:number
ANOVA	:analysis of variance
BCC	:box culvert cost
BCL	:box culvert length
BR=brid	:bridge
CBR	:California Bearing Ratio
CM	:cantimeter
COEF.	:coefficient
CUTVOL	:cut volume
DEV	:deviation
D.F	:degree of freedom
EQ	:equation
EXP	:exponent
G	:relative rise plus fall
GRF	:ground rise plus fall
H	:highway
KM	:kilometer
L=le=leng	:length
LN	:natural logarithm
M	:meter
MIT	:Massacussettes Institude of Technology
MM	:milimeter
MS	:mean squares
PCC	:pipe culvert cost

PCL	:pipe culvert length
PRE	:precipitation
PRED.	:predicted
Pt	:serviceability factor
R	:regional factor
R**2	:correlation coefficient
RES.	:residual
RF	:road rise plus fall
RW	:roadway width
S	:state
S.D.	:standard deviation
Si	:soil support value
SN	:pavement structural number
SS	:sum of squares
St	:standard
TCK	:Turkish Highway Department
TL	:Turkish Lira
TOTEV	:total earthwork volume
TOTEW	:total earthwork volume

CHAPTER 1.

INTRODUCTION

1.1 General

When selecting the best alternative among the highway projects , computing their costs and allocating resources for investment to the project , there is a need to some practical approach to be able to do these with minimal information . However , there is no method to decide which alternative is the best , or to find out or predict how much the total cost or the component costs are , what must be the range of investment for the project that will be accomplished .

There must be a method or an approach to compute costs or to give an idea about costs at the first stage of a highway project . And also the method or model should be simple and practical .

These are the reasons of this study _ to develop a model which can predict the costs with a required sensitiveness .

Major road construction costs and quantities , namely site preparation , earthwork , pavement , drainage , and bridge , can be predicted as a function of terrain severity and geometric standards . However , the site preparation analysis have not been placed in this study due to having no data . But the variables of the function must be provided easily . Here , _in this study_ terrain severity , and geometric standards are converted to some numeric values which are simple to calculate and to characterize the factors above and the same as in the study of World Bank and MIT (see Chapter 2. for more information).

Prediction relationships have been developed by using the actual data of highway projects which are completed and/or applicated in earthwork and drainage , or the data of overall Turkey in bridge , or AASHO method practically in pavement . These relationships are particularly useful in analysing the cost components . This is because the construction cost quantities predicted are sensitive to geometric standards , especially for severe terrain .

For this reason , the model user can gain more precise estimations of construction costs of highway project(s) . First condition is to determine the route of the road , and to prepare the longitudinal profile of the roadway for determination of the variables used in the model .

CHAPTER 2.

HISTORY

World Bank and Massachussetts Institude of Technology have done a study to predict road construction cost quantities for trophical climatic countries -in general .

The set of relationships have been reported by Aw firstly in 1981 and 1982 , and then by Aw and Markow in 1983 .

They have been used the data from 52 road projects located in 28 countries in Asia , Africa , Central and South America . These countries include : Indonesia , New Guinea , the Phillipines , Taiwan and Thailand in East Asia and the Pacific Region ; Nepal , Pakistan , in South Asia ; Syria and Turkey in the Middle East ; Ethiopia , Kenya , Malawi , Somalia , the Sudan , Swaziland , Uganda ,and Upper Volta in East and West Africa ; and Argentina , Bolivia , Chile , Columbia , Equador and Peru in South America .

They have developed the variables for terrain severity and geometric standards such as ;

Ground rise plus fall (GRF) which is the sum of the absolute values of total vertical rise and total vertical fall of the original ground , in meters , along the road alignment over the road section in either direction divided by the total section length , in kilometer.

Road rise plus fall (RF) which is the same as GRF but road's instead of ground's rises and falls in vertical direction .

Roadway width (RW) which is the total width of lanes and shoulders .

Rise plus fall differantial (G) which is the difference of GRF and RF .

The relationships are those :

Site preparation :

ACG = 1770 EXP(0.0278 GRF)+1610 EXP(-0.0114 GRF) RW

Where ACG = the average area of site clearing and grubbing per unit length of road in M**2 / KM .

R**2 = 0.51 number of observation = 35

Earthwork volume :

EWV = 1000 (RW + 0.731 H) H

H = 1.41 + 0.129 G + 0.0139 GRF

G = GRF - RF

Where RF = road rise plus fall (M / KM)

R**2 = 0.55 number of observation = 123

Pipe culverts :

ALPC = 2.57 EXP (-0.0031 GRF) RW**0.895

Where ALPC =the average length of regular pipe culverts in meters.

$$DRL = \begin{cases} 1.97\ ALPC & \text{if } 0 < GRF < 10 \text{ (flat)} \\ 1.74\ ALPC & \text{if } 10 < GRF < 40 \text{ (rolling)} \\ 2.02\ ALPC & \text{if } 40 < GRF < 100 \text{ (mountainous)} \end{cases}$$

Where DRL = the aggregate length of regular pipe culverts per unit length of road in M / KM .

Box culverts :

$$ANBC = \begin{cases} 0.27 & \text{if } 0 < GRF < 10 \\ 0.15 & \text{if } 10 < GRF < 40 \\ 0.62 & \text{if } 40 < GRF \end{cases}$$

Where ANBC = the average number of regular box culverts per unit length of road in culverts per kilometer .

Bridges :

$$AB = \begin{cases} 4.35\ RW & \text{if } 0 < GRF < 10 \\ 2.09\ RW & \text{if } 10 < GRF < 40 \\ 1.83\ RW & \text{if } 40 < GRF \end{cases}$$

Where AB = the average floor area of bridges per unit length of road in M**2 / KM .

Trying to generalize these kinds of predictions due to the lasting variations in the variables is exactly difficult . Aw and Markow tried to success these . But , it can easily be thought that to find required amount of data to be able to do these is hard especially for all these countries that they dealt with . So the precision degree may be refered as enough for the equation developed by using the provided data . However , it is not a realistic idea to expect a sensitivity as much as the one for these equations for all countries seperately.

In order to examine deviations of these relationships , if they are used for observed data of Turkey , altough they have restrictions(1),the result as observed , predicted quantities and percent deviations for earthwork and drainage which are shown in appendix C1 and C2 seems unreasonable for at least these examples that have approximately equal size of data used by Aw and Markow for all 28 countries .

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(1)restrictions of World Bank equations in the variables:

Variable	Units	Recommended range
Roadway width (RW)	M	5 - 25
Road rise plus fall (RF)	M/KM	0 - 75
Ground rise plus fall (GRF)	M/KM	0 - 100
Rise plus fall differential (G)	M/KM	0 - 50

CHAPTER 3.

ROAD CONSTRUCTION COSTS

AASHO has been classified the road construction costs as follows:

I. Preliminary Engineering

1. field engineering
2. aerial surveys
3. material investigation
4. test borings
5. traffic and speed studies on specific projects
6. consultant engineering
7. preparation of plans , specifications and estimate
8. other costs

II. Right-of-Way

1. purchase of land and easements
2. purchase of improvements
3. salaries and expenses of appraisers
4. fees of construct appraisers
5. salaries and expenses of rigth-of-way agents
6. moving of improvements

7. damages

8. legal title insurance , court cost , recording fees

9. economic studies

10. other costs

III. Construction Engineering

1. field engineering and inspection

2. office engineering

3. consultant engineering

4. material testing and inspection

5. preparation of the program and final estimates and reports

6. other costs

IV. Construction - roads and roadway surfacing

A. roadway earthwork and grading

1. clearing and grubbing

2. excavation

3. overhaul , borrow , bank sloping and finishing

4. right-of-way fences (digging , postholes , trenches , etc.)

5. moving building and structures - demolitian

6. subbase materials

7. wetting , rolling and compacting

8. detours and traffic services during construction

9. other costs

B. roadway drainage and related protective structures (culverts etc.)

1. structural excavation and backfill

2. metal culvert pipe

3. concrete culvert pipe

4. vitrified clay pipe

5. concrete work

6. reinforcing steel

7. structural steel

8. removal of superseded structures

9. storm sewers

10. cribbing

11. riprap

12. subdrains

13. curbs and gutters

14. other cost

C. Roadway base and surface

1. crusshed rock surfacing

2. bituminous treatment

3. bituminious road-mix

4. bituminious plant-mix

5. asphalt concrete

6. portland cement concrete

7. overhaul

8. wetting , rolling and compacting

9. other costs

D. Roadside development

1. removal and replacing top soil

2. initial seeding , sodding and planting

3. other costs

E. Miscellanecus construction

V. Construction - components major structures forming integral parts of the roadways system

A. Structure excavation

B. Foundations

1. forms

2. concrete work

3. others

C. Basic structures and super structures

1. concrete work

2. structural steel

3. reinforcing steel

4. others

D. Finishing , inspecting and testing

E. Building and installing traffic service facilities .

But these costs may be simplified as in Table 3.1 and , in general they may be broken down into eight components , right-of-way , site preparation , earthwork , pavement , drainage , bridge , other costs and overhead . Except for other costs and overhead , these components may further diaggregate into physical quantities and unit costs . For example , earthwork cost can be obtained as a unit volume - earthwork volume per unit road length - and the cost per unit volume .

TABLE 3.1

Construction costs

	COMPONENT COSTS	QUANTITIES	UNIT COSTS in
TOTAL COSTS	Right-of-Way cost (/ KM)	Area (M**2/KM)	(TL/KM)
	Site preparation cost (/KM)	Area (M**2/KM)	(TL/KM)
	Earthwork cost (/KM)	Volume (M**3/KM)	(TL/KM)
	Pavement cost (/KM)	Volume (M**3/KM)	(TL/KM)
	Drainage cost (/KM)	Pipe culvert length (M/KM)	(TL/KM)
		Box culvert length (M/KM)	(TL/KM)
	Bridge cost (/KM)	Floor area (M**2/KM)	(TL/KM)
	Other cost (/KM)	---	(TL/KM)
	Overhead cost (% or /KM)	---	(TL/KM)

CHAPTER 4

THE APPROACH TO THE MODEL

The approach may be explained in stepwise manner as below ;

1. The problem is to predict total cost or component cost of the highway project(s) . As described in Chapter 3. , construction costs are , Right-of-Way , Site preparation , Earthwork , Pavement , Drainage , Bridge , Other costs and Overhead cost . Earthwork , pavement , drainage and bridge costs are major and can be predicted as sensitive to geometric standards and terrain conditions . Right-of-way cost is constant and can be estimated easily according to the right-of-way width along the roadway and unit price .

2. To predict these component costs , variables which affect the cost quantities must be known . It is clear that the major factors in highway are geometric standard and terrain severity . However , since they are very complex factors , there is a need to simplify them. Here , road rise plus fall (RF) which is the sum of vertical rises and falls in road absolutely along the

roadway (M/KM) and roadway width (RW) which is the total width of lanes and shoulders , for geometric standard , ground rise plus fall (GRF) which is the same as RF but ground's vertical rises and falls are used instead road's , for terrain severity , have been used and by this way , an advantage has been gained - for example GRF prevents to fall in hesitation on defining the terrain type (sometimes it is not possible to distinguish the terrain as flat , rolling or mountainous when it is like flat as opposed to rolling , or rolling as opposed to mountainous .

3. Data which must include the variables above and quantities to be predicted with these variables have been collected . In earthwork analysis , there have been 119 projects or their parts from Turkish Highway Department's all regions excluding 1. , 13. , 14. and 16. regions . In drainage , 115 different data has been provided for box culverts and 65 ones for pipe culverts - and also meteorological map for precipitation in hand. In pavement , method itself have been come to the picture to determine layer thicknesses instead regression with data . And in bridge analysis , all bridge inventory have been supplied .

4. The last is the regression analysis (1) with the data collected and the selection of the best

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(1) In regression analysis , Minitab package program has been used to get results and its outputs are given in Appendix.B

relationships (2) .

In earthwork and drainage parts it gave successfull results but in bridges , it did not due to the lack of definite data to get a relation with the variables so ,instead a prediction relationship , avarage values provided from bridge inventory have been offered .

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(2) Selection of the best relationship was done according to the rules of Statistics that are to concern the correlation coefficient of equation and coefficients , and t-statistic with confidence interval by observing the physical meanings of the variables .

CHAPTER 5.

DETERMINING COMPONENT COST QUANTITIES AND THEIR UNIT PRICES

5.1. Earthwork cost

5.1.1. General

Earthwork cost which was defined in Chapter 3. - Road Construction costs - has been taken , here , as the portion of materials to convert the original ground feature from its natural condition or configuration to prescribed sections and grades . Among the major cost components , earthwork is the one which is the most sensitive to geometric standards and terrain conditions.

Data used in prediction regression analysis of earthwork is shown in appendix A. as a base of regions in Turkish Highway Department , roadway (RW) as meter , ground rise plus fall (GRF) as M/KM , road rise plus fall (RF) as M/KM , Cut and Fill volumes as a M**3/KM . As seen in appendix A., there is available data of a lot of regions (almost all regions) to develop generalized relationships . But it was not easy to get them . For example , when GRF and RF were used together in the same equation , it was not possible to provide a good result (e.g. positive coefficient of RF) , but when using GRF*RF as a variable ,it gave more successfull results . However to define this variable physically is difficult. Instead of these two variables , one variable - G - which is called as relative rise plus fall or rise plus fall differential .

$$G = GRF - RF \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5.1$$

has been used .

Before the explanation of the regression equations, it is necessary to look at the relationships between the quantities , cut , fill , and total earthwork volumes and variables GRF,RF,G ;

The relations to control the equation coefficients and their physical effects on volumes , between quantities and the variables must be clear in minds .

GRF shows the terrain severity such as according to accumulated data

when	GRF <=20	flat terrain (1)
20 <	GRF <=70	rolling terrain
70 <	GRF	mountainous terrain

It is obvious that the earthwork volume on rolling terrain is greater than the one on flat terrain and smaller than the one on mountainous terrain .

---

(1) these limits look like the same as the limits in

AUSTRALIAN (Victoria) Road Design Manual Chapter 6. pp. 6-13 January 1982 .

17% <		very steep
7.5%<	<17	steep
2% <	<7.5	gently sloping
0.5%<	<2%	flat
0.1%<	<0.5	very flat

these percentages are of ground slopes given for drainage. and the values are in hundreds rather than in thousands like in GRF.

RF shows the geometric standard of the road increase in RF means reaching the ground's slope (but it can never be greater than GRF) . So reacning the ground's slope will bring less earthwork ,as an amount, directly in the point of RF view .The class of the road can be adjusted according to RF by using the standards of maximum longitudinal slope and minimum vertical curve length such as :

for class I.	RF<=40	flat terrain
	RF<=60	rolling terrain
	RF<=70	mountainous terrain
for class II.	RF<=50	flat
	RF<=60	rolling
	RF<=80	mountainous
for class III.	RF<=60	flat
	RF<=80	rolling
	RF<=90	mountainous

G is also like GRF . Because of its definition when the difference between ground and road slopes increases, earthwork volume increases also .

So , when GRF and G increase , earthwork volumes increase too . But they decrease in increase of RF .

The figures E1 , E2 and E3 shows the plots , unit cut volumes versus GRF , RF and G respectively . Unit cut volume which is proportion of cut volume per KM to the roadway width (RW) was used both to eliminate the

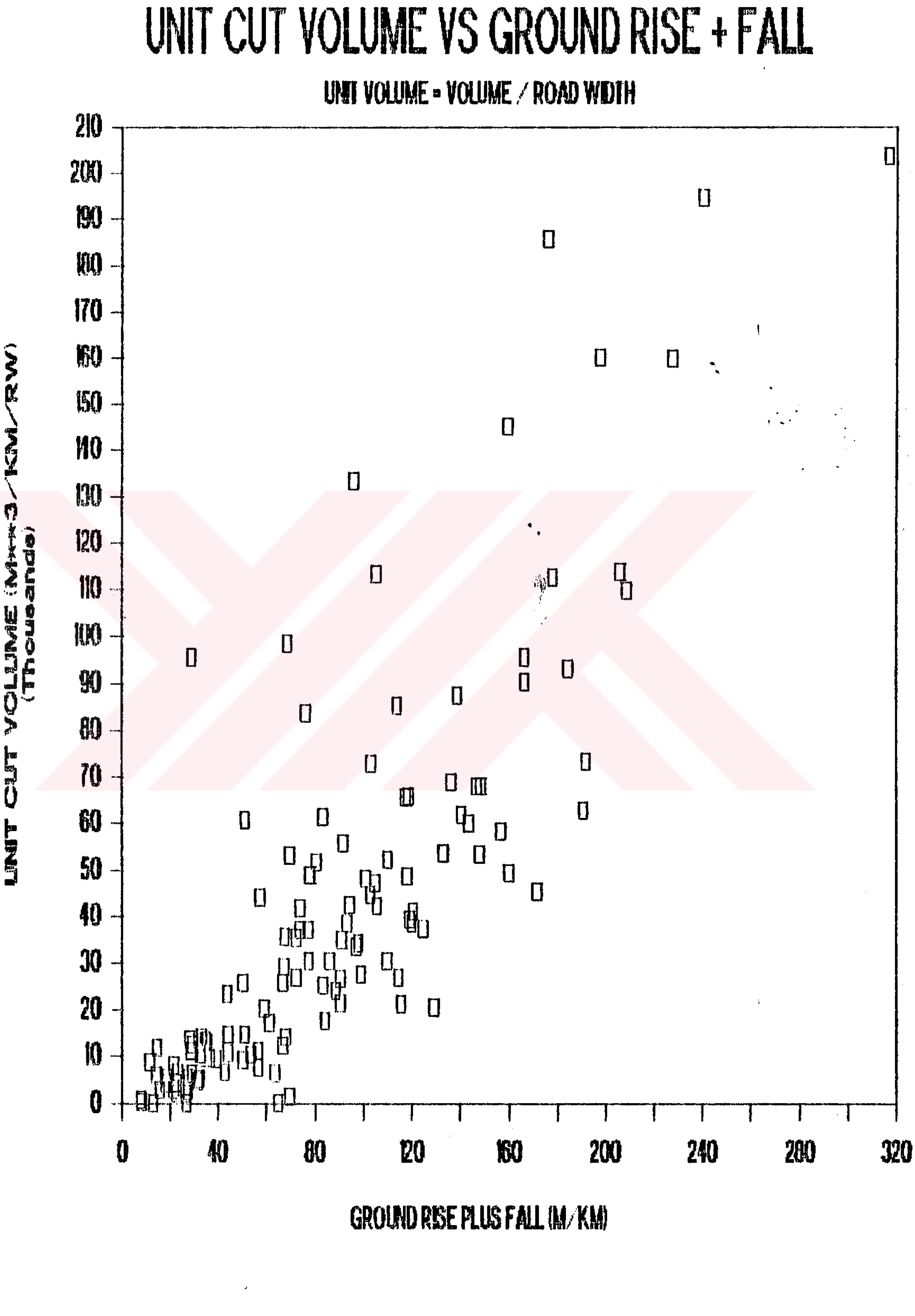
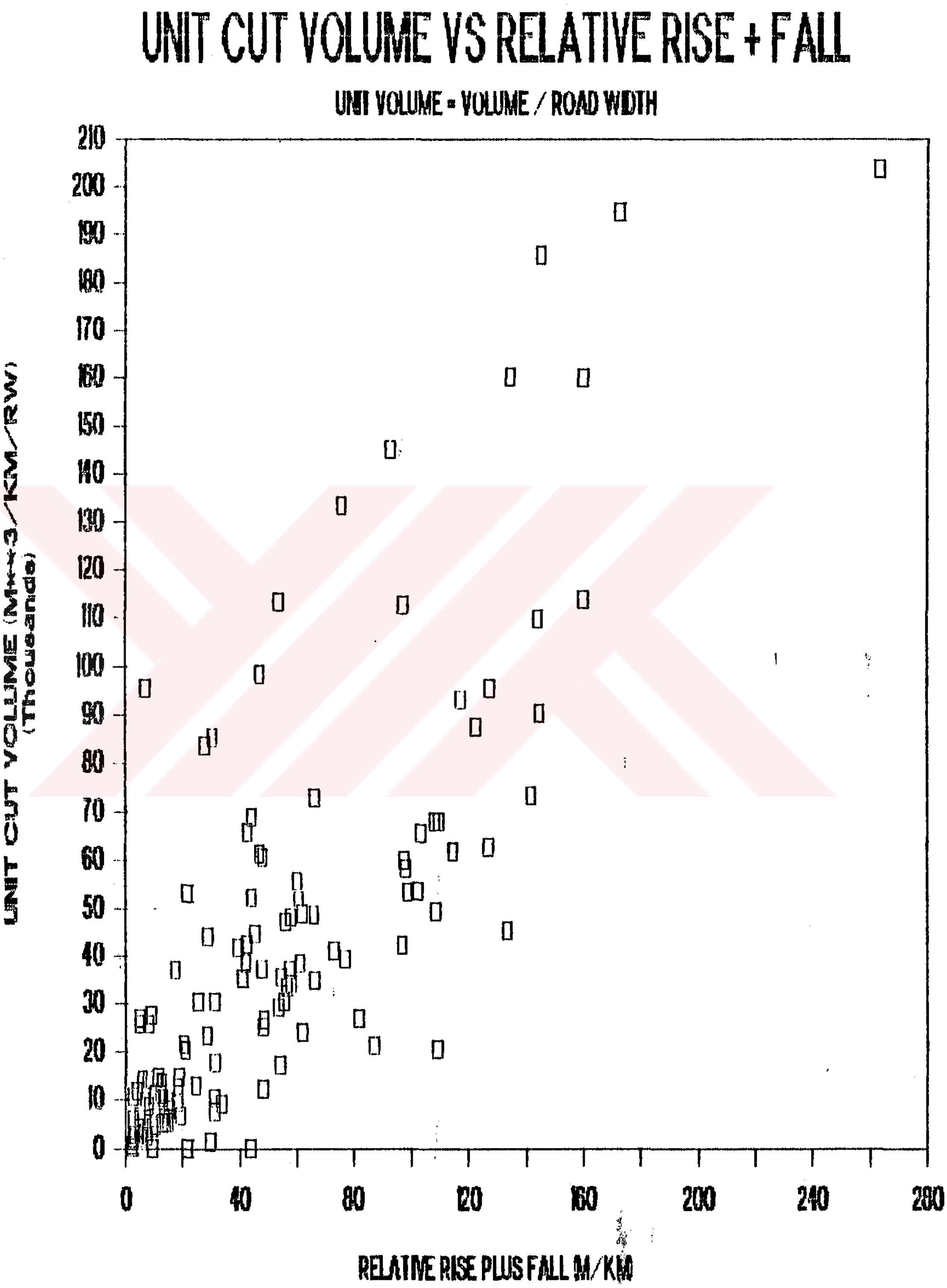

UNIT CUT VOLUME VS GROUND RISE + FALL
UNIT VOLUME = VOLUME / ROAD WIDTH
UNIT CUT VOLUME (M**3/KM/RW)
(Thousands)
GROUND RISE PLUS FALL (M/KM)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
0
40
80
120
160
200
240
280
320

FIGURE E.1

UNIT CUT VOLUME VS ROAD RISE + FALL
UNIT VOLUME = VOLUME / ROAD WIDTH
UNIT CUT VOLUME (M**3/KM/RW)
(Thousands)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
0
20
40
60
80
100
ROAD RISE PLUS FALL (M/KM)

FIGURE E.2



UNIT CUT VOLUME VS RELATIVE RISE + FALL
UNIT VOLUME = VOLUME / ROAD WIDTH
UNIT CUT VOLUME (M**3/KM/RW)
(Thousands)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
0
40
80
120
160
200
240
280
RELATIVE RISE PLUS FALL M/KM

FIGURE E.3

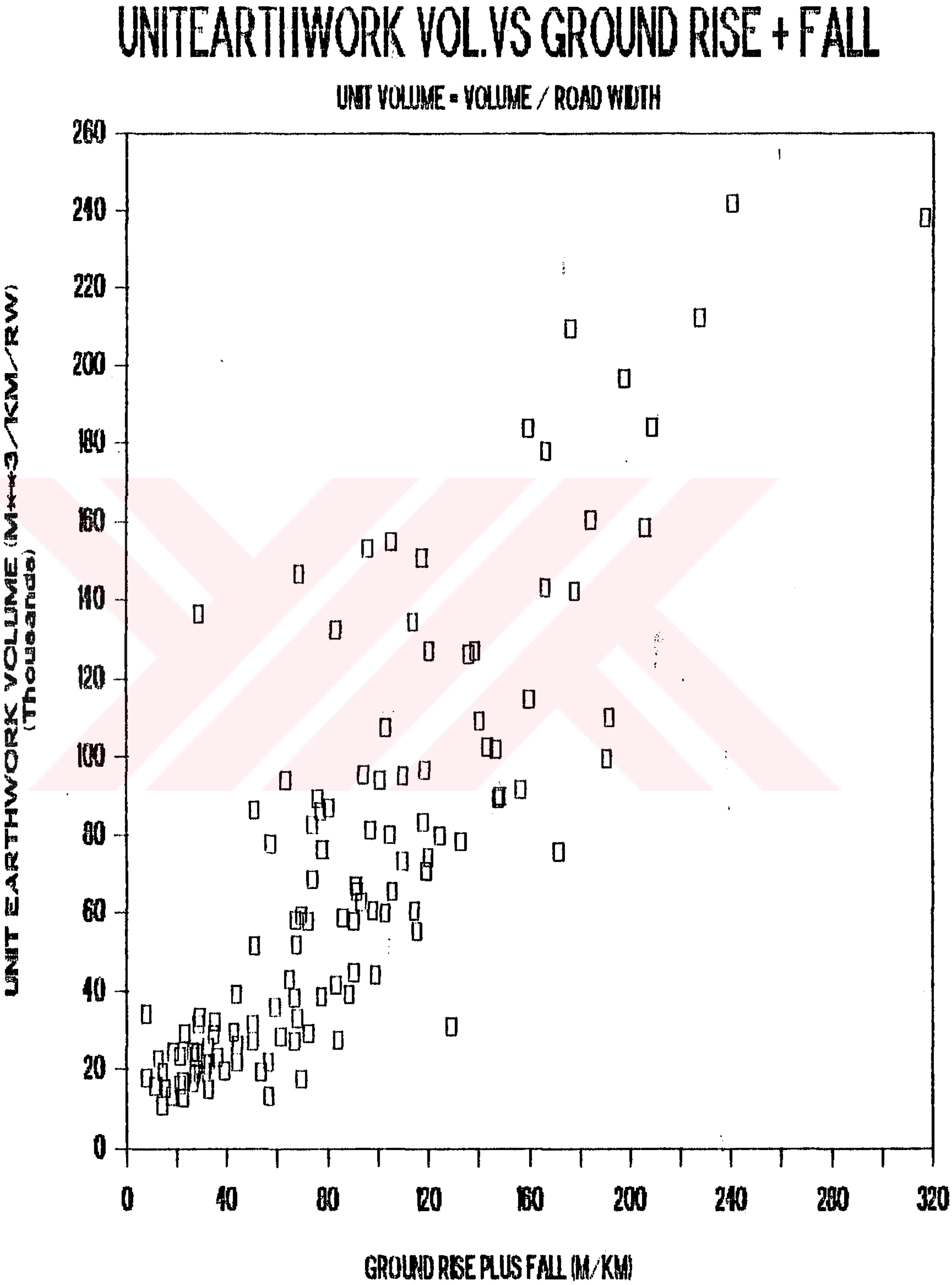
other important variable roadway width which is constant along the roadway and to see the relations talked about above , clearly .

It can be understood from the figures concerned , G and GRF have same relation between unit cut volume but RF does not . For this reason RF can not give an additional advantage to the prediction equation , but it is a variable representing geometric standards of the roads . It must be in the equation . By the way , instead of GRF and RF , G is used only , because prediction equation will have some error due to autocorrelation between GRF and G (because G is directly proportional to GRF) if both GRF and G are used in the same equation .

Unit total earthwork versus GRF , RF and G plots are on the figures E4 , E5 and E6 respectively . The general toughts above are also present here such as ; for elimination of the variable roadway width , unit total earthwork which is the total earthwork volume (fill plus cut) per KM per roadway width is used to observe the relations and to decide the use of only G in the equations -of course other than the roadway width - is the same .

5.1.2 Equations developed for earthwork

G and RW can be used as variables in the equations



UNITEARTHWORK VOL.VS GROUND RISE + FALL
UNIT VOLUME = VOLUME / ROAD WIDTH
UNIT EARTHWORK VOLUME (M**3/KM/RW)
(Thousands)
GROUND RISE PLUS FALL (M/KM)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
320

FIGURE E.4

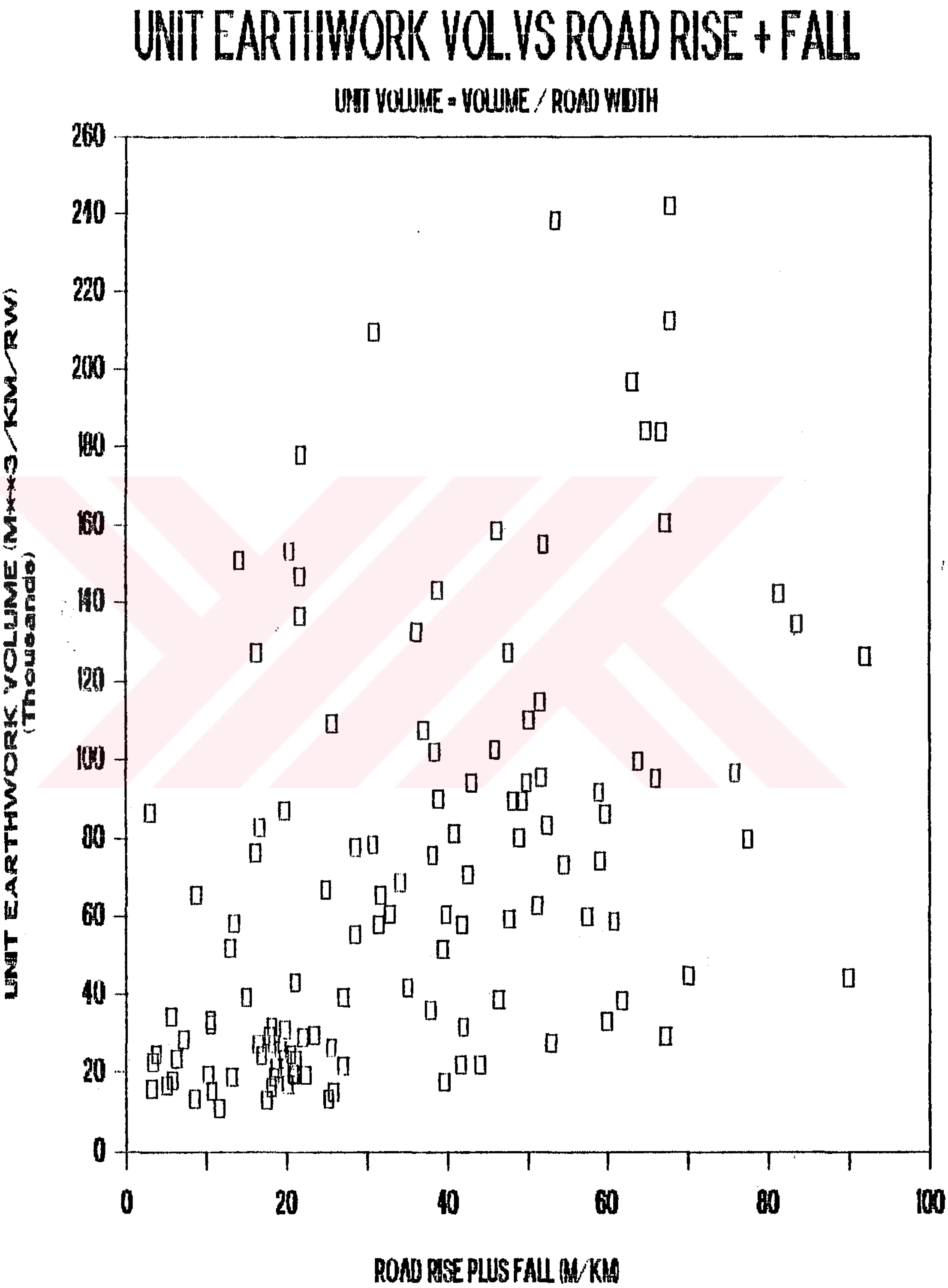

UNIT EARTHWORK VOL.VS ROAD RISE + FALL
UNIT VOLUME = VOLUME / ROAD WIDTH
UNIT EARTHWORK VOLUME (M**3/KM/RW)
(Thousands)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
ROAD RISE PLUS FALL (M/KM)

FIGURE E.5

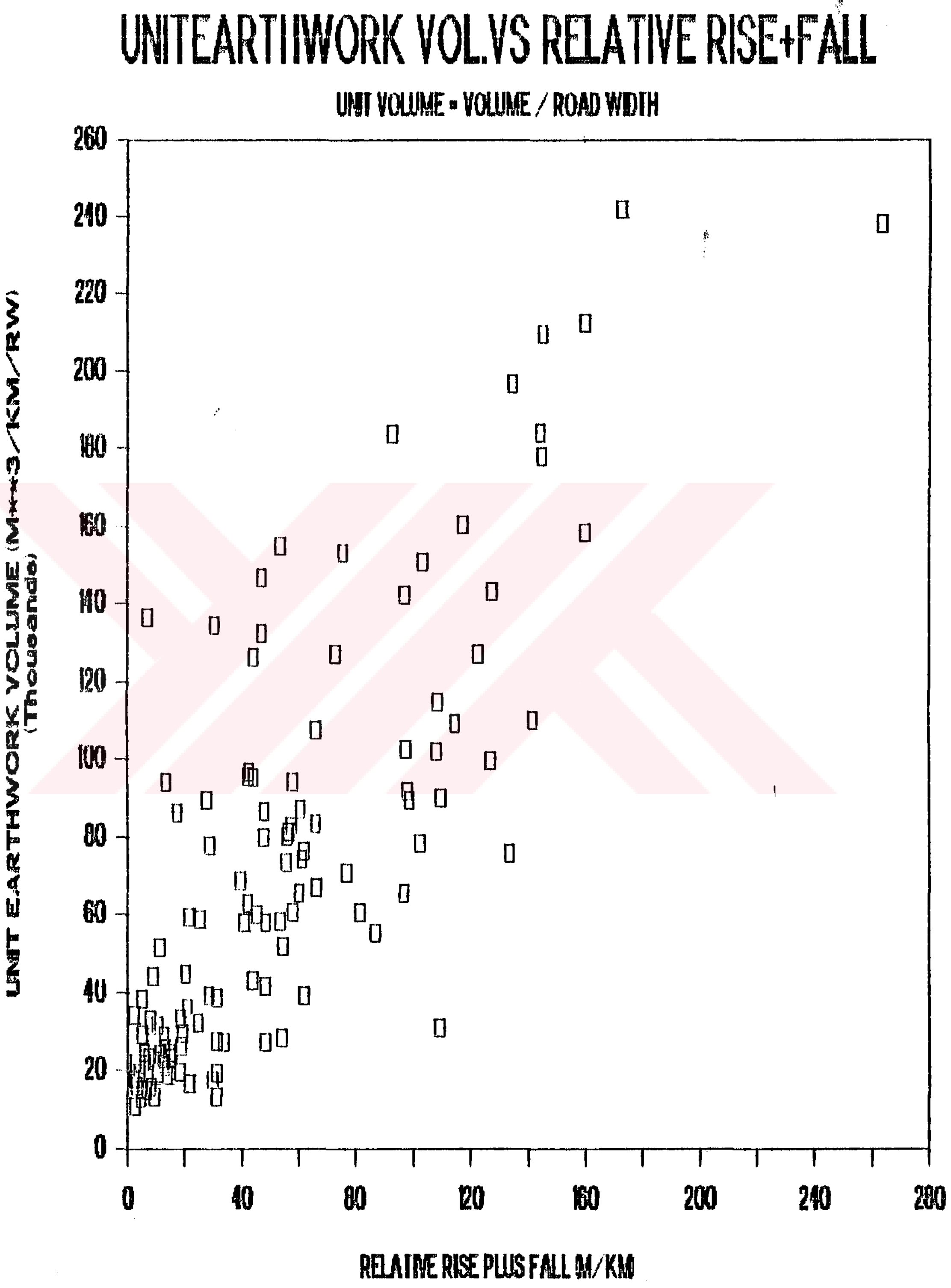

UNITEARTIIWORK VOL.VS RELATIVE RISE+FALL
UNIT VOLUME = VOLUME / ROAD WIDTH
UNIT EARTHWORK VOLUME (M**3/KM/RW)
(Thousands)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
40
80
120
160
200
240
280
RELATIVE RISE PLUS FALL M/KM

FIGURE E.6

in two ways ; first, seperately and second as multiplication . The relationships provided with these two ways have the same precision degree approximately but both are given below for total earthwork and cut volume .

5.1.2.1 Total earthwork volume

The equations developed for total earthwork volume in M**3/KM are below ;

TOTEV = 21274 + 96.2*G*RW 5.2

TOTEV = -20790 + 953*G + 4219*RW 5.3

Where TOTEV = total earthwork volume (cut plus fill volume) per KM (M**3/KM)

G = relative rise plus fall (M/KM)

G = GRF - RF

GRF = ground rise plus fall (M/KM)

RF = road rise plus fall (M/KM)

RW = roadway width which is the total width of lanes and two shoulders (M)

The variable G*RW can be explained as relative rise plus fall area which is the area that earthwork volume is estimated on (image that two triangular prisms whose two dimensions are the same ,first of them ,height is equal to RW and the second is length of the roadway . The third dimension is GRF*L and RF*L for the large and small prisms respectively . Since this is a method dealing with the quantities -i.e. all computations cover a 1 KM of roadway - L which is the length of roadway can be taken as a unity . The quantity to be estimated or predicted for the earthwork is an amount that the volume which is the difference between the prisms can be found out by the use of GRF-RF (i.e. G) because of the equality of the other dimensions , RW and 1 instead of L) . Because the rises and the falls on the line in longitudinal direction of road or ground , are assumed as equal along the cross section or roadway width . this is because the longitudinal profile (ground and grade lines) is prepared for center line of the road and the variables are calculated according to the central line of the road .

The goodness of fit of the predicted total earthwork volume (TOTEV) by using the equation 5.2 versus observed total earthwork volume and the equality line which shows 100% correlation are shown in Fig.E.7 . And the correlation coefficient (R**2) of predicted versus observed total earthwork volume is 91% for all data . For the second TOTEV equation (equation 5.3) the observed and predicted TOTEV is on the Fig. E.8 and shows 96% correlation for the same data . These two equations satisfy all conditions defined above,it can be said that equation 5.3 is being seen more satisfactory by comparing the correlation coefficient . However , a

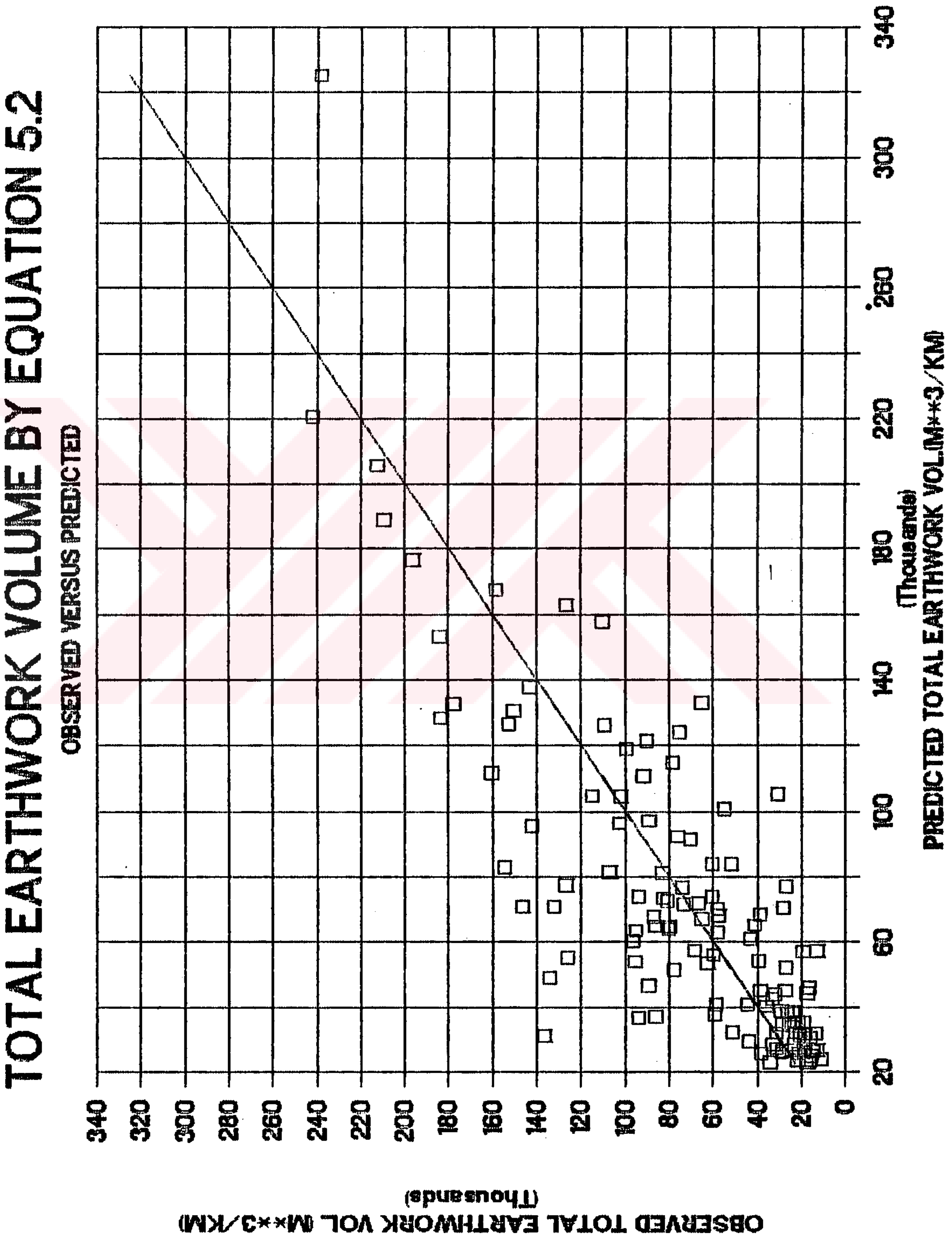

TOTAL EARTHWORK VOLUME BY EQUATION 5.2
OBSERVED VERSUS PREDICTED
PREDICTED TOTAL EARTHWORK VOL.(M**3/KM)
(Thousands)
OBSERVED TOTAL EARTHWORK VOL (M**3/KM)
(Thousands)
20 60 100 140 180 220 260 300 340
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340

FIGURE E.7

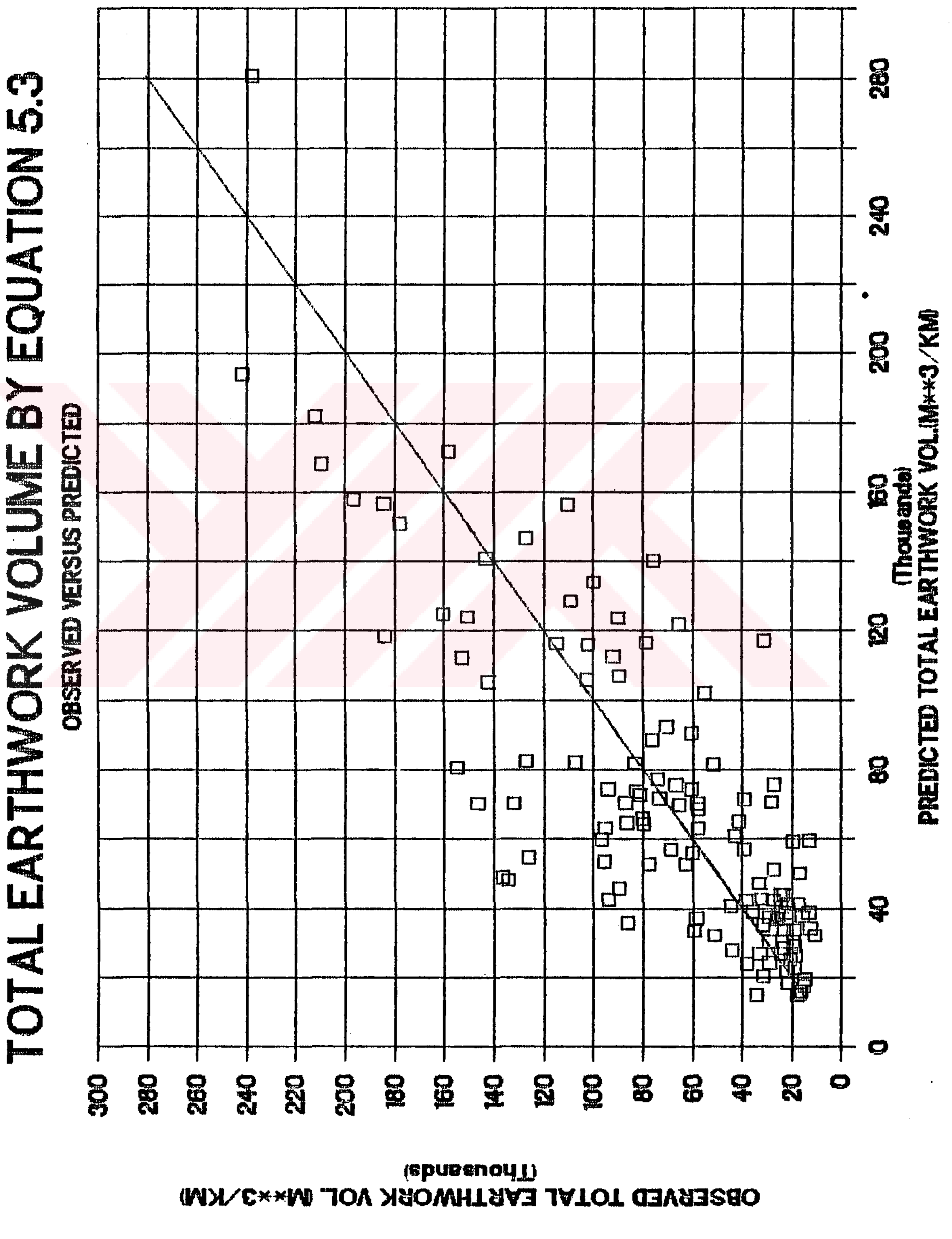

TOTAL EARTHWORK VOLUME BY EQUATION 5.3
OBSERVED VERSUS PREDICTED
PREDICTED TOTAL EARTHWORK VOL.(M**3/KM)
(Thousands)
OBSERVED TOTAL EARTHWORK VOL (M**3/KM)
(Thousands)
0
40
80
120
160
200
240
280
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

FIGURE E.8

result must be a value taken out after treating the two equaitons adequately . The effects of G and RW on TOTEW are also shown in Figures E.9 , E.10 , E.11 and E.12 . As one for equation 5.2 and one for equation 5.3 alternately .

5.1.2.2 Cut volume

Cut volume relationships are ;

CUTVOL = 3576 + 75*G*RW 5.4

CUTVOL = -42363 + 718*G + 4770* RW 5.5

Where CUTVOL = cut volume per KM (M**3/KM)
the other variables and the general approaches to select variables are as defined in 5.1.2.1 .

Predicted cut volume by using equation 5.4 and equation 5.5 versus observed cut volumes are plotted in the Figures E.13 and E.14 respectively . The correlation coefficients of equation 5.4 and equation 5.5 with the observed ones are 91% and 97% respectively .

However , one thing to be considered in equation 5.5 is that it gives unreasonable value when G is smaller than 5.85 (M/KM) if RW is taken as minimum value as 8 M .

The sensitivity of the predicted cut volume to the relative rise plus fall -representing terrain severity and geometric standard of road such a way that as known (G = GRF - RF) G shows the terrain severity if RF is

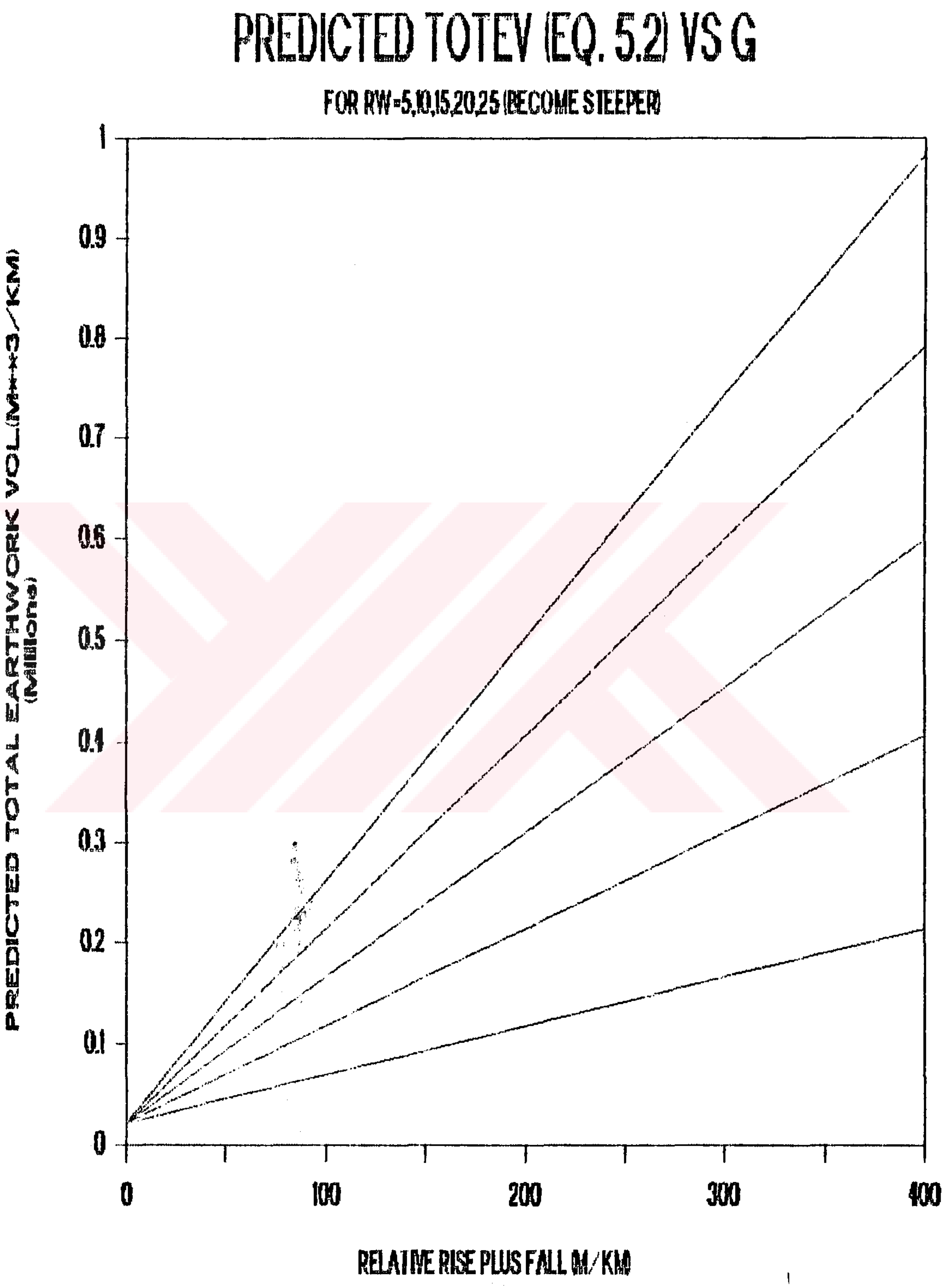
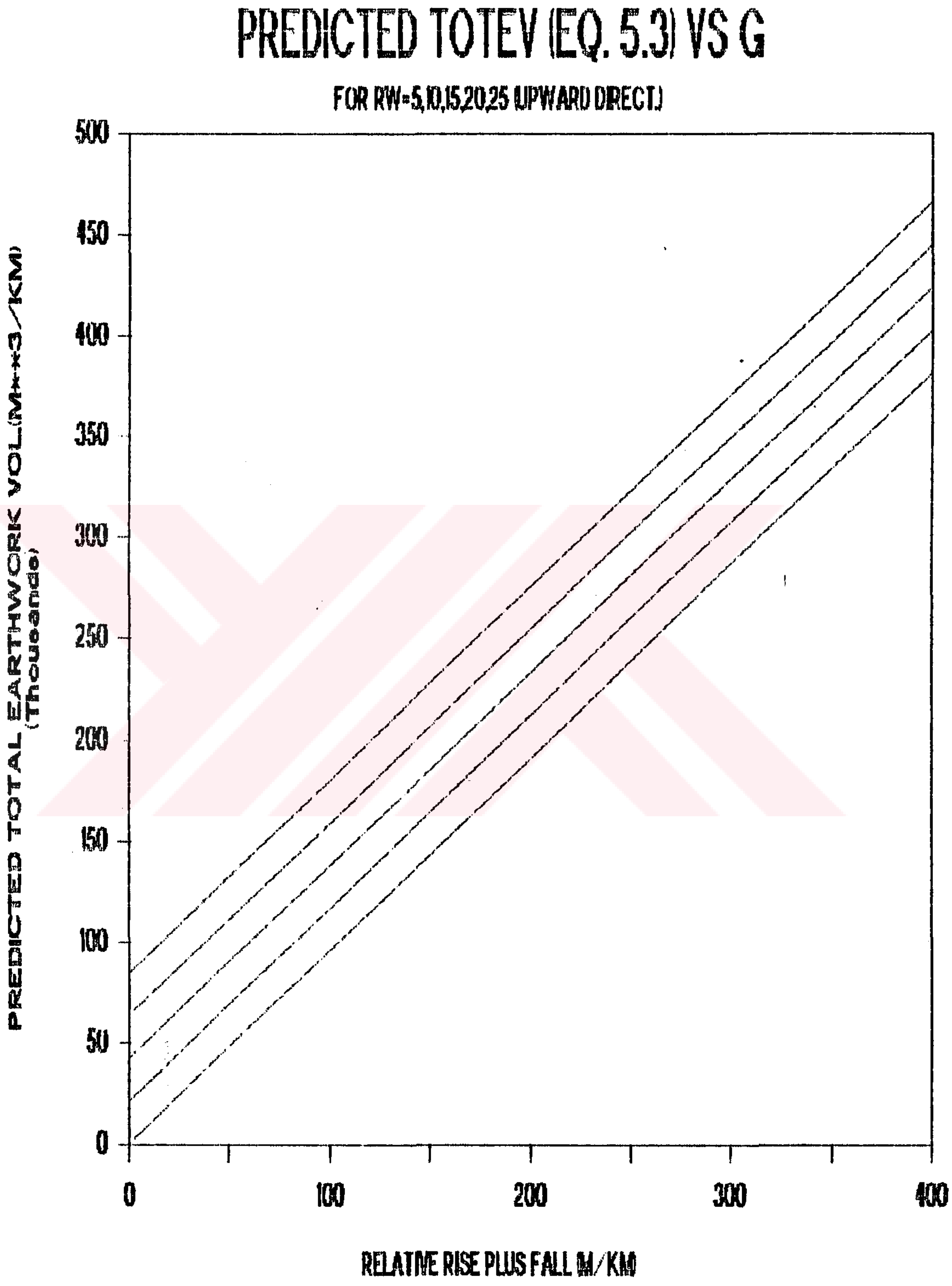

PREDICTED TOTEV (EQ. 5.2) VS G
FOR RW=5,10,15,20,25 (BECOME STEEPER)
PREDICTED TOTAL EARTHWORK VOL(M**3/KM)
(Millions)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
RELATIVE RISE PLUS FALL (M/KM)

FIGURE E.9



PREDICTED TOTEV (EQ. 5.3) VS G
FOR RW=5,10,15,20,25 (UPWARD DIRECT.)
PREDICTED TOTAL EARTHWORK VOL.(M**3/KM)
(Thousands)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
RELATIVE RISE PLUS FALL M/KM

FIGURE E.10

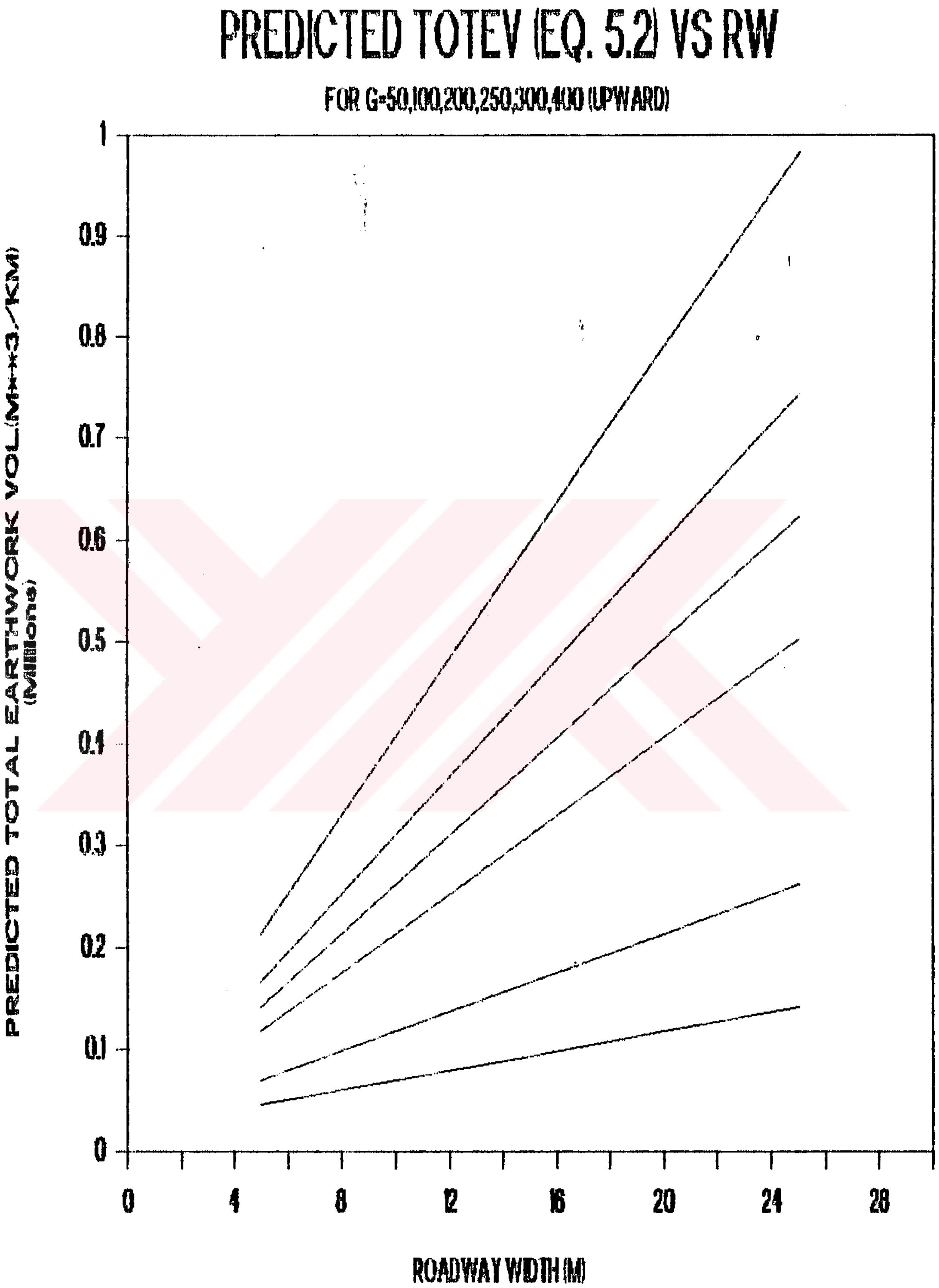
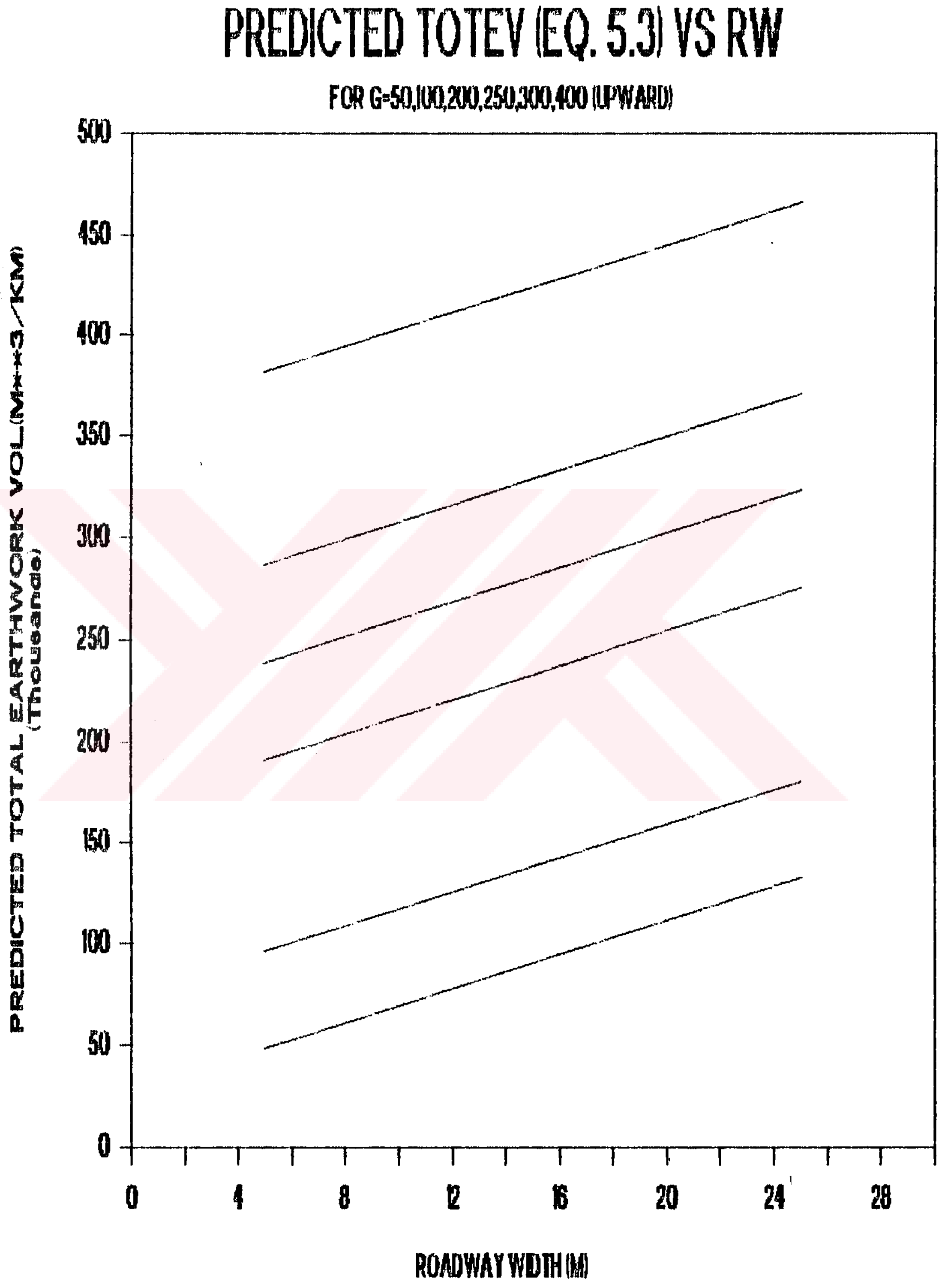

PREDICTED TOTEV (EQ. 5.2) VS RW
FOR G=50,100,200,250,300,400 (UPWARD)
PREDICTED TOTAL EARTHWORK VOL.(M**3./KM)
(Millions)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
4
8
12
16
20
24
28
ROADWAY WIDTH (M)

FIGURE E.11



PREDICTED TOTEV (EQ. 5.3) VS RW
FOR G=50,100,200,250,300,400 (UPWARD)
PREDICTED TOTAL EARTHWORK VOL.(M**3/KM)
(Thousands)
500
450
400
350
300
250
200
150
100
50
0
0
4
8
12
16
20
24
28
ROADWAY WIDTH (M)

FIGURE E.12

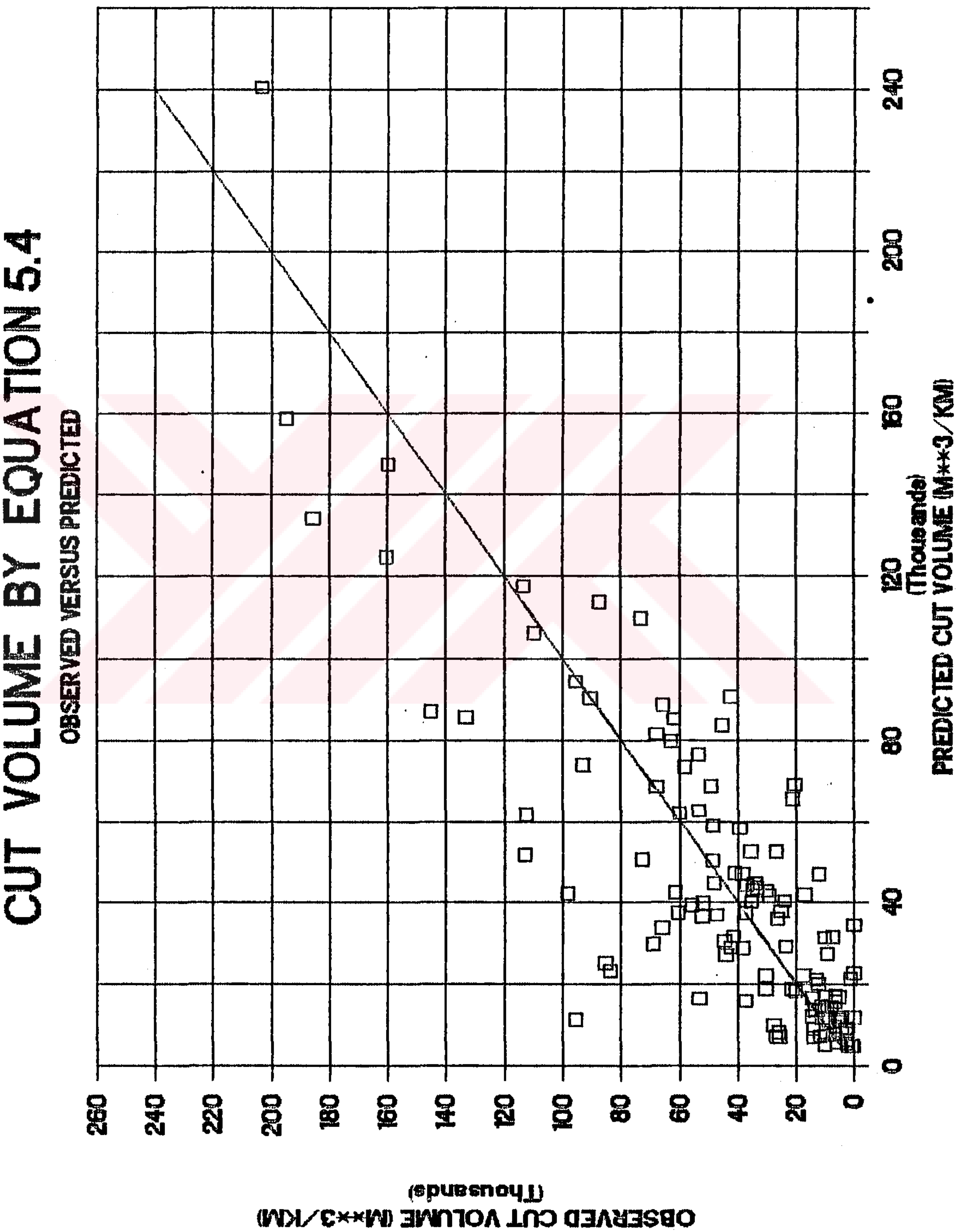

CUT VOLUME BY EQUATION 5.4
OBSERVED VERSUS PREDICTED
OBSERVED CUT VOLUME (M**3/KM)
(Thousands)
PREDICTED CUT VOLUME (M**3/KM)
(Thousands)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
0
40
80
120
160
200
240

FIGURE E.13

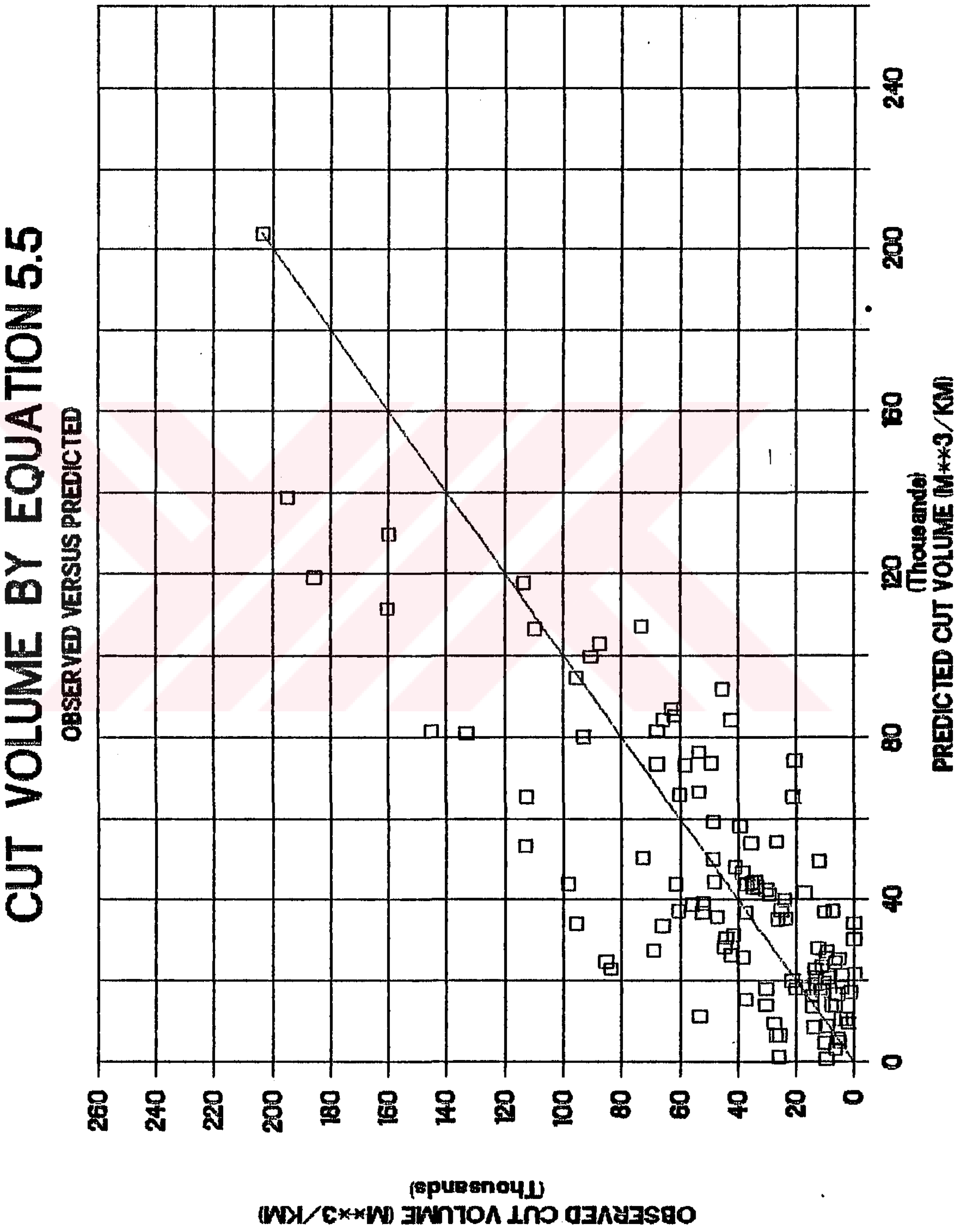

CUT VOLUME BY EQUATION 5.5
OBSERVED VERSUS PREDICTED
PREDICTED CUT VOLUME (M**3/KM)
(Thousands)
OBSERVED CUT VOLUME (M**3/KM)
(Thousands)
0
40
80
120
160
200
240
0
20
40
60
80
100
120
140
160
180
200
220
240
260

FIGURE E.14

constant (i.e. terrain from flat to mountainous when GRF being greater) or geometric standard if GRF is constant (i.e. from Class I.to Class III. when RF being greater)- is shown in Figures E.15 , E.16 , E.17 , E18 for the equations 5.4 and 5.5 alternately .

5.1.2.3 Fill volume

No relationship could be developed but by means of uses equations for total earthwork and cut volume , to get an idea about fill volume is simple and useful since total earthwork equals to sum of cut and fill volumes absolutely .

5.1.3 Unit price

Unit price of earthwork is published by Turkish Highway Department for year in the basis of region . But one unit price can not be useful because of different unit prices in the regions so for earthwork unit price , it is convenient to use unit price of related region . Here , unit prices ,estimated for contractor, which are belong to the regions according to 1986 are listed below :

Region of TCK	Unit price (TL/M**3)
1.	1085.
2.	964.
3.	964.
4.	1059.
5.	1296.
6.	466.

PREDICTED CUT VOL. (EQ. 5.4) VS G

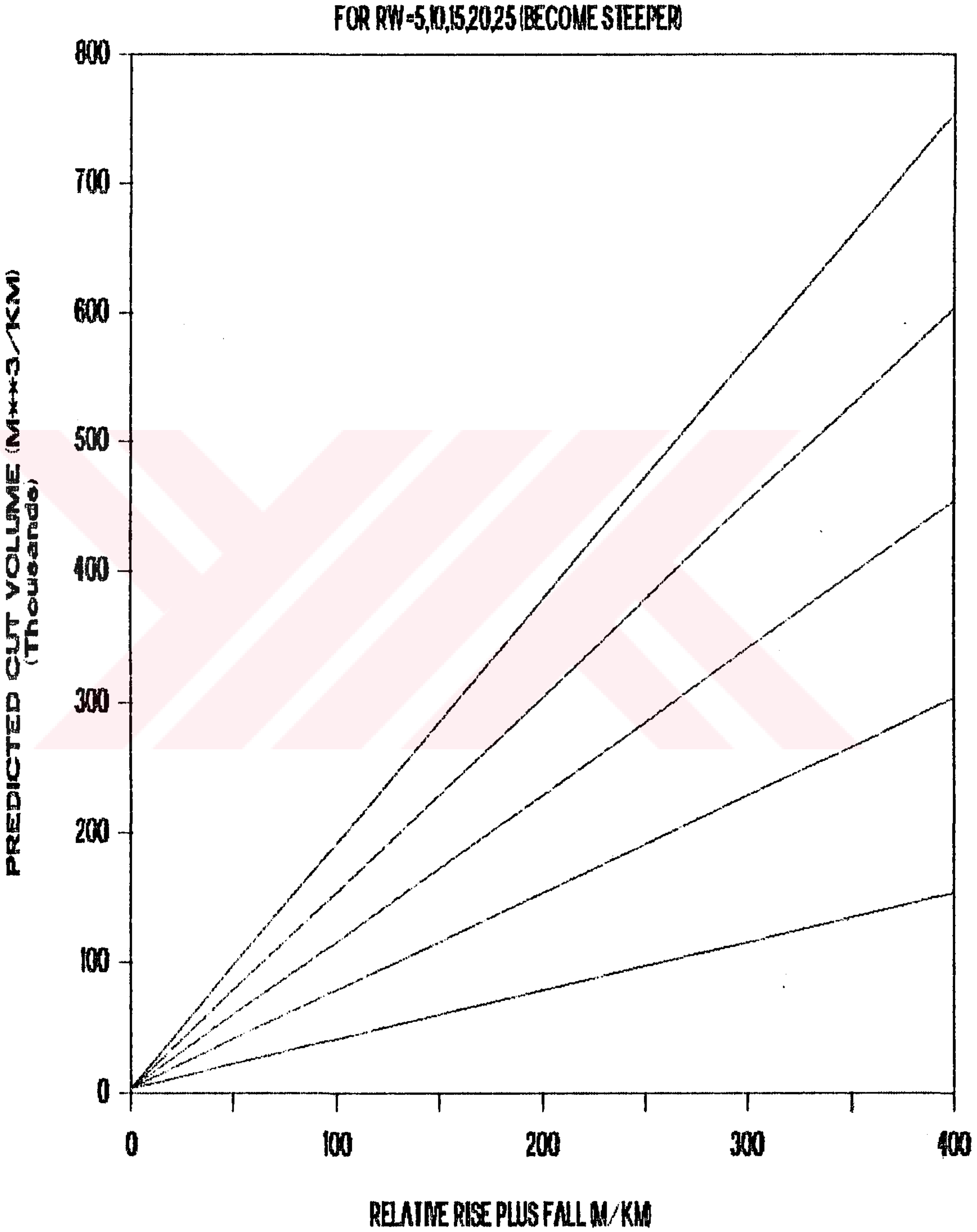
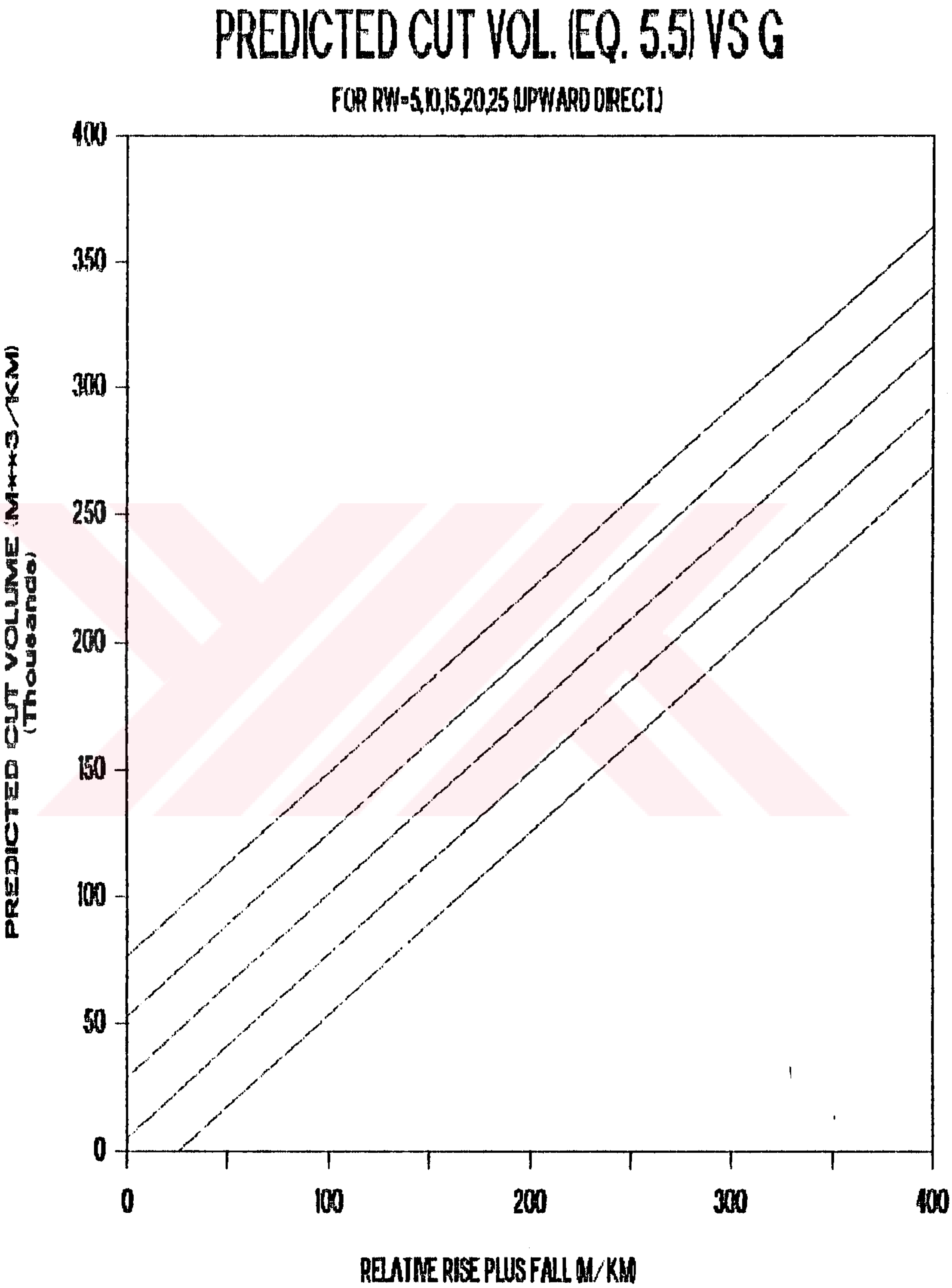


FIGURE E.15



PREDICTED CUT VOL. (EQ. 5.5) VS G
FOR RW=5,10,15,20,25 (UPWARD DIRECT.)
PREDICTED CUT VOLUME (M**3/KM)
(Thousands)
400
350
300
250
200
150
100
50
0
0
100
200
300
400
RELATIVE RISE PLUS FALL (M/KM)

FIGURE E.16

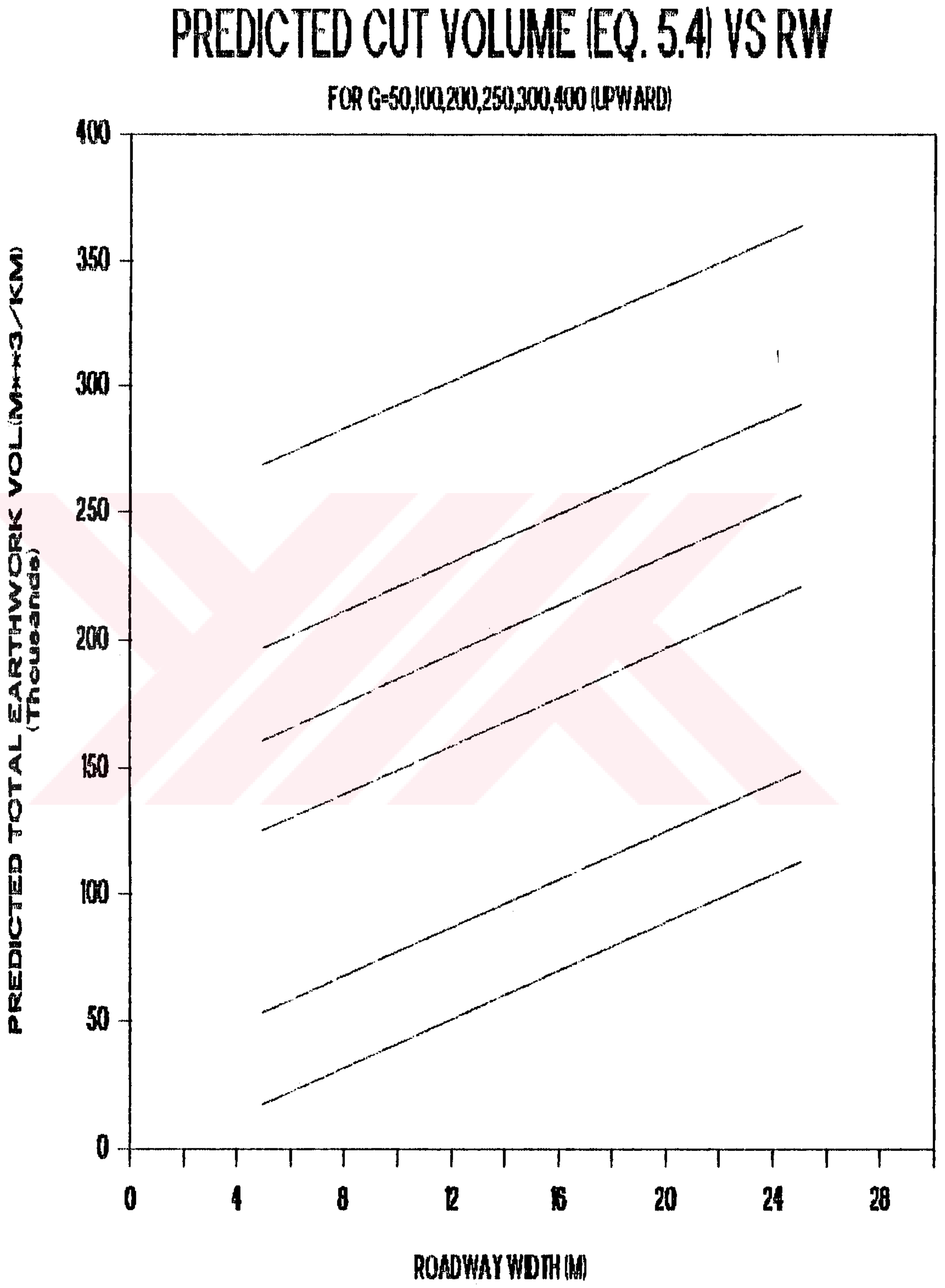

PREDICTED CUT VOLUME (EQ. 5.4) VS RW
FOR G=50,100,200,250,300,400 (UPWARD)
PREDICTED TOTAL EARTHWORK VOL.(M**3/KM)
(Thousands)
400
350
300
250
200
150
100
50
0
0
4
8
12
16
20
24
28
ROADWAY WIDTH (M)

FIGURE E.17

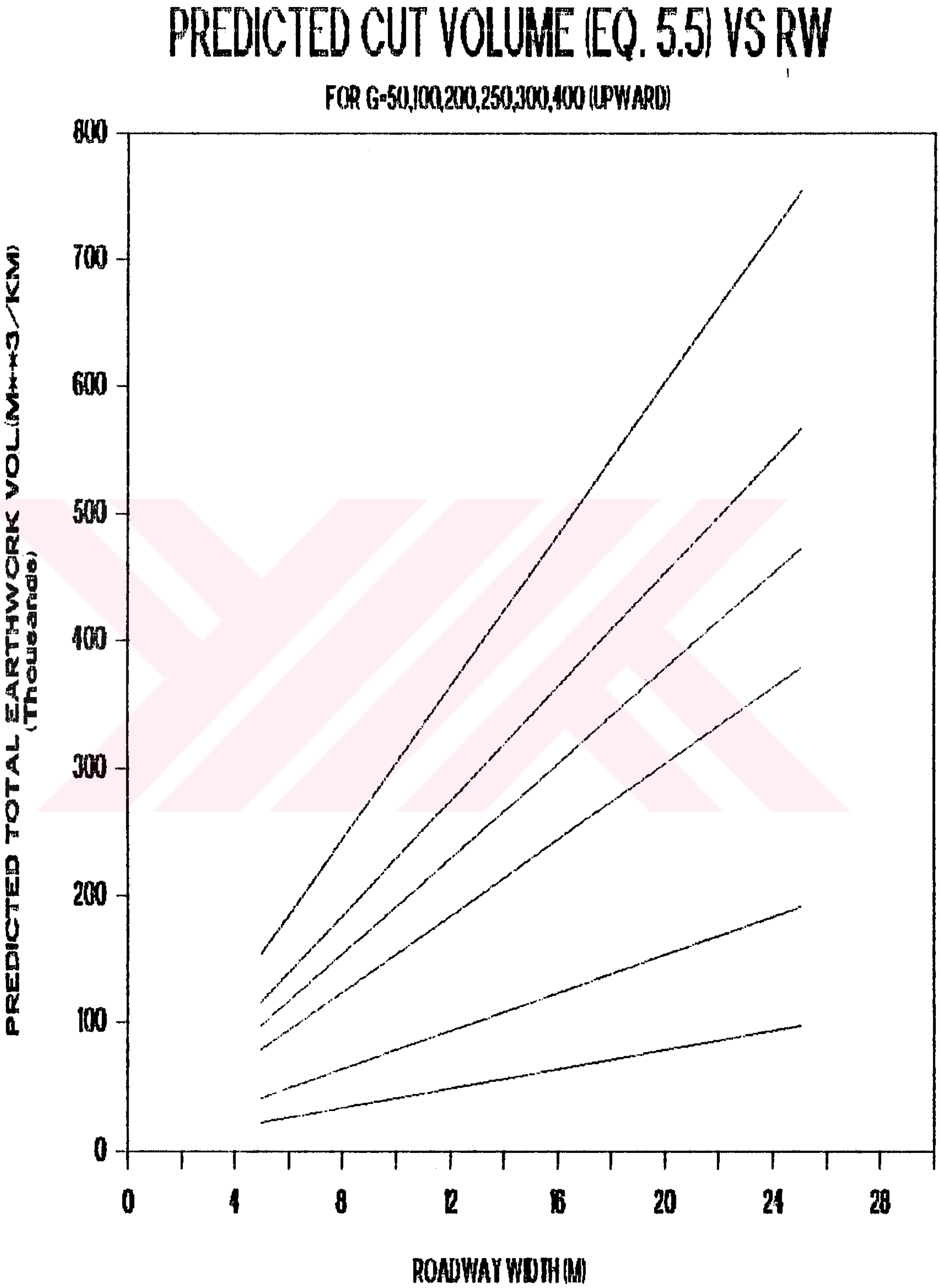

PREDICTED CUT VOLUME (EQ. 5.5) VS RW
FOR G=50,100,200,250,300,400 (UPWARD)
PREDICTED TOTAL EARTHWORK VOL(M**3/KM)
(Thousands)
0
100
200
300
400
500
600
700
800
0
4
8
12
16
20
24
28
ROADWAY WIDTH (M)

FIGURE E.18

Region	Unit price (TL/M**3)
7.	770.
8.	739.
9.	1215.
10.	1717.
11.	1000.
12.	585.
13.	2305.
14.	898.
15.	1052.
16.	483.

5.2 Pavement cost

5.2.1 General

Pavement cost includes the costs of the subbase , base ,and the surface which are directly proportional to the thicknesses . For this reason , to estimate the cost of pavement only depends on to find out the thicknesses of the pavement layers .

Turkish Highway Department (TCK) accepts the AASHO flexible pavement design method (see 5.2.2) to calculate thicknesses .

Instead to develop a prediction equation for pavements , it was prefered to use method itself because the variables that must be needed for prediction to be done , are almost same as in the method . This requirement directed the study to this way - to calculate the thicknesses exactly by means of the method rather than by means of a prediction equation with some error .

5.2.2 Tabulation of AASHO method for design

The design procedure has been developed by the American Association of State Highway Officials , and first published an Interim Design Guide in 1961 and then a revised edition in 1972 . AASHO also published most recent edition in 1986 (see appendix.D) since TCK uses the former one , here the version in 1972 of the formulae was used .

Serviceability defined as the ability of a pavement to serve the trraffic for which it was designed , is the first concept of the method . Performance is the ability of a pavement to satisfactorily serve the traffic over a period of time .

AASHO equations are ;

$$LOG(T8.2) = 9.36LOG(SN+1) - 0.20 + \frac{Gt}{\left(0.40 + \frac{1094}{(SN+1)^{5.19}}\right)} + LOG\left(\frac{1}{R}\right) + 0.372(Si - 3.0)$$

$$Gt = LOG\left(\frac{4.2 - Pt}{4.2 - 1.5}\right)$$

Where T8.2 = total number of 8.2 tons single-axle load repetitions up to terminal serviceability level (Pt)

SN = structural number of a pavement

SN = a1*D1 + a2*D2 + a3*D3
Di = respective layer thicknesses
ai = coefficient of the layers

Pt = serviceability factor

R = regional factor

Si = soil support value

Gt = a function (a logarithm) of the ratio of loss in serviceability at time t to the potential loss taken to a point where Pt=1.5 .

A relation between Si and CBR (california Bearing Ratio) can be provided by using the graph of AASHO method , like as

Si = 1.168850936 + 3.837911319 LOG(CBR)

From these equations , SN value can be found out without using charts but with the help of an iteration . Table 5.1 have been prepared by computerizing the half method in iteration . Table 5.1 contains the SN values -in cantimeter- calculated corresponds to average region factor (R=1) and serviceability factor (Pt=2.5).

5.2.3 An approach for practical use

The " a " coefficients of the layers are these ;

Wearing course = 0.42 - 0.44

Binder course = 0.40 - 0.42

Bituminous base = 0.32 - 0.34

Plant-mix base = 0.15

Subbase = 0.11

TABLE 5.1

*************STRUCTURAL NUMBER (SN) TABLE*************

REGIONAL FACTOR= 1 SERVICEABILITY FACTOR= 2.5

* EWL * *10^6 *	CALIFORNIA BEARING RATIO (CBR) VALUES					
* *	3	5	10	15	20	25
* 2 *	11.15	9.97	8.51	7.71	7.19	6.85
* 5 *	12.75	11.5	9.83	9	8.37	7.96
* 10 *	14.07	12.68	11.01	10.04	9.42	8.93
* 15 *	14.9	13.44	11.71	10.67	10.04	9.55
* 20 *	15.46	14	12.19	11.15	10.46	9.97
* 25 *	15.88	14.42	12.54	11.57	10.87	10.32
* 30 *	16.29	14.76	12.89	11.85	11.15	10.6
* 35 *	16.57	15.11	13.17	12.12	11.43	10.87
* 40 *	16.85	15.32	13.44	12.4	11.64	11.08
* 45 *	17.13	15.6	13.65	12.61	11.85	11.29
* 50 *	17.4	15.81	13.86	12.82	12.06	11.5
* 55 *	17.54	16.01	14.07	12.96	12.19	11.64
* 60 *	17.82	16.15	14.21	13.1	12.4	11.78
* 65 *	17.96	16.36	14.35	13.24	12.54	11.99
* 70 *	18.1	16.57	14.49	13.37	12.68	12.06
* 75 *	18.31	16.71	14.62	13.51	12.75	12.19
* 80 *	18.44	16.85	14.76	13.65	12.89	12.33
* 85 *	18.58	16.99	14.9	13.79	12.96	12.4
* 90 *	18.72	17.06	15.04	13.86	13.1	12.54
* 95 *	18.79	17.19	15.11	14	13.24	12.61
* 100 *	18.93	17.26	15.18	14.07	13.31	12.68

TABLE 5.1 (CONTINUED)

* 105 *	19.07	17.4	15.32	14.21	13.37	12.82
* 110 *	19.21	17.54	15.39	14.28	13.51	12.89
* 115 *	19.28	17.61	15.46	14.35	13.58	12.96
* 120 *	19.35	17.68	15.6	14.42	13.65	13.03
* 125 *	19.49	17.82	15.67	14.49	13.72	13.1
* 130 *	19.63	17.89	15.74	14.62	13.79	13.24
* 135 *	19.63	17.96	15.88	14.62	13.86	13.24
* 140 *	19.76	18.1	15.88	14.76	13.93	13.37
* 145 *	19.9	18.1	16.01	14.76	14	13.37
* 150 *	19.9	18.24	16.01	14.9	14.07	13.44

NOTE : INTERPOLATION CAN BE DONE FOR THE VALUES OUT OF THE TABLE

TABLE 5.1 (CONTINUED)

*************STRUCTURAL NUMBER (SN) TABLE*************

REGIONAL FACTOR= 1 SERVICEABILITY FACTOR= 2.5

* EWL * *10^6 *	CALIFORNIA BEARING RATIO (CBR) VALUES					
* *	30	35	40	45	50	55
* 2 *	6.57	6.29	6.12	5.94	5.8	5.67
* 5 *	7.61	7.33	7.12	6.92	6.78	6.6
* 10 *	8.55	8.24	7.96	7.75	7.58	7.4
* 15 *	9.140001	8.79	8.51	8.3	8.100001	7.92
* 20 *	9.55	9.21	8.93	8.72	8.51	8.3
* 25 *	9.899999	9.55	9.28	9	8.79	8.62
* 30 *	10.18	9.83	9.55	9.28	9.07	8.859999
* 35 *	10.46	10.11	9.83	9.55	9.28	9.140001
* 40 *	10.67	10.32	10.04	9.76	9.49	9.28
* 45 *	10.87	10.53	10.18	9.899999	9.689999	9.49
* 50 *	11.01	10.67	10.39	10.11	9.83	9.62
* 55 *	11.22	10.87	10.53	10.25	10.04	9.76
* 60 *	11.36	11.01	10.67	10.39	10.18	9.899999
* 65 *	11.5	11.15	10.8	10.53	10.25	10.04
* 70 *	11.64	11.22	10.94	10.67	10.39	10.18
* 75 *	11.71	11.36	11.01	10.74	10.53	10.32
* 80 *	11.85	11.5	11.15	10.87	10.6	10.39
* 85 *	11.99	11.57	11.22	10.94	10.74	10.46
* 90 *	12.06	11.71	11.36	11.08	10.8	10.6
* 95 *	12.12	11.78	11.43	11.15	10.87	10.67
* 100 *	12.26	11.85	11.5	11.22	11.01	10.74

TABLE 5.1 (CONTINUED)

* 105 *	12.33	11.92	11.64	11.29	11.08	10.87
* 110 *	12.4	11.99	11.71	11.43	11.15	10.94
* 115 *	12.47	12.12	11.78	11.5	11.22	11.01
* 120 *	12.54	12.19	11.85	11.57	11.29	11.08
* 125 *	12.68	12.26	11.92	11.64	11.36	11.15
* 130 *	12.68	12.33	11.99	11.71	11.43	11.22
* 135 *	12.82	12.4	12.06	11.78	11.5	11.29
* 140 *	12.82	12.47	12.12	11.85	11.57	11.29
* 145 *	12.96	12.54	12.19	11.85	11.64	11.36
* 150 *	12.96	12.54	12.26	11.92	11.71	11.43

NOTE : INTERPOLATION CAN BE DONE FOR THE VALUES OUT OF THE TABLE

TABLE 5.1 (CONTINUED)

*************STRUCTURAL NUMBER (SN) TABLE*************

REGIONAL FACTOR= 1 SERVICEABILITY FACTOR= 2.5

* EWL * *10^6 *	CALIFORNIA BEARING RATIO (CBR) VALUES					
* *	60	65	70	75	80	85
* 2 *	5.56	5.46	5.35	5.25	5.18	5.11
* 5 *	6.46	6.36	6.22	6.15	6.05	5.94
* 10 *	7.26	7.12	6.99	6.88	6.78	6.67
* 15 *	7.75	7.61	7.47	7.37	7.26	7.12
* 20 *	8.17	7.96	7.82	7.75	7.61	7.47
* 25 *	8.439999	8.3	8.17	8.03	7.89	7.75
* 30 *	8.72	8.51	8.37	8.24	8.13	8.03
* 35 *	8.93	8.79	8.58	8.439999	8.34	8.24
* 40 *	9.140001	8.93	8.79	8.649999	8.51	8.41
* 45 *	9.28	9.140001	9	8.83	8.72	8.58
* 50 *	9.49	9.28	9.140001	9	8.859999	8.72
* 55 *	9.62	9.42	9.28	9.140001	9	8.859999
* 60 *	9.76	9.55	9.42	9.28	9.140001	9
* 65 *	9.83	9.689999	9.55	9.350001	9.21	9.100001
* 70 *	9.97	9.83	9.62	9.49	9.350001	9.21
* 75 *	10.11	9.899999	9.76	9.62	9.42	9.350001
* 80 *	10.18	10.04	9.83	9.689999	9.55	9.42
* 85 *	10.32	10.11	9.899999	9.76	9.62	9.49
* 90 *	10.39	10.18	10.04	9.899999	9.76	9.62
* 95 *	10.46	10.32	10.11	9.97	9.83	9.689999
* 100 *	10.53	10.39	10.18	10.04	9.899999	9.76

TABLE 5.1 (CONTINUED)

* 105 *	10.6	10.46	10.25	10.11	9.97	9.83
* 110 *	10.74	10.53	10.32	10.18	10.04	9.899999
* 115 *	10.8	10.6	10.46	10.25	10.11	9.97
* 120 *	10.87	10.67	10.46	10.32	10.18	10.04
* 125 *	10.94	10.74	10.6	10.39	10.25	10.11
* 130 *	11.01	10.8	10.6	10.46	10.32	10.18
* 135 *	11.08	10.87	10.67	10.53	10.39	10.25
* 140 *	11.15	10.94	10.74	10.6	10.46	10.32
* 145 *	11.15	11.01	10.8	10.67	10.46	10.32
* 150 *	11.22	11.01	10.87	10.67	10.53	10.39

NOTE : INTERPOLATION CAN BE DONE FOR THE VALUES OUT OF THE TABLE

TABLE 5.1 (CONTINUED)

*************STRUCTURAL NUMBER (SN) TABLE*************

REGIONAL FACTOR= 1   SERVICEABILITY FACTOR= 2.5

* EWL * *10^6 *	CALIFORNIA BEARING RATIO (CBR) VALUES					
* *	90	92	94	96	98	100
* 2 *	5.04	5.01	4.97	4.97	4.94	4.9
* 5 *	5.87	5.84	5.8	5.8	5.73	5.73
* 10 *	6.57	6.57	6.5	6.5	6.46	6.43
* 15 *	7.05	7.02	6.99	6.95	6.92	6.88
* 20 *	7.4	7.33	7.33	7.26	7.26	7.19
* 25 *	7.68	7.61	7.61	7.54	7.54	7.47
* 30 *	7.89	7.89	7.82	7.82	7.75	7.71
* 35 *	8.100001	8.100001	8.03	7.99	7.96	7.89
* 40 *	8.3	8.24	8.24	8.17	8.13	8.100001
* 45 *	8.439999	8.439999	8.37	8.3	8.3	8.24
* 50 *	8.58	8.58	8.51	8.439999	8.439999	8.37
* 55 *	8.72	8.72	8.649999	8.58	8.58	8.51
* 60 *	8.859999	8.79	8.79	8.72	8.72	8.649999
* 65 *	9	8.93	8.859999	8.859999	8.79	8.79
* 70 *	9.07	9.07	9	8.93	8.93	8.859999
* 75 *	9.21	9.140001	9.07	9.07	9	9
* 80 *	9.28	9.28	9.21	9.140001	9.140001	9.07
* 85 *	9.42	9.350001	9.28	9.28	9.21	9.140001
* 90 *	9.49	9.42	9.350001	9.350001	9.28	9.24
* 95 *	9.55	9.49	9.49	9.42	9.350001	9.350001
* 100 *	9.62	9.55	9.55	9.49	9.42	9.42

TABLE 5.1 (CONTINUED)

* 105 *	9.689999	9.62	9.62	9.55	9.49	9.49
* 110 *	9.76	9.76	9.689999	9.62	9.62	9.55
* 115 *	9.83	9.83	9.76	9.689999	9.62	9.62
* 120 *	9.899999	9.899999	9.83	9.76	9.689999	9.689999
* 125 *	9.97	9.899999	9.899999	9.83	9.76	9.76
* 130 *	10.04	9.97	9.97	9.899999	9.83	9.83
* 135 *	10.11	10.04	9.97	9.97	9.899999	9.83
* 140 *	10.18	10.11	10.04	10.04	9.97	9.899999
* 145 *	10.25	10.18	10.11	10.04	10.04	9.97
* 150 *	10.25	10.25	10.18	10.11	10.04	10.04

NOTE : INTERPOLATION CAN BE DONE FOR THE VALUES OUT OF THE TABLE

Minimum values of coefficients are advised by TCK . For practical uses , values for thicknesses of wearing , binder , and bituminous base courses used in practice are in Table 5.2 .

Table 5.2
Practical thicknesses for pavement layers .

EQUIVALENT WHEEL LOAD CUMULATIVE (MILLIONS)	WEARING COURSE THICKNESS (CM)	BINDER COURSE THICKNESS (CM)	BITUMINOUS BASE THICKNESS (CM)
80 - 150	4	8	14
50 - 80	5	7	10
25 - 50	4	6	10
8 - 25	4	6	8
3 - 8	5	8	--
< 3	4	6	--

The thicknesses with respect to the wheel loads in the table were taken from actual designs of pavements because of their repetitive thicknesses in the many applied projects .

The SN values in Table 5.1 shows the total pavement thichness including the coefficients , so the subbase or/and plant-mix thickness can be found out by subtracting the values with their related coefficient from SN and dividing the coefficient of the layer interested .

5.2.4 Unit price

These unit prices of 1987 and 1988 are estimated as

TL/M**2/KM for the practical estimation of costs for every RW and every thickness . The unit (TL/M**2/KM) has been prefered because - altough alignment length of the road is tought as a unit length (1KM)- roadway width and thicknesses of the layers change according to the variables (load and soil support value especially) if the same materials will have been used . For this reason these two dimensions are being given as meter is the reason of M**2 . For example 5 CM of binder and 8 M of roadway width has the binder cost of (0.05*8*71.564 millions) TL.

LAYER	UNIT PRICE (TL/M**2/KM)
WEARING course	71.564 millions
BINDER course	67.991 millions
BITUMINOUS treated b.	55.890 millions
PLANT-MIX base	33.709 millions
SUBBASE	4.445 millions

(These unit costs are taken from Reference 9.)

5.3 Drainage cost

5.3.1 General

Major components of drainage costs are pipe and box culverts . The prediction relationships have been developed for regular pipe culverts which have 0.80 M diameter for regular box culverts that are in 1*1 dimensions as meter . The reason of the selection of this dimensions is the mostly used dimension and the need to be able to consider pipe and box culverts with a comparable value approximately without interesting more detail dimensions .

5.3.2 Prediction equations

When developing the prediction equations , GRF , RW and precipitation measures in the roadway zone have been taken as a major variables .

To get a relationship precisely as much as in earthwork would not be possible with these variables that are chosen due to simplicity to provide and being the same variables in the former parts , but the relationships given below can gain a tought about the quntities interested to predict cost .

5.3.2.1 Pipe culverts

The relationship below predicts the aggregate length of pipe culverts in 0.80 m dimension , per unit road length .

$$LN(PCL) = 1.102 + 0.8736*LN(RW) + 0.0065*LN(GRF)*LN(PRE/100)$$

Where PCL = pipe culvert which has 0.80 M diameter , total length along the road length (M / KM)

RW = roadway width (M)

GRF = groud rise plus fall (M / KM)

PRE = amount of precipitation in the roadway zone in an average of the year (MM).

As seen in the equation RW , GRF and PRE affect the pipe culverts length positively . This is physically true because , when RW increases , PCL must increase directly due to hardness to drain the water especially comes from the roadsides , on the road . PCL is almost directly proportional to PRE (increase in PRE shows the amount to drain . For GRF causes to increase in PCL for the reason that since the slope is getting steeper to accumulate the drain water is being quicker , to prevent the accumulation of water on the road there is a need to drainage elements in such number which is sometimes greater than the required number or dimension . Since PCL is the hypotenious length if it is thought as a triangle , so greater slope brings greater lenght of PCL.

5.3.2.2 Box culverts

The variables are the same as in pipe culverts . But here , they are used with another form . the resuls are ;

LN(BCL) = -1.25+2.6485*LN(GRF)*(1.63+0.535*LN(PRE/100)
+LN(RW)*(1.63-0.535*LN(PRE/100)

Where BCL = aggregate box culvert length (which is in 1*1 dimensions) per unit length of road (M/KM).

5.3.3 Unit prices

PIPE CULVERT (0.80 m diameter) : 7445 TL / M

BOX CULVERT (1*1 in dimension) : 54700 TL / M .

These costs are of concrete culverts .

5.4 Bridge cost

5.4.1 General

In bridge quantity estimations , all data of 16 regions , as bridge lengths and total road lengths of both state and provincial highways , of Turkish Highway Department have been concerned to get the average bridge number and length per kilometer of the road . The width of the bridges taken as roadway width may not be wrong for practical approach .

The data and the average bridge number and the length in the region basis for state and provincial highways are shown below .

5.4.2 Cost quantities

The quantities of bridge length and number are on Table 5.3 as per unit length of road .

As shown in table , there is a need to have 5.04527 meters of bridge length per kilometer of the road on 0.113850 bridge per kilometer for state highways and 2.505134 meters of length per KM on 0.071245 bridge per KM for provincial highways in the first region - ISTANBUL .

5.4.3 Unit price

It is not possible to standardize bridges on a type as size , depth , and length . So here , it is suitable

TABLE 5.3 BRIDGE LENGTHS AND NUMBERS AS AVERAGE

REGION	S.H.LE	P.H.LE	S#BRID	S.BR.LE	P#BRID	P.BR.L
ISTANBUL (1)	2231	1558	254	11256	111	3903
IZMIR (2)	2703	2456	293	10784	169	5785
KONYA (3)	2283	1947	113	2765	56	1117
ANKARA (4)	1883	1902	200	5905	110	3079
MERSIN (5)	2208	2410	264	9490	132	3780
KAYSERI (6)	1777	2033	106	2782	71	2012
SAMSUN (7)	2366	1806	307	10627	125	3752
ELAZIG (8)	1461	2554	150	6499	103	3355
DIYARBAKIR (9)	1969	1733	119	4769	71	1889
TRABZON (10)	1101	641	243	9642	110	2700
VAN (11)	1450	1273	75	2172	45	1166
ERZURUM (12)	2784	1215	215	6859	70	2011
ANTALYA (13)	1786	1409	145	5227	60	1558
BURSA (14)	2257	2354	257	8728	155	4842
KASTAMONU (15)	1476	1275	197	7294	106	3377
SIVAS (16)	1354	1328	129	4255	86	3356

S=STATE
P=PROVINCIAL
H=HIGHWAY
B=BRIDGE
LE=LENGTH
#=NUMBER

TABLE 5.3 BRIDGE LENGTHS AND NUMBERS AS AVERAGE

MEAN#S	MEANLE.S	MEAN#P	MEANLE.P
0.113850	5.045271	0.071245	2.505134
0.108398	3.989641	0.068811	2.355456
0.049496	1.211125	0.028762	0.573703
0.106213	3.135953	0.057833	1.618822
0.119565	4.298007	0.054771	1.568464
0.059651	1.565559	0.034923	0.989670
0.129754	4.491546	0.069213	2.077519
0.102669	4.448323	0.040328	1.313625
0.060436	2.422041	0.040969	1.090017
0.220708	8.757493	0.171606	4.212168
0.051724	1.497931	0.035349	0.915946
0.077227	2.463721	0.057613	1.655144
0.081187	2.926651	0.042583	1.105748
0.113867	3.867080	0.065845	2.056924
0.133468	4.941734	0.083137	2.648627
0.095273	3.142540	0.064759	2.527108

to give an average unit cost for M**2 of bridges .

Unit cost for a unit M**2 of bridge is 590000 TL for year 1987 and 1988 . This value has been taken from the Bridge Department of TCK .

CHAPTER 6

CASE STUDY

6.1 Data

It can give an idea about the risks and usefullness of the equation , if a comparison is done , by taking a few data between used ones in regression and applying the prediction relationships with these inputs .

Since there are three types of terrain severity as a group , it is suitable to select the data belonging to these terrain types such as ;

For flat terrain ;

NAME = DERINKUYU - IHLARA

REGION = 3.

RW = 8.0 M

GRF = 7.91 M/KM

RF = 5.74 M/KM

G = 2.17 M/KM

CUT VOLUME (CUTVOL) = 226.18 M**3/KM

FILL VOLUME (FILLVOL) = 17730.0 M**3/KM

TOTAL ERTHWORK VOLUME (TOTEV) = 17956.18 M**3/KM

PIPE CULVERT LENGTH (PCL) = 15.81 M/KM

BOX CULVERT LENGTH (BCL) = 0

PRECIPITATION VALUE (PRE) = 300 MM

For rolling terrain ;

NAME = MALATYA - SURGU

REGION = 8.

RW = 11 M

GRF = 28.3 M/KM

RF = 18.11 M/KM

G = 10.19 M/KM

CUTVOL = 11080.59 M**3/KM

FILLVOL= 20670.78 M**3/KM

TOTEV = 31751.37 M**3/KM

PCL = 1.15 M/KM

BCL = 69.75 M/KM

PRE = 400 MM

For mountainous terrain ;

NAME = KARGI - DURAGAN

REGION = 7.

RW = 9.5 M

GRF = 102.89 M/KM

RF = 37 M/KM

G = 65.89 M/KM

CUTVOL = 72880.65 M**3/KM

FILLVOL = 34562.73 M**3/KM

TOTEV = 107443.38 M**3/KM

PCL = 0

BCL = 35.42 M/KM

PRE = 1000 MM

6.2 Predicting the related component cost quantities

6.2.1 Earthwork

When predicting total earthwork volume and cut volume , all relationships given have been used the results are

for flat terrain data

EQ.5.2 ...... TOTEV = 22943.8 M**3/KM (22%)

EQ.5.3 ...... TOTEV = 15981 .0 M**3/KM (12%)

EQ.5.4 ...... CUTVOL = 5479 M**3/KM (96%)

EQ.5.5 ...... CUTVOL = -1924 (112%)

for rolling terrain data

EQ.5.2 ...... TOTEV = 32055 M**3/KM (1%)

EQ.5.3 ...... TOTEV = 35.328 M**3/KM (10%)

EQ.5.4 ...... CUTVOL = 11984 M**3/KM (7%)

EQ.5.5 ...... CUTVOL = 17427 M**3/KM (36%)

for mountainous terrain data

EQ.5.2 ...... TOTEV = 81318 M**3/KM (32%)

EQ.5.3 ...... TOTEV = 81913 M**3/KM (31%)

EQ.5.4 ...... CUTVOL = 50401 M**3/KM (45%)

EQ.5.5 ...... CUTVOL = 50131 M**3/KM (45%)

6.2.2 Drainage

For flat terrain data

6.2.2 Drainage

For flat terrain data

PCL = 18.77 M/KM	(16%)	139.7 E3 TL
BCL = 14.24 M/KM	(--)	778.9 E3 TL
		TOTAL COST = 918.6 E3 TL

For rolling terrain data

PCL = 23.2 M/KM	(95%)	172.7 E3 TL
BCL = 48.69 M/KM	(43%)	2.663 E6 TL
		TOTAL COST = 2.836 E6 TL

For mountainous terrain data

PCL = 22.97 M/KM	(--)	171.0 E3 TL
BCL = 106.7 M/KM	(67%)	5.836 E6 TL
		TOTAL COST = 6.007 E6 TL

6.3 Comparison of predicted and observed quantities

Since the pavement thicknesses are being calculated by means of the method itself , and the bridge lengths are taken as the mean , there is no need to compare these components .

The values in the paranthesis given in section 6.2 shows the deviations from the actual quantities of the roads taken as examples .

If TOTEV and CUTVOL is concerned , they seem to be more precise (these percentages are not great for earthwork predictions if they are compared with the

So it can be said that relationships has the required sensitivity .

When predicting the earthwork volumes before the project , to approach to the actual results with at most these risks is the need of all highway sector .

But in drainage , the prediction equations have more deviations . However , to get an idea about the culverts to be used in a project is possible . The reason can be explained by talking about the practices and knowledge of the project engineer in drainage , he or she may prefer a box culvert instead a pipe culvert or vice versa , of course this affects the amounts of culverts in the road . These prediction equations may give good results to some engineers , but not to the others .

Considering the costs ;

the error in earthwork costs will be the same as its quantity base because of using the same unit prices .

Turkish Highway Department takes 40% of the earthwork cost as total drainage cost . So ,according to TCK , drainage costs for the examples flat , rolling and montainous terrains are ;

FLAT : Drainage cost = 17956.18*964*0.40

= 6.924 E6 TL /KM

ROLLING : Drainage cost = 31751.37*739*0.40

= 9.386 E6 TL/KM

MOUNTAINOUS : Drainage cost = 107443.38*770*0.40

= 33.093 E6 TL/KM

Actual costs for the examples are ;

FLAT ; Pipe culvert cost (PCC)= 15.81*7445 = 117705.45

Box culvert cost (BCC) = 0

TOTAL = 117705.45 TL/KM

ROLLING ; PCC = 1.15*7445 =8561.75

BCC = 69.75*54700 = 3.815 E6

TOTAL = 3.824 E6 TL/KM

MOUNTAINOUS ; PCC = 0

BCC = 35.42*54700 = 1.937 E6

TOTAL = 1.937 E6 TL/KM

By TCK approach , costs are predicted with the error of 98% , 59% and 94% with respect to the examples in the order given .

But by comparing these results with the predicted costs of drainage 87% , 31% and 68% errors are counted respectively . These percentages show the less amount of error than ones provided from the approach of THD .

If it is necessary to find the cost of major drainage components (PCC and BCC) as a percent of earthwork cost , with the concern of these examples 0.7% , 16% and 15% are found out , so drainage costs can be checked by using 20% of earthwork cost . 20% of earthwork cost more reasonable than to use 40% of earthwork cost . For this reason , by comparing the drainage cost with the cost taken as a percentage of the earthwork cost the sensitivity of the drainage cost elements prediction can be increased totally .

Instead using 40% or 20% , user can use his/her own percentage found out with the practice in this subject .

CHAPTER 7.

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

1. World Bank and MIT study does not seem as efficient and reasonable for Turkey .

A. The relationships developed have restrictions in the variables (defined in Chapter 2.) such as GRF must be in the range of 0 and 100 or RF should be between 0 and 75 and G has to be in the range between 0 and 50 . But in Turkey , it is possible to come to the picture that GRF is equal to 400 and G is being 350 M/KM .

B. Deviations of these relationships when they are used for Turkey are very great and unacceptable as shown in appendix C1 for earthwork and appendix C2 for drainage to use them for prediction purpose in Turkey .

C. Altough Aw and Markow have been provided the data from Turkey , it can easily be understood that the relationships can never give reasonable results for all countries seperately . This is because the data is not enough to be able to generalize the relationships for all these countries having different geometric and topographic structure naturally.

2. This thesis reveals a method which :

A. gives more reasonable predictions to be able to use for pre-estimation of the project(s) -for selection of best alternative and for allocating the resources to the project(s). Predicted quantities deviates from the observed ones , 30% and 45% (see appendix E) for earthwork and drainage respectively . 45% deviation in drainage is inadequate but it can be reduced either by means of practices gained on drainage designs or comparing the results got by TCK approach by a correlation with the design policy of designer or project engineer .

B. is the first for only Turkey in the point of sensitiveness and simplicity views .

C. submits the simple variables that have been used first by World Bank and MIT for the complex ones (geometric standard and terrain severity) - road rise plus fall and roadway width for geometric standard and ground rise plus fall for terrain severity .

So it can be said that the recommended approach which had the goal of determining major road construction costs , achieved its goal .

7.2 Recommendations

First of all , the variables that are GRF , RF , RW and PRE should be determined very carefully . For this purpose , it is enough to prepare ground and grade lines on the longitudinal profile sensitively (RW is due to decision of roadway width and PRE is from the precipitation map according to the zone of road) .

Second and the most important thing is to decide which equation gives the more precise estimation in earthwork . This can be done such a way ;

the selection of alternatives ; greater or lesser value can be used as a quantity or an average value of them , may be suitable for analysis .

investment schedule ; average or the larger quantity can be used according to the money in hand .

In the point of drainage view , the relationships may not be sensitive from condition to condition . So it will be more valuable to compare the other roadways neighbour to the road designing or to be designed and to add the practices gained in the drainage projects .

The average length of bridges is a general approach to know the quantity but they can increased or decreased with a factor belongs to the user .

Pavement quantities and costs never creates a problem due to simplifying the method itself (AASHO flexible pavement design method) . It is simple to determine thicknesses according to the road instead of using practical values given in 5.2.3 after knowing the traffic volume (as standard axle load) and soil support value or CBR (California Bearing Ratio) and determining the materials to be used in the layers.

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APPENDICES

A1.....DATA USED FOR EARTHWORK VOLUME PREDICTION ANALYSIS

REGION	RW	GRF	RF	CUT	FILL	G	TOTEV
KONYA.3	8.00	7.71	5.57	854.02	33439.62	2.14	34293.64
KONYA.3	8.00	7.91	5.74	226.18	17730.00	2.17	17956.18
KAYSERI.6	12.00	11.39	3.24	8901.31	7047.39	8.15	15948.7
KAYSERI.6	12.00	12.62	3.32	15.81	22498.24	9.3	22514.05
KAYSERI.6	12.00	14.13	11.69	5857.03	4986.66	2.44	10843.69
KAYSERI.6	12.00	14.44	10.27	11848.72	7496.80	4.17	19345.52
KONYA.3	8.00	15.44	10.69	2852.39	12367.52	4.75	15219.91
KAYSERI.6	12.00	17.82	8.56	4306.64	9011.64	9.26	13318.28
KONYA.3	12.00	18.43	3.79	5465.87	19048.22	14.64	24514.09
KONYA.3	8.00	21.31	18.13	2866.20	13370.31	3.18	16236.51
ANKARA.4	9.50	21.43	6.25	8053.15	15527.58	15.18	23580.73
KAYSERI.6	12.00	22.36	17.53	4416.15	8442.56	4.83	12858.71
KONYA.3	8.00	22.51	20.10	2283.17	14681.48	2.41	16964.65
ELAZIG.8	11.00	22.84	17.87	6659.26	22527.17	4.97	29186.43
ERZURUM12	10.00	26.32	20.55	2240.08	22274.63	5.77	24514.71
KONYA.3	12.00	26.50	5.09	165.31	16502.01	21.41	16667.32
ERZURUM12	10.00	27.03	19.68	2697.57	20608.48	7.35	23306.05
KONYA.3	8.00	27.06	13.21	5585.80	13155.65	13.85	18741.45
KAYSERI.6	12.00	28.06	16.92	13795.24	10598.45	11.14	24393.69
ELAZIG.8	11.00	28.30	18.11	11080.59	20670.78	10.19	31751.37
KASTAM.15	15.00	28.68	21.69	95674.02	40831.76	6.99	136505.7
KONYA.3	8.00	28.70	18.48	6435.35	12389.39	10.22	18824.74
KONYA.3	12.00	28.84	10.51	12512.82	20921.75	18.33	33434.57
ANKARA.4	9.50	31.25	20.91	4795.06	14484.26	10.34	19279.32
KONYA.3	8.00	31.64	18.77	5279.12	15697.58	12.87	20976.7
ELAZIG.8	11.00	32.32	19.28	10502.51	15285.06	13.04	25787.57
ELAZIG.8	8.00	32.59	25.82	9686.43	5249.82	6.77	14936.25
ELAZIG.8	8.00	32.81	27.05	14195.62	7606.36	5.76	21801.98
ELAZIG.8	11.00	34.49	21.98	13543.41	15568.16	12.51	29111.57
ANKARA.4	9.50	35.23	10.53	13132.39	19188.06	24.7	32320.45
D.BAKIR.9	12.00	36.11	21.17	9849.02	13439.49	14.94	23288.51
KONYA.3	8.00	39.02	20.77	9481.51	10053.30	18.25	19534.81
MERSIN.5	9.50	42.43	23.40	6674.17	22820.12	19.03	29494.29
KAYSERI.6	12.00	43.54	15.00	23489.58	15778.44	28.54	39268.02
SAMSUN.7	9.50	44.02	25.54	14768.32	11499.04	18.48	26267.36
SAMSUN.7	9.50	44.12	41.64	10587.46	11416.23	2.48	22003.69
ELAZIG.8	8.00	49.82	41.98	25851.25	5650.28	7.84	31501.53
MERSIN.5	9.50	50.14	16.55	9349.33	17813.77	33.59	27163.1
ERZURUM12	10.00	50.85	39.49	14746.19	36617.54	11.36	51363.73
KASTAM.15	9.50	50.86	3.05	60593.69	25860.36	47.81	86454.05
KAYSERI.6	12.00	53.33	22.33	10377.34	9093.85	31	19471.19
KAYSERI.6	12.00	56.36	44.16	11215.43	10759.05	12.2	21974.48
KAYSERI.6	12.00	56.40	25.23	7603.28	5556.97	31.17	13160.25
ELAZIG.8	11.00	57.14	28.52	44266.79	33446.86	28.62	77713.65

A1.....DATA USED FOR EARTHWORK VOLUME PREDICTION ANALYSIS

SAMSUN.7	9.50	58.73	37.97	20256.18	15868.15	20.76	36124.33
ANKARA.4	9.50	61.12	7.15	17240.60	11158.31	53.97	28398.91
D.BAKIR.9	12.00	63.36	49.94	6374.15	87668.68	13.42	94042.83
ANKARA.4	9.50	64.65	21.05	130.00	42965.00	43.6	43095
D.BAKIR.9	12.00	66.69	18.42	12315.54	15033.22	48.27	27348.76
SAMSUN.7	9.50	66.72	61.72	25765.15	12495.98	5	38261.13
ANKARA.4	9.50	67.07	13.58	29283.33	28867.97	53.49	58151.3
D.BAKIR.9	12.00	67.32	13.01	35583.80	16135.42	54.31	51719.22
SAMSUN.7	9.50	67.71	59.86	14252.61	18801.12	7.85	33053.73
ELAZIG.8	11.00	68.59	21.65	98399.19	48293.35	46.94	146692.5
IZMIR.2	8.00	69.24	47.77	53141.51	6250.36	21.47	59391.87
KONYA.3	8.00	69.37	39.63	1396.38	16130.28	29.74	17526.66
D.BAKIR.9	12.00	72.19	31.46	35481.99	22356.24	40.73	57838.23
SAMSUN.7	9.50	72.23	67.10	27002.15	2157.72	5.13	29159.87
SAMSUN.7	9.50	73.63	34.06	41768.57	26951.65	39.57	68720.22
MERSIN.5	9.50	73.89	16.68	37163.54	45649.53	57.21	82813.07
SAMSUN.7	9.50	76.09	48.30	83837.74	5537.43	27.79	89375.17
SAMSUN.7	9.50	76.95	59.65	37192.31	49119.23	17.3	86311.54
ELAZIG.8	8.00	77.32	46.35	30551.43	7959.64	30.97	38511.07
D.BAKIR.9	12.00	77.80	16.18	48805.98	27642.79	61.62	76448.77
IZMIR.2	8.00	80.25	19.79	51837.42	35231.61	60.46	87069.03
SAMSUN.7	9.50	80.27	44.25	125394.20	62793.27	36.02	188187.4
ELAZIG.8	11.00	83.19	36.19	61347.99	71027.81	47	132375.8
ANKARA.4	9.50	83.29	35.08	25282.71	16301.26	48.21	41583.97
IZMIR.2	8.00	83.93	52.93	17738.13	9730.59	31	27468.72
ELAZIG.8	8.00	86.09	60.76	30596.68	28060.18	25.33	58656.86
ELAZIG.8	8.00	88.50	27.05	24182.75	14973.69	61.45	39156.44
ANKARA.4	9.00	90.19	41.87	26648.96	31386.18	48.32	58035.14
VAN.11	10.00	90.26	69.99	21510.17	23141.84	20.27	44652.01
ELAZIG.8	8.00	90.76	24.89	34970.35	31957.47	65.87	66927.82
IZMIR.2	8.00	91.57	31.74	55765.20	9650.55	59.83	65415.75
ELAZIG.8	8.00	93.18	51.19	38446.76	24399.15	41.99	62845.91
ELAZIG.8	8.00	94.20	51.76	42631.12	52850.01	42.44	95481.13
SAMSUN.7	14.50	95.75	20.34	133284.90	19725.92	75.41	153010.8
MERSIN.5	9.50	97.10	40.81	33575.88	47625.67	56.29	81201.55
ANKARA.4	9.50	97.73	39.88	34313.69	26320.53	57.85	60634.22
SAMSUN.7	9.50	98.97	89.90	27551.28	16597.78	9.07	44149.06
ANKARA.4	9.50	100.81	43.08	48241.43	45923.46	57.73	94164.89
ELAZIG.8	8.00	102.76	57.48	44715.03	15243.13	45.28	59958.16
SAMSUN.7	9.50	102.89	37.00	72880.65	34562.73	65.89	107443.3
IZMIR.2	8.00	104.81	49.01	47297.76	32896.82	55.8	80194.58
TRABZON10	12.00	105.33	51.97	113204.30	41781.43	53.36	154985.7
D.BAKIR.9	12.00	105.44	8.74	42412.23	22974.82	96.7	65387.05
SAMSUN.7	9.50	109.71	54.51	30574.91	42924.24	55.2	73499.15
IZMIR.2	10.00	109.98	65.96	52287.79	42968.16	44.02	95255.95
SAMSUN.7	9.50	113.86	83.46	85459.91	49099.59	30.4	134559.5

A1.....DATA USED FOR EARTHWORK VOLUME PREDICTION ANALYSIS

ELAZIG.8	8.00	114.35	32.86	26917.41	33758.70	81.49	60676.11
ANKARA.4	9.50	115.54	28.63	21187.72	33969.43	86.91	55157.15
ELAZIG.8	11.00	117.47	14.17	65767.25	85027.46	103.3	150794.7
SAMSUN.7	9.50	118.13	52.42	48605.65	34590.86	65.71	83196.51
SAMSUN.7	9.50	118.38	75.80	65969.65	30763.69	42.58	96733.34
SAMSUN.7	9.50	119.29	42.62	39484.45	31149.45	76.67	70633.9
MERSIN.5	9.50	119.82	58.96	38607.11	35661.32	60.86	74268.43
ELAZIG.8	8.00	120.50	47.65	41213.47	86046.68	72.85	127260.1
SAMSUN.7	9.50	124.86	77.38	37371.10	42406.00	47.48	79777.1
IZMIR.2	8.00	129.03	19.78	20561.46	10422.73	109.25	30984.19
ANKARA.4	9.50	132.90	30.72	53536.28	24944.45	102.18	78480.73
IZMIR.2	8.00	136.07	92.01	68979.06	57279.73	44.06	126258.7
TRABZON10	12.00	138.76	16.26	87680.94	39434.53	122.5	127115.4
SAMSUN.7	9.50	140.29	25.70	61940.77	47443.63	114.59	109384.4
IZMIR.2	8.00	143.51	45.91	60014.98	42511.23	97.6	102526.2
IZMIR.2	8.00	146.56	38.43	67934.45	34141.11	108.13	102075.5
SAMSUN.7	9.50	146.95	93.27	234565.30	139791.70	53.68	374357
IZMIR.2	8.00	147.90	49.30	53289.97	36111.27	98.6	89401.24
SAMSUN.7	9.50	148.44	38.94	67971.53	22187.50	109.5	90159.03
ANKARA.4	9.5	156.73	58.89	58349.31	33599.75	97.84	91949.06
TRABZON10	12.00	159.33	66.56	145245.60	38568.95	92.77	183814.5
IZMIR.2	8.00	159.99	51.55	49291.37	65623.35	108.44	114914.7
ANKARA.4	9.50	166.31	38.78	95663.91	47649.34	127.53	143313.2
IZMIR.2	8.00	166.41	21.75	90526.49	87365.41	144.66	177891.9
ELAZIG.8	8.00	171.64	38.14	45329.35	30304.17	133.5	75633.52
TRABZON10	12.00	175.88	30.83	185789.20	23784.87	145.05	209574.0
IZMIR.2	8.00	178.00	81.23	112592.70	29807.29	96.77	142399.9
IZMIR.2	8.00	184.41	67.14	93162.74	67406.86	117.27	160569.6
ELAZIG.8	8.00	190.63	63.72	62773.01	36992.19	126.91	99765.2
IZMIR.2	10.00	191.76	50.14	73404.72	36905.46	141.62	110310.1
TRABZON10	12.00	197.44	63.01	160360.70	36276.00	134.43	196636.7
ANKARA.4	9.50	206.09	46.24	113692.60	44754.34	159.85	158446.9
SAMSUN.7	9.50	208.78	64.65	109759.60	74373.46	144.13	184133.0
TRABZON10	12.00	227.39	67.66	160141.70	52447.03	159.73	212588.7
TRABZON10	12.00	240.14	67.62	194801.20	47082.37	172.52	241883.5
TRABZON10	12.00	316.63	53.37	203571.30	34539.93	263.26	238111.2
TRABZON10	12.00	382.85	39.32	156980.00	9228.33	343.53	166208.3

DATA USED FOR PIPE AND BOX CULVERT LENGTH PREDICTIONS

ROW	BCL	GRF.	PCL	PRE.
1	6	67.71	0	10.0
2	10	76.95	1	10.0
3	3	72.23	0	10.0
4	4	44.12	3	10.0
5	0	148.40	5	10.0
6	2	80.27	0	10.0
7	3	118.30	2	10.0
8	5	113.80	0	10.0
9	1	146.90	4	10.0
10	2	124.80	0	10.0
11	3	58.73	0	10.0
12	6	118.10	0	10.0
13	5	102.80	0	10.0
14	0	*	0	*
15	7	109.70	0	10.0
16	3	98.97	0	10.0
17	8	208.70	0	10.0
18	12	140.20	0	10.0
19	4	119.20	0	10.0
20	0	*	0	*
21	4	66.72	0	10.0
22	12	44.02	0	10.0
23	7	73.63	0	10.0
24	41	90.19	27	4.0
25	6	102.80	9	10.0
26	6	90.76	3	10.0
27	13	120.50	4	10.0
28	14	190.60	1	10.0
29	21	27.03	0	10.0
30	11	50.85	0	10.0
31	15	26.32	0	10.0
32	18	73.89	0	8.0
33	6	97.10	0	8.0
34	6	119.80	0	8.0
35	20	42.43	0	8.0
36	29	50.14	0	8.0
37	19	129.00	0	12.5
38	3	147.90	0	12.5
39	6	184.40	0	12.5
40	5	146.50	0	12.5
41	1	80.25	0	12.5
42	7	178.00	0	12.5
43	11	136.00	0	12.5

A2 (CONTINUE)

44	3	166.40	0	12.5
45	8	104.80	0	12.5
46	10	83.93	0	12.5
47	4	159.90	0	12.5
48	3	143.50	0	12.5
49	3	69.24	0	12.5
50	1	91.57	0	12.5
51	13	109.98	11	10.0
52	8	42.00	1	12.5
53	2	17.82	25	4.5
54	0	12.62	2	4.5
55	5	28.06	23	4.5
56	3	11.39	13	4.5
57	1	56.40	9	4.5
58	6	53.33	28	4.5
59	5	43.54	8	4.5
60	1	14.13	19	4.5
61	2	14.44	13	4.5
62	3	22.36	21	4.5
63	4	56.36	11	4.5
64	5	36.11	10	5.0
65	1	72.19	4	5.0
66	3	66.69	20	5.0
67	6	77.80	5	5.0
68	8	105.00	6	5.0
69	5	67.32	15	5.0
70	10	227.30	8	11.0
71	0	197.40	0	11.0
72	9	197.40	4	11.0
73	13	105.30	12	11.0
74	17	97.73	0	6.0
75	12	83.29	0	6.0
76	15	132.90	0	6.0
77	16	115.50	0	6.0
78	10	31.25	0	6.0
79	25	100.80	1	6.0
80	30	156.70	0	6.0
81	14	206.00	0	6.0
82	17	67.07	0	6.0
83	30	35.23	0	6.0
84	23	61.12	0	6.0
85	8	21.43	0	6.0
86	4	68.59	0	4.0
87	7	117.40	0	4.0
88	22	83.19	0	4.0
89	11	57.14	0	4.0
90	10	34.49	3	4.0

A2 (CONTINUE)

91	12	32.32	0	4.0
92	10	28.30	1	4.0
93	2	14.97	1	4.0
94	13	88.50	2	4.0
95	9	171.60	0	4.0
96	9	114.30	0	4.0
97	1	77.32	0	4.0
98	2	49.82	0	4.0
99	9	93.18	0	4.0
100	6	94.20	0	4.0
101	14	86.09	0	4.0
102	0	7.91	19	3.0
103	0	7.71	22	3.0
104	2	22.51	24	3.0
105	2	31.64	8	3.0
106	1	15.44	11	3.0
107	5	21.31	12	3.0
108	0	27.06	4	3.0
109	1	28.70	9	3.0
110	0	39.02	8	3.0
111	0	69.37	1	3.0
112	5	28.84	6	3.0
113	2	18.43	6	3.0
114	3	26.50	7	3.0
115	6	95.75	6	8.0
116	3	90.26	12	10.0
117	14	191.76	12	10.0

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MTB > REGRESS C4 ON 1,C47

THE REGRESSION EQUATION IS
CUT = 3576 + 75.0 G*RW

   119 CASES USED    10 CASES CONTAIN MISSING VALUES

                                    ST. DEV.     T-RATIO =
COLUMN       COEFFICIENT            OF COEF.     COEF/S.D.
                    3576               2955           1.21
G*RW              75.011              4.435          16.91

S =  21723

R-SQUARED = 71.0 PERCENT
R-SQUARED = 70.7 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

 DUE TO       DF            SS        MS=SS/DF
REGRESSION     1  134989119488   134989119488
RESIDUAL     117   55210270720      471882656
TOTAL        118  190199398400
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ROW	G*RW	Y CUT	PRED. Y VALUE	ST.DEV. PRED. Y	RESIDUAL	ST.RES.
62	264	83838	23379	2234	60458	2.80R
80	1093	133285	85597	3328	47688	2.22R
88	640	113204	51607	2097	61597	2.85R
89	1160	42412	90619	3570	-48207	-2.25R
92	289	85460	25239	2186	60221	2.79R
94	826	21188	65509	2480	-44321	-2.05R
102	874	20561	69136	2614	-48574	-2.25R
113	1113	145246	87081	3399	58164	2.71R
118	1741	185789	134140	5884	51649	2.47RX
119	774	112593	61647	2351	50946	2.36R
123	1613	160361	124581	5355	35780	1.70 X
124	1519	113693	117486	4968	-3793	-0.18 X
126	1917	160142	147354	6624	12788	0.62 X
127	2070	194801	158867	7276	35934	1.76 X

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R DENOTES AN OBS. WITH A LARGE ST. RES.
X DENOTES AN OBS. WHOSE X VALUE GIVES IT LARGE INFLUENCE.

DURBIN-WATSON STATISTIC = 1.94
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MTB > REGRESS C4 ON 2,C46,C1

THE REGRESSION EQUATION IS
CUT = - 45026 + 709 G + 5169 RW

   116 CASES USED     13 CASES CONTAIN MISSING VALUES

                                   ST. DEV.    T-RATIO =
COLUMN      COEFFICIENT            OF COEF.    COEF/S.D.
                 -45026              14210        -3.17
G                708.86              49.88        14.21
RW                 5169               1422         3.64

S =  23766

R-SQUARED = 65.5 PERCENT
R-SQUARED = 64.9 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

 DUE TO      DF            SS       MS=SS/DF
REGRESSION    2 121353682944    60676841472
RESIDUAL    113  63824281600      564816640
TOTAL       115 185177964544

FURTHER ANALYSIS OF VARIANCE
SS EXPLAINED BY EACH VARIABLE WHEN ENTERED IN THE ORDER GIVEN
 DUE TO      DF            SS
REGRESSION    2 121353682944
G             1 113885937664
RW            1   7467743232

                          Y     PRED. Y   ST.DEV.
 ROW          G         CUT       VALUE   FRED. Y   RESIDUAL     ST.RES.
  62         28       83838       23780      2517      60058       2.54R
  80         75      133285       83381      7271      49904       2.21RX
  88         53      113204       54828      3943      58376       2.49R
  92         30       85460       25630      2459      59830       2.53R
 102        109       20561       73770      4360     -53208      -2.28R
 113         93      145246       82764      4455      62482       2.68R
 118        145      185789      119823      6121      65966       2.87R
 119         97      112593       64923      3977      47670       2.03R
 123        134      160361      112295      5726      48066       2.08R
 126        160      160142      130229      6698      29913       1.31 X
 127        173      194801      139295      7224      55506       2.45RX

R DENOTES AN OBS. WITH A LARGE ST. RES.
X DENOTES AN OBS. WHOSE X VALUE GIVES IT LARGE INFLUENCE.

DURBIN-WATSON STATISTIC = 1.89
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MTB > REGRESS C22 ON 1,C47

THE REGRESSION EQUATION IS
TOTEWV = 21274 + 96.2 G*RW

   119 CASES USED    10 CASES CONTAIN MISSING VALUES

                                    ST. DEV.    T-RATIO =
COLUMN      COEFFICIENT             OF COEF.    COEF/S.D.
                 21274                  3784         5.62
G*RW            96.187                 5.680        16.93

S =  27821

R-SQUARED = 71.0 PERCENT
R-SQUARED = 70.8 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

 DUE TO      DF            SS       MS=SS/DF
REGRESSION    1 221962682368  221962682368
RESIDUAL    117  90556661760     773988544
TOTAL       118 312519360512

                          Y     PRED. Y    ST.DEV.
 ROW       G*RW      TOTEWV      VALUE    PRED. Y   RESIDUAL     ST.RES.
  48        161       94043      36764       3169      57279       2.07R
  69        517      132376      71002       2554      61373       2.22R
  88        640      154986      82864       2685      72122       2.60R
  89       1160       65387     132889       4573     -67502      -2.46R
  92        289      134560      49053       2800      85507       3.09R
 102        874       30984     105341       3348     -74357      -2.69R
 104        352      121259      55178       2671      66081       2.39R
 113       1113      183815     128353       4353      55462       2.02R
 118       1741      209574     188696       7535      20878       0.78 X
 123       1613      196637     176438       6859      20198       0.75 X
 124       1519      158447     167341       6363      -8894      -0.33 X
 126       1917      212589     205641       8484       6948       0.26 X
 127       2070      241884     220403       9319      21480       0.82 X

R DENOTES AN OBS. WITH A LARGE ST. RES.
X DENOTES AN OBS. WHOSE X VALUE GIVES IT LARGE INFLUENCE.

DURBIN-WATSON STATISTIC = 2.08
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MTB > REGRESS C22 ON 2, C46,C1

THE REGRESSION EQUATION IS
TOTEWV = - 23634 + 945 G + 4614 RW

116 CASES USED 13 CASES CONTAIN MISSING VALUES

COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
	-23634	17646	-1.34
G	945.06	61.94	15.26
RW	4614	1765	2.61

S = 29512

R-SQUARED = 67.9 PERCENT
R-SQUARED = 67.4 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	2	208494428160	104247214080
RESIDUAL	113	98417573888	870952000
TOTAL	115	306912002048	

FURTHER ANALYSIS OF VARIANCE
SS EXPLAINED BY EACH VARIABLE WHEN ENTERED IN THE ORDER GIVEN

DUE TO	DF	SS
REGRESSION	2	208494428160
G	1	202544021504
RW	1	5950397440

ROW	G	Y TOTEWV	PRED. Y VALUE	ST.DEV. PRED. Y	RESIDUAL	ST.RES.
69	47	132376	71539	3581	60836	2.08R
80	75	153011	114538	9030	38473	1.37 X
88	53	154986	82164	4896	72822	2.50R
92	30	134560	48930	3054	85629	2.92R
102	109	30984	116527	5415	-85543	-2.95R
104	44	121259	54918	4093	66340	2.27R
113	93	183815	119409	5532	64406	2.22R
117	134	75634	139444	6505	-63811	-2.22R
126	160	212589	182690	8318	29899	1.06 X
127	173	241884	194777	8970	47106	1.68 X

R DENOTES AN OBS. WITH A LARGE ST. RES.
X DENOTES AN OBS. WHOSE X VALUE GIVES IT LARGE INFLUENCE.

DURBIN-WATSON STATISTIC = 2.08

RESULTS OF WORLD BANK EQUATIONS USED FOR OBSERVED DATA IN TURKEY

ROADWI	GRF	RF	CUT	FILL	G	TOTEW	H	EWV	%DEVIATI
8.00	7.71	5.57	854.02	33439.62	2.14	34293.64	1.793229	16696.48	51.31316
8.00	7.91	5.74	226.18	17730.00	2.17	17956.16	1.799879	16767.15	6.621822
12.00	11.39	3.24	8901.31	7047.39	8.15	15948.7	2.619671	36452.66	-128.562
12.00	12.62	3.02	15.81	22499.24	9.3	22514.05	2.795118	39091.69	-73.6324
12.00	14.13	11.69	5857.03	4986.66	2.44	10843.69	1.921167	25752.03	-137.484
12.00	14.44	10.27	11848.72	7496.80	4.17	19345.52	2.148646	29158.54	-50.7250
8.00	15.44	10.69	2852.39	12367.52	4.75	15219.91	2.237366	21558.17	-41.6445
12.00	17.82	8.56	4306.64	9011.64	9.26	13318.28	2.852238	40172.73	-201.643
12.00	18.43	3.79	5465.87	19048.22	14.64	24514.09	3.554737	51893.87	-111.689
8.00	21.31	18.13	2866.20	13370.31	3.18	16236.51	2.116429	20205.77	-24.4465
9.50	21.43	6.25	8053.15	15527.59	15.18	23580.73	3.666097	44652.75	-89.3612
12.00	22.36	17.53	4416.15	8442.56	4.83	12858.71	2.343874	32142.41	-149.966
8.00	22.51	20.10	2283.17	14681.48	2.41	16964.65	2.033779	19293.83	-13.7296
11.00	22.84	17.87	6659.26	22527.17	4.97	29186.43	2.368606	30155.79	-3.32127
10.00	26.32	20.55	2240.08	22274.63	5.77	24514.71	2.520178	29844.57	-21.7415
12.00	26.50	5.09	165.31	16502.01	21.41	16667.32	4.54024	69551.55	-317.292
10.00	27.03	19.68	2697.57	20608.48	7.35	23306.05	2.733867	32802.18	-40.7453
8.00	27.06	13.21	5585.80	13155.65	13.85	18741.45	3.572784	37913.33	-102.296
12.00	28.06	16.92	13795.24	10598.45	11.14	24393.69	3.237094	46505.11	-90.6440
11.00	28.30	18.11	11080.59	20670.78	10.19	31751.37	3.11788	41402.85	-30.3970
15.00	28.68	21.69	95674.02	40831.76	6.99	136505.7	2.710362	46025.40	66.28318
8.00	28.70	18.48	6435.35	12389.39	10.22	18824.74	3.12731	32167.70	-70.8799
12.00	28.84	10.51	12512.82	20921.75	18.33	33434.57	4.175446	62849.86	-87.9786
9.50	31.25	20.91	4795.06	14484.26	10.34	19279.32	3.178235	37577.19	-94.9093
8.00	31.64	18.77	5279.12	15697.58	12.87	20976.7	3.510026	37086.33	-76.7977
11.00	32.32	19.28	10502.51	15285.06	13.04	25787.57	3.541408	48123.37	-86.6146
8.00	32.59	25.82	9686.43	5249.82	6.77	14936.25	2.736331	27364.01	-83.2053
8.00	32.81	27.05	14195.62	7606.36	5.76	21801.98	2.609099	25848.99	-18.5626
11.00	34.49	21.98	13543.41	15568.16	12.51	29111.57	3.503201	47506.34	-63.1871
9.50	35.23	10.53	13132.39	19188.06	24.7	32320.45	5.085997	67226.01	-107.998
12.00	36.11	21.17	9849.02	13439.49	14.94	23288.51	3.839189	56844.74	-144.089
8.00	39.02	20.77	9481.51	10053.30	18.25	19534.81	4.306628	48010.91	-145.771
9.50	42.43	23.40	6674.17	22820.12	19.03	29494.29	4.454647	56825.02	-92.6644
12.00	43.54	15.00	23489.58	15778.44	28.54	39268.02	5.696866	92086.47	-134.507
9.50	44.02	25.54	14768.32	11499.04	18.48	26267.36	4.405798	56044.56	-113.361
9.50	44.12	41.64	10587.46	11416.23	2.48	22003.69	2.343188	26273.86	-19.4066
8.00	49.82	41.98	25851.25	5650.28	7.84	31501.53	3.113858	31998.72	-1.57830
9.50	50.14	16.55	9349.33	17813.77	33.59	27163.1	6.440056	91498.26	-236.847
10.00	50.85	39.49	14746.19	36617.54	11.36	51363.73	3.582255	45203.14	11.99403
9.50	50.86	3.05	60593.69	25860.36	47.81	86454.05	8.284444	128872.2	-49.0644
12.00	53.33	22.33	10377.34	9093.85	31	19471.19	6.150287	101454.2	-421.048
12.00	56.36	44.16	11215.43	10759.05	12.2	21974.48	3.767204	55580.67	-152.932
12.00	56.40	25.23	7603.28	5556.97	31.17	13160.25	6.21489	102813.4	-681.242
11.00	57.14	28.52	44266.79	33446.86	28.62	77713.65	5.896226	90272.05	-16.1598
9.50	58.73	37.97	20256.18	15868.15	20.76	36124.33	4.904387	64174.42	-77.6487
9.50	61.12	7.13	17240.60	11158.31	53.97	28398.91	9.221698	149770.1	-427.379
12.00	63.36	49.94	6374.15	87668.68	13.42	94042.83	4.021884	60086.93	36.10684
9.50	64.65	21.05	130.00	42965.00	43.6	43095	7.933035	121367.8	-181.628
12.00	66.69	18.42	12315.54	15033.22	48.27	27348.76	6.563821	156376.6	-471.767
9.50	66.72	61.72	25765.15	12495.98	5	38261.13	2.982408	34834.94	8.954744
9.50	67.07	13.58	29283.33	28867.97	53.49	58151.3	9.242483	150248.1	-158.374
12.00	67.32	13.01	35583.80	16135.42	54.31	51719.22	9.351738	176150.4	-240.589
9.50	67.71	59.86	14252.61	18801.12	7.85	33053.73	3.363819	40227.74	-21.7041

H=EFFECTIVE EARTHWORK HEIGHT AND EWV=PREDICTED TOTEW %DEVIATION=(OBS.VOL.-PRE.VOL.)/OBS.VOL.*100

RESULTS OF WORLD BANK EQUATIONS USED FOR OBSERVED DATA IN TURKEY

11.00	68.59	21.65	98399.19	48293.35	46.94	146692.5	8.418661	144414.0	1.553236
8.00	69.24	47.77	53141.51	6250.36	21.47	59391.87	5.142066	60464.78	-1.80649
8.00	69.37	39.63	1396.38	16130.28	29.74	17526.66	6.210703	77882.36	-344.365
12.00	72.19	31.46	35481.99	22356.24	40.73	57838.23	7.667611	134988.4	-133.389
9.50	72.23	67.10	27002.15	2157.72	5.13	29159.87	3.075767	36135.29	-23.9213
9.50	73.63	34.06	41768.57	26951.65	39.57	68720.22	7.537987	113147.2	-64.6490
9.50	73.89	16.68	37163.54	45649.53	57.21	82813.07	9.817161	163714.3	-97.6914
9.50	76.09	48.30	83837.74	5537.43	27.79	89375.17	6.052561	84278.41	5.702653
9.50	76.95	59.65	37192.31	49119.23	17.3	86311.54	4.711305	60982.96	29.34552
8.00	77.32	46.35	30551.43	7959.64	30.97	38511.07	6.479878	82532.85	-114.309
12.00	77.80	16.18	48805.98	27642.79	61.62	76448.77	10.4404	204965.2	-168.107
8.00	80.25	19.79	51837.42	35231.61	60.46	87069.03	10.32481	160524.4	-84.3645
11.00	83.19	36.19	61347.99	71027.81	47	132375.8	8.629341	149357.0	-12.8280
9.50	83.29	35.08	25282.71	16301.26	46.21	41583.97	8.786321	139914.0	-236.461
8.00	83.93	52.93	17738.13	9730.59	31	27468.72	6.575627	84212.63	-206.576
8.00	86.09	60.76	30596.68	28060.18	25.33	58656.86	5.874221	72217.99	-23.1194
8.00	88.50	27.05	24182.75	14973.69	61.45	39156.44	10.5672	166165.2	-324.362
9.00	90.19	41.87	26648.96	31386.18	48.32	58035.14	8.896921	137934.7	-137.674
10.00	90.26	69.99	21510.17	23141.84	20.27	44652.01	5.279444	73169.25	-63.8655
8.00	90.76	24.89	34970.35	31957.47	65.87	66927.82	11.16879	180536.7	-169.748
8.00	91.57	31.74	55765.20	9650.55	59.83	65415.75	10.40099	162285.6	-148.093
8.00	93.18	51.19	38446.76	24399.15	41.99	62845.91	8.121912	113196.0	-80.1168
8.00	94.20	51.76	42631.12	52850.01	42.44	95481.13	8.19414	114635.3	-20.0607
14.50	95.75	20.34	133284.90	19725.92	75.41	153010.8	12.46881	294447.3	-92.4356
9.50	97.10	40.81	33575.88	47625.67	56.29	81201.55	10.0211	168609.2	-107.642
9.50	97.73	39.88	34313.69	26320.53	57.85	60634.22	10.23109	173713.0	-186.493

MEAN DEVIATION = -110.524

APPENDIX C2. THE RESULTS OF WORLD BANK'S DRAINAGE EQUATIONS USED FOR TURKEY

FOR FLAT TERRAIN

ROW	G.R.F	BOX#	PIPEL	ALPC.	PR.PIPE	PR.BOX	DEV.PIPE	DEV.B
1	7.91	0	20.1299	16.1268	31.7699	0.27	-57.8242	
2	7.71	0	21.7342	16.1368	31.7896	0.27	-46.2653	

FOR ROLLING TERRAIN

ROW	G.R.F	BOX#	PIPEL	ALPC.	PR.PIPE	PR.BOX	DEV.PIPE	DEV.B
1	27.03	4.0410	0.0000	18.5585	32.2917	0.15	*	96.28
2	26.32	2.6210	0.0000	18.5994	32.3629	0.15	*	94.27
3	17.82	0.4650	28.2405	22.4807	39.1163	0.15	-38.51	67.74
4	12.62	0.0000	34.2374	22.8460	39.7520	0.15	-16.11	
5	28.06	6.2333	40.9983	21.7782	37.8941	0.15	7.57	97.59
6	11.39	2.3550	27.6930	22.9333	39.9039	0.15	-44.09	93.63
7	14.13	0.2700	25.6176	22.7393	39.5664	0.15	-54.45	44.44
8	14.44	2.9375	24.7772	22.7174	39.5284	0.15	-59.53	94.89
9	22.36	1.1642	20.6774	22.1665	38.5697	0.15	-86.53	87.11
10	36.11	6.3192	33.5499	21.2415	36.9602	0.15	-10.16	97.62
11	31.25	6.4526	0.0000	17.4954	30.4420	0.15	*	97.67
12	35.23	8.0842	0.0000	17.2809	30.0687	0.15	*	98.14
13	21.43	5.6505	0.0000	18.0362	31.3829	0.15	*	97.34
14	34.49	7.5082	4.4563	19.7490	34.3633	0.15	-671.11	98.00
15	32.32	10.8691	0.0000	19.8823	34.5952	0.15	*	98.61
16	28.30	6.3409	1.4642	20.1316	35.0290	0.15	-2292.33	97.63
17	14.97	2.0912	27.7948	15.7777	27.4532	0.15	1.23	92.82
18	22.51	1.6037	24.4971	15.4132	26.8190	0.15	-9.48	90.64
19	31.64	2.6775	22.2817	14.9831	26.0706	0.15	-17.00	94.39
20	15.44	0.7000	15.5208	15.7548	27.4133	0.15	-76.62	78.57
21	21.31	2.7762	11.0772	15.4707	26.9189	0.15	-143.01	94.59

23	28.70	4.2613	26.0250	15.1203	26.3093	0.15	-1.09	96.47
24	39.02	0.0000	44.3215	14.6442	25.4809	0.15	42.51	
25	28.84	7.6217	18.4492	21.7256	37.8026	0.15	-104.90	98.03
26	18.43	1.7417	15.4953	22.4382	39.0424	0.15	-151.96	91.38
27	26.50	4.1592	16.7049	21.8838	38.0778	0.15	-127.94	96.39

FOR MOUNTAINOUS TERRAIN

ROW	G.R.F	BOX#	PIPEL	ALPC.	PR.PIPE	PR.BOX	DEV.PIPE	DEV.B
1	67.71	8.0032	76.03	15.6256	31.5637	0.62	58.485	92.25
2	76.95	18.8263	178.85	15.1844	30.6724	0.62	82.850	96.70
3	72.23	2.7695	26.31	15.4082	31.1245	0.62	-18.299	77.61
4	44.12	1.5179	14.42	16.8111	33.9584	0.62	-135.495	59.15
5	80.27	4.7568	45.19	15.0289	30.3584	0.62	32.821	86.96
6	58.73	25.8368	245.45	16.0667	32.4547	0.62	86.777	97.60
7	98.97	4.0253	38.24	14.1824	28.6485	0.62	25.082	84.59
8	66.72	4.7621	45.24	15.6736	31.6607	0.62	30.016	86.98

APPENDIX C2. (CONTINUE)

9	44.02	5.6179	53.37	16.8163	33.9690	0.62	36.352	88.96
10	73.63	6.4811	61.57	15.3415	30.9898	0.62	49.667	90.43
11	90.19	13.3144	119.83	13.8853	28.0484	0.62	76.593	95.34
12	90.76	11.9700	95.76	12.4740	25.1976	0.62	73.687	94.82
13	50.85	4.5610	45.61	17.2375	34.8197	0.62	23.658	86.40
14	73.89	16.4021	155.82	15.3291	30.9648	0.62	80.128	96.22
15	97.10	21.3063	202.41	14.2649	28.8151	0.62	85.764	97.09
16	42.43	12.2726	116.59	16.8994	34.1368	0.62	70.721	94.94
17	50.14	13.8505	131.58	16.5003	33.3306	0.62	74.669	95.52
18	80.25	1.7737	14.19	12.8872	26.0320	0.62	-83.453	65.04
19	63.93	11.6512	93.21	12.7410	25.7368	0.62	72.388	94.67
20	69.24	12.1550	97.24	13.3346	26.9359	0.62	72.300	94.89
21	91.57	7.7688	62.15	12.4428	25.1344	0.62	59.559	92.01
22	42.00	34.9474	332.00	16.9220	34.1824	0.62	89.704	98.22
23	56.40	0.4608	5.53	19.9466	40.2921	0.62	-628.609	-34.53
24	53.33	4.3317	51.98	20.1373	40.6774	0.62	21.744	85.68
25	43.54	12.0233	144.28	20.7578	41.9308	0.62	70.938	94.84
26	56.36	1.8808	22.57	19.9490	40.2971	0.62	-78.543	67.03
27	72.19	1.0392	12.47	18.9937	38.3673	0.62	-207.677	40.33
28	66.69	1.3833	16.60	19.3203	39.0271	0.62	-135.103	55.18
29	77.80	7.8117	93.74	18.6663	37.7058	0.62	59.776	92.06
30	67.32	4.6350	55.62	19.2826	38.9509	0.62	29.970	86.62
31	97.73	13.6021	129.22	14.2371	28.7589	0.62	77.744	95.44
32	83.29	8.9568	85.09	14.8889	30.0755	0.62	64.654	93.07
33	67.07	9.5905	91.11	15.6566	31.6264	0.62	65.288	93.53
34	61.12	5.9905	56.91	15.9481	32.2152	0.62	43.393	89.65
35	68.59	18.2136	200.35	17.7679	35.8911	0.62	82.086	96.59
36	83.19	37.8682	416.55	16.9816	34.3029	0.62	91.765	98.36
37	57.14	5.7655	63.42	18.4099	37.1880	0.62	41.362	89.24
38	88.50	12.4838	99.87	12.5617	25.3747	0.62	74.592	95.03

40	49.82	5.0500	40.40	14.1620	28.6073	0.62	29.190	87.72
41	93.18	8.1388	65.11	12.3808	25.0092	0.62	61.589	92.38
42	94.20	12.4113	99.29	12.3417	24.9303	0.62	74.891	95.00
43	86.09	7.9650	63.72	12.6559	25.5650	0.62	59.879	92.21
44	69.37	0.0000	0.00	13.3292	26.9250	0.62	*	
45	95.75	8.1552	118.25	20.9145	42.2473	0.62	64.273	92.39
46	90.26	1.3230	13.23	15.2551	30.8153	0.62	-132.920	53.13

G.R.F=GROUND RISE PLUS FALL M/KM
BOX#=AVERAGE REGULAR (1*1) BOX CULVERT NUMBER
PIPEL=PIPE LENGTH
ALPC=AVERAGE LENGTH OF PIPE CULVERT (WORLD BANK)
PR.PIPE=PREDICTED PIPE LENGTH
PR.BOX=PREDICTED BOX NUMBER
DEV.PIPE=DEVIATION OF PIPE PREDICTION FROM THE ACTUAL
DEV.B=DEVIATION OF AVERAGE BOX CULVERT NUMBER PREDICTION FROM THE ACTUAL

DEVIATION=(OBSERVED-PREDICTED)/OBSERVED*100

APPENDIX D. 1986 VERSION OF AASHO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES

The relationships are refered for design in 1986 ;

$$LOG(W18)=ZR*So+9.36*LOG(SN+1)-0.20+\frac{LOG\left|\frac{Po-Pt}{4.2-1.5}\right|}{0.40+\frac{1094}{(SN+1)^{5.19}}}+2.32*LOG(MR)-8.07$$

Where W18= predicted number of 18-kips equivalent single axle load applications .

W18=Dd*Dl*w18

Dd=a directional distribution factor, expressed as a ratio that accounts for the distribution of ESAL (equivalent single axle load) units by direction (north-south , east-west etc.).It is in the range of 0.3-0.7 depending on the loaded and unloaded vehicles . But it is generally taken as 0.5 in many countries .

Dl=a lane distribution factor, expressed as a ratio that accounts for distribution of traffic when two or more lanes are available in one direction .

no.of lanes in each direction	percent of 18-kips ESAL in design lane
1	100
2	80-100
3	60-80
4	50-75

w18=the cumulative two-directional 18 kips ESAL units predicted for specific section of higkway during the analysis period (from the planning group).

ZR=standard normal deviate

Reliability percent	Standard normal deviate ZR
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
96	-1.751
97	-1.881
98	-2.054
99	-2.327
99.9	-3.090
99.99	-3.750

So= combined standard error of the traffic prediction and performance prediction.it has the value between 0.40 and 0.50 but it is generally equal to 0.45 for flexible pavements.

Po= initial design serviceability index ,it is 4.2 for flexible pavements from AASHO Road Test.

Pt= terminal serviceability index , it is 2.5 or more for major highways , 2.0 for highways with lesser traffic volumes .

MR= resilient modulus.

= 1500*CBR (Corps of Engineers)

OR

= A+B*(R-value)

A= 772 to 1155

B= 369 to 555

MR= 1000+555*(R-value)

R= reliability

Functional Classification	Recommended level of reliability	
	Urban	Rural
Interstate and other freeways	85-99.9	80-99.9
Principal Arterials	80-99	75-95
Collectors	80-95	75-95
Local	50-80	50-80

Note:results based on a survey of the AASHTO Pavement Design Task Force

APPENDIX E

DATA USED FOR EARTHWORK ANALYSIS AND THE DEVIATIONS OF PREDICTED TOTAL EARTHWORK VOLUME QUANTITIES FROM THE OBSERVED ONES.

G=relative rise plus fall (M/KM)

RW=roadway width (M)

CUT=cut volume (M**3/KM)

OB.TEV= observed total earthwork volume (M**3/KM)

PR.TEV.i= predicted total earthwork volume provided the i th equation (M**/KM)

PR.CUT.i= predicted cut volume provided by using the i th equation (M**3/KM)

REGION	G	RW	CUT	OB.TEV	FR.TEV.2
ELAZIG.8	5.76	8	14195.62	21801.98	25706.89
ELAZIG.8	65.87	8	34970.35	66927.82	71967.55
ELAZIG.8	45.28	8	44715.03	59958.16	56121.48
ELAZIG.8	72.85	8	41213.47	127260.1	77339.36
ELAZIG.8	126.91	8	62773.01	99765.2	118943.9
ERZURUM12	5.77	10	2240.08	24514.71	26824.74
ERZURUM12	7.35	10	2697.57	23306.05	28344.7
ERZURUM12	11.36	10	14746.19	51363.73	32202.32
SAMSUN.7	75.41	14.5	133284.9	153010.8	126463.4
VAN.11	20.27	10	21510.17	44652.01	40773.74
ANKARA.4	48.32	9	26648.96	58035.14	63109.45
KONYA.3	18.25	8	9481.51	19534.81	35319.2
KONYA.3	29.74	8	1396.38	17526.66	44161.90
KONYA.3	2.14	8	854.02	34293.64	22920.94
KONYA.3	4.75	8	2852.39	15219.91	24929.6
KONYA.3	3.18	8	2866.2	16236.51	23721.32
KONYA.3	2.41	8	2283.17	16964.65	23128.73
KONYA.3	13.85	8	5585.8	18741.45	31932.96
KONYA.3	10.22	8	6435.35	18824.74	29139.31
KONYA.3	12.87	8	5279.12	20976.7	31178.75
KONYA.3	2.17	8	226.18	17956.18	22944.03
D.BAKIR.9	13.42	12	6374.15	94042.83	36766.04
IZMIR.2	44.02	10	52287.79	95255.95	63621.24
KASTAM.15	6.99	15	95674.02	136505.7	31360.57
SAMSUN.7	18.48	9.5	14768.32	26267.36	38162.87
SAMSUN.7	2.48	9.5	10587.46	22003.69	23540.47
SAMSUN.7	20.76	9.5	20256.18	36124.33	40246.56
SAMSUN.7	5	9.5	25765.15	38261.13	25843.5
SAMSUN.7	5.13	9.5	27002.15	29159.87	25962.30
SAMSUN.7	39.57	9.5	41768.57	68720.22	57437.02
SAMSUN.7	27.79	9.5	83837.74	89375.17	46671.28
SAMSUN.7	17.3	9.5	37192.31	86311.54	37084.47
SAMSUN.7	36.02	9.5	125394.2	188187.4	54192.67
SAMSUN.7	9.07	9.5	27551.28	44149.06	29563.07
SAMSUN.7	65.89	9.5	72880.65	107443.3	81490.87
SAMSUN.7	55.2	9.5	30574.91	73499.15	71721.28
SAMSUN.7	30.4	9.5	85459.91	134559.5	49056.56
SAMSUN.7	65.71	9.5	48605.65	83196.51	81326.36
SAMSUN.7	42.58	9.5	65969.65	96733.34	60187.86
SAMSUN.7	76.67	9.5	39484.45	70633.9	91342.71
SAMSUN.7	47.48	9.5	37371.1	79777.1	64665.97
SAMSUN.7	114.59	9.5	61940.77	109384.4	125997.8
SAMSUN.7	53.68	9.5	234565.3	374357	70332.15
SAMSUN.7	109.5	9.5	67971.53	90159.03	121346.0
SAMSUN.7	144.13	9.5	109759.6	184133.0	152994.4
SAMSUN.7	7.85	9.5	14252.61	33053.73	28448.11
KAYSERI.6	4.17	12	11848.72	19345.52	26087.84
KAYSERI.6	8.15	12	8901.31	15948.7	30682.36
KAYSERI.6	2.44	12	5857.03	10843.69	24090.73
KAYSERI.6	4.83	12	4416.15	12858.71	26849.75
KAYSERI.6	28.54	12	23489.58	39268.02	54220.57
KAYSERI.6	31	12	10377.34	19471.19	57060.4
KAYSERI.6	12.2	12	11215.43	21974.48	35357.68
KAYSERI.6	31.17	12	7603.28	13160.25	57256.64

PR.TEV.3	PR.CUT.4	PR.CUT.5	%DEV.5.2	%DEV.5.3
18532.28	7032	-67.32	-17.9108	14.99726
75817.11	43098	43091.66	-7.53010	-13.2819
56194.84	30744	28308.04	6.398915	6.276576
82469.05	47286	48103.3	39.22735	35.19648
133988.2	79722	86918.38	-19.2238	-34.3035
26979.81	7903.5	9479.86	-9.42303	-10.0555
28485.55	9088.5	10614.3	-21.6194	-22.2238
32307.08	12096	13493.48	37.30533	37.10137
112332.2	85584.37	80946.38	17.35002	26.58543
40798.31	18778.5	19890.86	8.685544	8.630518
63310.96	36192	35260.76	-8.74352	-9.09073
30435.25	14526	8900.5	-80.8013	-55.6000
41385.22	21420	17150.32	-151.969	-136.127
15082.42	4860	-2666.48	33.16269	56.01977
17569.75	6426	-792.5	-63.7959	-15.4392
16073.54	5484	-1919.76	-46.0986	1.003725
15339.73	5022	-2472.62	-36.3348	9.578270
26242.05	11886	5741.3	-70.3868	-40.0214
22782.66	9708	3134.96	-54.7926	-21.0250
25308.11	11298	5037.66	-48.6351	-20.6486
15111.01	4878	-2644.94	-27.7779	15.84507
42708.26	15654	24512.56	60.90499	54.58637
63432.06	36591	36943.36	33.21021	33.40882
49237.47	11439.75	34205.82	77.02619	63.93012
36982.94	16743	16220.64	-45.2862	-40.7942
21734.94	5343	4732.64	-6.98420	1.221386
39155.78	18367.5	17857.68	-11.4112	-6.39171
24136.5	7138.5	6542	32.45494	36.91639
24260.39	7231.125	6635.34	10.96562	16.80213
57081.71	31769.62	31363.26	16.41903	16.93607
45855.37	23376.37	22905.22	47.78048	48.69338
35858.4	15902.25	15373.4	57.03416	58.45468
53698.56	29240.25	28814.36	71.20282	71.46539
28015.21	10038.37	9464.26	33.03804	36.54403
82164.67	50522.62	50261.02	24.15459	23.52747
71977.1	42906	42585.6	2.418898	2.070840
48342.7	25236	24779.2	63.54284	64.07336
81993.13	50394.37	50131.78	2.247859	1.446430
59950.24	33914.25	33524.44	37.77960	38.02525
92438.01	58203.37	58001.06	-29.3185	-30.8691
64619.94	37405.5	37042.64	18.94168	18.99938
128575.7	85221.37	85227.62	-15.1880	-17.5449
70528.54	41823	41494.24	81.21254	81.16008
123725	81594.75	81573	-34.5911	-37.2297
156727.3	106268.6	106437.3	16.91095	14.88362
26852.55	9169.125	8588.3	13.93372	18.76090
33893.01	7329	17871.06	-34.8521	-75.1982
37685.95	10911	20728.7	-92.3815	-136.294
32244.32	5772	16628.92	-122.163	-197.355
34521.99	7923	18344.94	-108.805	-168.471
57117.62	29262	35368.72	-38.0782	-45.4558
59462	31476	37135	-193.050	-205.384
41545.6	14556	23636.6	-60.9033	-89.0629
59624.01	31629	37257.06	-335.072	-353.061

KAYSERI.6	9.3	12	15.81	22514.05	32009.92
KAYSERI.6	9.26	12	4306.64	13318.28	31963.74
KAYSERI.6	11.14	12	13795.24	24393.69	34134.01
KONYA.3	14.64	12	5465.87	24514.09	38174.41
KONYA.3	21.41	12	165.31	16667.32	45989.70
KONYA.3	18.33	12	12512.62	33434.57	42434.15
KASTAM.15	47.81	9.5	60593.69	86454.05	64967.55
ELAZIG.8	30.97	8	30551.43	38511.07	45108.51
ELAZIG.8	25.33	8	30596.68	58656.86	40767.96
ELAZIG.8	61.45	8	24182.75	39156.44	68565.92
ELAZIG.8	41.99	8	38446.76	62845.91	53589.50
ELAZIG.8	42.44	8	42631.12	95481.13	53935.82
ELAZIG.8	133.5	8	45329.35	75633.52	124015.6
ELAZIG.8	7.84	8	25851.25	31501.53	27307.66
ELAZIG.8	81.49	8	26917.41	60676.11	83988.70
ELAZIG.8	6.77	8	9686.43	14936.25	26484.19
TRABZON10	53.36	12	113204.3	154985.7	82872.78
TRABZON10	92.77	12	145245.6	183814.5	128367.6
TRABZON10	134.43	12	160360.7	196636.7	176459.9
TRABZON10	159.73	12	160141.7	212588.7	205666.3
TRABZON10	172.52	12	194801.2	241883.5	220431.0
TRABZON10	263.26	12	203571.3	238111.2	325181.3
TRABZON10	343.53	12	156980	166208.3	417845.0
TRABZON10	122.5	12	87680.94	127115.4	162688
TRABZON10	145.05	12	185789.2	209574.0	188719.7
ELAZIG.8	4.97	11	6659.26	29186.43	26533.25
ELAZIG.8	10.19	11	11080.59	31751.37	32057.05
ELAZIG.8	13.04	11	10502.51	25787.57	35072.92
ELAZIG.8	12.51	11	13543.41	29111.57	34512.08
ELAZIG.8	28.62	11	44266.79	77713.65	51559.68
ELAZIG.8	47	11	61347.99	132375.8	71009.4
ELAZIG.8	103.3	11	65767.25	150794.7	130586.0
ELAZIG.8	46.94	11	98399.19	146692.5	70945.90
IZMIR.2	31	8	17738.13	27468.72	45131.6
IZMIR.2	44.06	8	68979.06	126258.7	55182.57
IZMIR.2	97.6	8	60014.98	102526.2	96386.96
IZMIR.2	108.13	8	67934.45	102075.5	104490.8
IZMIR.2	144.66	8	90526.49	177891.9	132604.3
IZMIR.2	96.77	8	112592.7	142399.9	95748.19
IZMIR.2	21.47	8	53141.51	59391.87	37797.31
IZMIR.2	60.46	8	51837.42	87069.03	67804.01
IZMIR.2	59.83	8	55765.2	65415.75	67319.16
IZMIR.2	55.8	8	47297.76	80194.58	64217.68
IZMIR.2	98.6	8	53289.97	89401.24	97156.56
IZMIR.2	108.44	8	49291.37	114914.7	104729.4
IZMIR.2	117.27	8	93162.74	160569.6	111524.9
IZMIR.2	109.25	8	20561.46	30984.19	105352.8
IZMIR.2	141.62	10	73404.72	110310.1	157512.4
ANKARA.4	15.18	9.5	8053.15	23580.73	35147.00
ANKARA.4	10.34	9.5	4795.06	19279.32	30723.72
ANKARA.4	24.7	9.5	13132.39	32320.45	43847.33
ANKARA.4	53.97	9.5	17240.6	28398.91	70597.18
ANKARA.4	43.6	9.5	130	43095	61120.04
ANKARA.4	53.49	9.5	29283.33	58151.3	70158.51
ANKARA.4	48.21	9.5	25282.71	41583.97	65333.11
ANKARA.4	57.85	9.5	34313.69	60634.22	74143.11

38781.9	11946	21554.4	-42.1775	-72.2564
38743.78	11910	21525.68	-139.999	-190.906
40535.42	13602	22875.52	-39.9296	-66.1717
43870.92	16752	25388.52	-55.7243	-78.9620
50322.73	22845	30249.38	-175.927	-201.924
47387.49	20073	28037.94	-26.9169	-41.7320
64934.43	37640.62	37279.58	24.25307	24.89139
42557.41	22158	18033.46	-17.1312	-10.5069
37182.49	18774	13983.94	30.49752	36.61015
71604.85	40446	39918.1	-75.1076	-82.8686
53059.47	28770	25945.82	14.72873	15.57211
53488.32	29040	26268.92	43.51153	43.98021
140268.5	83676	91650	-63.9690	-85.4581
20514.52	8280	1426.12	13.31321	34.87770
90702.97	52470	54306.82	-38.4213	-49.4871
19494.81	7638	657.86	-77.3148	-30.5201
80771.08	51600	53189.48	46.52876	47.88482
118328.8	87069	81485.86	30.16456	35.62598
158030.7	124563	111397.7	10.26090	19.63311
182141.6	147333	129563.1	3.256248	14.32203
194330.5	158844	138746.3	8.868928	19.65946
280805.7	240510	203897.6	-36.5669	-17.9305
357303.0	312753	261531.5	-151.398	-114.973
146661.5	113826	102832	-27.9844	-15.3765
168151.6	134121	119022.9	9.950825	19.76505
30436.41	7676.25	13675.46	9.090443	-4.28274
35411.07	11982.75	17423.42	-0.96275	-11.5261
38127.12	14334	19469.72	-36.0071	-47.8507
37622.03	13896.75	19089.18	-18.5510	-29.2339
52974.86	27187.5	30656.16	33.65427	31.83326
70491	42351	43853	46.35771	46.74933
124144.9	88798.5	84276.4	13.40143	17.67290
70433.82	42301.5	43809.92	51.63632	51.98541
42586	22176	18055	-64.3017	-55.0345
55032.18	30012	27432.08	56.29407	56.41318
106055.8	62136	65873.8	5.987981	-3.44262
116090.8	68454	73434.34	-2.36617	-13.7303
150903.9	90372	99662.88	25.45791	15.17096
105264.8	61638	65277.86	32.76109	26.07807
33503.91	16458	11212.46	36.35945	43.58839
70661.38	39852	39207.28	22.12613	18.84441
70060.99	39474	38754.94	-2.90972	-7.10110
66220.4	37056	35861.4	19.92266	17.42534
107008.8	62736	66591.8	-8.67473	-19.6949
116386.3	68640	73656.92	8.863351	-1.28060
124801.3	73938	79996.86	30.54414	22.27587
117158.2	69126	74238.5	-240.021	-278.122
156444.8	109791	107020.1	-42.7904	-41.8226
33838.04	14391.75	13851.24	-49.0496	-43.4986
29225.52	10943.25	10376.12	-59.3610	-51.5899
42910.6	21174.75	20686.6	-35.6643	-32.7660
70804.91	42029.62	41702.46	-148.591	-149.322
60922.3	34641	34256.8	-41.8262	-41.3674
70347.47	41687.62	41357.82	-20.6482	-20.9731
65315.63	37925.62	37566.78	-57.1113	-57.0692
74502.55	44794.12	44488.3	-22.2793	-22.8721

ANKARA.4	57.73	9.5	48241.43	94164.89	74033.44
ANKARA.4	86.91	9.5	21187.72	55157.15	100701.0
ANKARA.4	102.18	9.5	53536.28	78480.73	114656.3
ANKARA.4	127.53	9.5	95663.91	143313.2	137823.6
ANKARA.4	97.84	9.5	58349.31	91949.06	110689.9
ANKARA.4	159.85	9.5	113692.6	158446.9	167360.9
MERSIN.5	33.59	9.5	9349.33	27163.1	51971.90
MERSIN.5	19.03	9.5	6674.17	29494.29	38665.51
MERSIN.5	57.21	9.5	37163.54	62813.07	73558.21
MERSIN.5	56.29	9.5	33575.88	81201.55	72717.43
MERSIN.5	60.86	9.5	38607.11	74268.43	76893.75
D.BAKIR.9	54.31	12	35583.8	51719.22	83969.46
D.BAKIR.9	96.7	12	42412.23	65387.05	132904.4
D.BAKIR.9	14.94	12	9849.02	23288.51	38520.73
D.BAKIR.9	48.27	12	12315.54	27348.76	76996.88
D.BAKIR.9	40.73	12	35481.99	57838.23	68292.71
D.BAKIR.9	61.62	12	48805.98	76448.77	92408.12

74368.19	44708.62	44402.14	21.37892	21.00220
102196.7	65499.37	65353.38	-82.5711	-85.2828
116749.0	76379.25	76317.24	-46.0948	-48.7614
140907.5	94441.12	94518.54	3.830478	1.678602
112613.0	73287	73201.12	-20.3818	-22.4732
171708.5	117469.1	117724.3	-5.62584	-8.36974
51382.77	27508.87	27069.62	-91.3327	-89.1638
37507.09	17134.87	16615.54	-31.0949	-27.1672
73892.63	44338.12	44028.78	11.17559	10.77177
73015.87	43682.62	43368.22	10.44822	10.08067
77371.08	46938.75	46649.48	-3.53518	-4.17761
81676.43	52455	53671.58	-62.3564	-57.9227
122074.1	90606	84307.6	-103.258	-86.6946
44156.82	17022	25603.92	-65.4066	-89.6077
75920.31	47019	49534.86	-181.537	-177.600
68734.69	40233	44121.14	-18.0753	-18.8395
88642.86	59034	59120.16	-20.8758	-15.9506