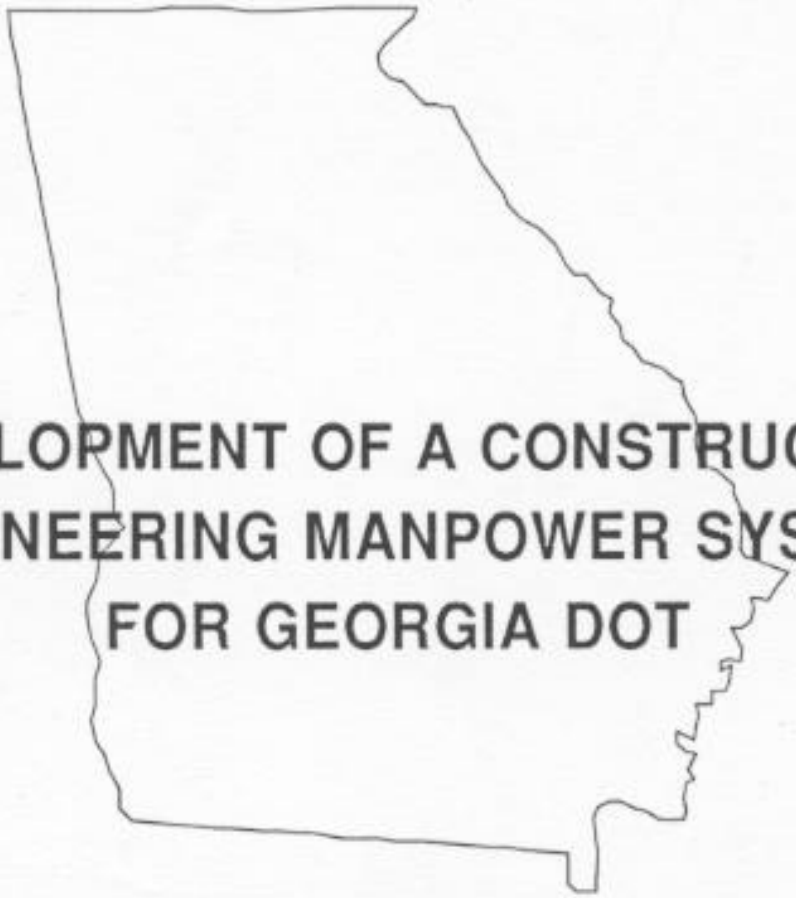
DEPARTMENTAL RESEARCH
GDOT SPECIAL RESEARCH STUDY NO. 9212
FINAL REPORT

GEORGIA DEPARTMENT OF TRANSPORTATION



DEVELOPMENT OF A CONSTRUCTION ENGINEERING MANPOWER SYSTEM FOR GEORGIA DOT

OFFICE OF MATERIALS & RESEARCH
RESEARCH AND DEVELOPMENT BRANCH

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Georgia Department of Transportation
Office of Materials and Research

DEVELOPMENT OF A CONSTRUCTION ENGINEERING MANPOWER SYSTEM FOR GEORGIA DOT

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July 1993

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-GA-93-9212		

4. Title and Subtitle	5. Report Date
Development of a Construction Engineering Manpower System for Georgia DOT	July 1993
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Lanka Santha, P.E. Associate Research Engineer Brad Young Associate Research Engineer	SRS 9212

9. Performing Organization Name and Address	10. Work Unit No.
Office of Materials and Research Georgia Department of Transportation 15 Kennedy Drive Forest Park, Georgia 30050	11. Contract or Grant No.

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Georgia Department of Transportation No. 2 Capitol Square Atlanta, Georgia 30334	Final 1992-1993
	14. Sponsoring Agency Code

15. Supplementary Notes
Prepared in cooperation with the U.S. Department of Transportation Federal Highway Administration.

16. Abstract

The objective of this special research study was to develop a construction engineering manpower management system based primarily on construction dollars and to determine if this type of system will be adequate for the GDOT.

The following information was collected: project cost, project type, project duration, number of employees working on project, and employee's title. After these data were collected, they were grouped according to project type.

Two sets of linear regressions were performed on each project type data set to determine the correlations of total employees per month versus project cost per month and transportation engineers (T.E.'s) per month versus project cost per month. The total employees per month versus project cost per month linear regression correlations were very satisfactory. The linear regression correlations between T.E.'s per month and project cost per month were poor.

From this study, a manpower management system based primarily on construction dollars was developed for GDOT. This system is able to estimate the number of employees and engineers required on construction projects. The manpower prediction procedure developed to estimate the required number of engineers should be utilized cautiously. This manpower system should be used as an aid in estimating manpower needs and should not be substituted for good engineering judgements. It is recommended that the manpower management system developed in this study be utilized on future construction projects during their planning stage to predict manpower needs.

17. Key Words	18. Distribution Statement
manpower, construction, management, personnel, regression, prediction, staffing	No Restrictions

19. Security Classif. (of this report)	20. Security classif.(of this Page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT 1700.7 (8-69)

EXECUTIVE SUMMARY

Objective

The objective of this special research study is to develop a construction engineering manpower management system based primarily on construction dollars and to determine if this type of system will be adequate for the GDOT.

Data Collection

It was determined that the following information should be collected: project cost, project type, project duration, number of employees working on project, and employee's title. A questionnaire to collect this information was prepared and sent to selected project and area engineers throughout the state. After all the completed questionnaires were received, they were grouped according to project type and the data were analyzed.

Data Analysis

Data analysis was performed on each project type separately. Two sets of linear regressions were performed on each project type to determine the correlations of employees per month versus project cost per month and transportation engineers (T.E.'s) per month versus project cost per month.

The coefficient of determinations (R^2) for the linear regressions between employees per month and project cost per month were found to be very satisfactory. The manpower prediction procedure developed in this study utilizing employees per month and project cost per month data can be used with confidence on future construction projects for predicting manpower needs.

The linear regression correlations between T.E.'s per month and project cost per month were poor. T.E.II trainees in construction projects could be a possible cause for this poor

correlation. Although they are accounted for as T.E.'s they do not carry responsibilities of regular T.E.'s. The manpower prediction procedure developed in this study utilizing T.E.'s per month and project cost per month data should be utilized cautiously.

Conclusions

1. A manpower management system based primarily on construction dollars was developed for GDOT.
2. This system is able to estimate the number of employees and engineers required for different construction projects.
3. The developed system is presented in a simple computer program "MANPOWER" and a set of charts. This computer program and charts will be helpful in implementation of the findings of this study.

Recommendations

1. It is recommended that the manpower system developed in this study be utilized on future construction projects during their planning stage to predict manpower needs.
2. It is recommended that a database of personnel use be maintained in the future on all project types. After a few years, the new database can be used to upgrade the developed manpower system and also to include the project types that are not in the present manpower system.
3. This manpower management system should be used as an aid in estimating manpower needs, and it should not be substituted for any good engineering judgements.
4. The manpower prediction procedure developed in this study to estimate the required number of engineers (T.E.'s) should be utilized cautiously.

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I. INTRODUCTION

Accurate estimates of the number of employees required on construction projects are essential to maintaining a high quality construction program. Currently the Georgia Department of Transportation (GADOT) does not have manpower guidelines to guide supervisors in properly staffing construction projects for either long or short term manpower needs. Thus, the GADOT determined that there was a need to develop an effective method to assess and project the needed level of staffing for construction projects.

The purpose of this special research study is to develop an initial set of manpower guidelines for estimating the number of required employees on construction projects. These manpower guidelines would not substitute for good judgement, but their use would provide more uniform inspection ensuring quality construction and would make the best use of available personnel.

The simplest method of determining construction manpower needs is to base the primary guidelines on the dollar value of the construction contract. Even though some state DOT's have found this method to be inadequate, it was determined that this method based primarily on construction dollars would be a good starting point for developing a construction engineering manpower system for GADOT.

II. OBJECTIVE

The objective of this special research study is to develop a construction engineering manpower management system based primarily on construction dollars and to determine if this type of system will be adequate for the GADOT.

III. DATA COLLECTION

The first step in data collection was to determine what other information would be needed in the data base besides project cost (Note, project cost was obtained from the detailed cost estimate.). This was accomplished by meeting with personnel from the construction office to determine other major factors they felt should be considered for predicting construction project manpower needs. It was first determined from this meeting that only recently completed construction projects should be utilized. It was also determined that the following additional information should be included in the data base:

1. Project type.
2. Project duration.
3. Number of employees working on project.
4. Employee's title.

It was determined that project type should be broken down into nineteen different project type categories. The following is a list of the nineteen different project type categories used in this study:

IA1. Urban, New Construction, Multi-Lane Roadway (including Bridges).
IA2. Urban, New Construction, Two-Lane Roadway.
IA3. Urban, New Construction, Other (Intersections, Signals, etc.).
IA4. Urban, New Construction, Bridge.

IB1. Urban, Reconstruction, Multi-Lane Roadway (including Bridges).
IB2. Urban, Reconstruction, Two-Lane Roadway.
IB3. Urban, Reconstruction, Other (Intersections, Signals, etc.).
IB4. Urban, Reconstruction, Bridge.
IB5. Urban, Reconstruction, Resurface (all Categories).

IIA1. Rural, New Construction, Multi-Lane Roadway (including Bridges).
IIA2. Rural, New Construction, Two-Lane Roadway.
IIA3. Rural, New Construction, Other (Intersections, Signals, etc.).

IIA4. Rural, New Construction, Bridge.

IIB1. Rural, Reconstruction, Multi-Lane Roadway (including Bridges).
IIB2. Rural, Reconstruction, Two-Lane Roadway.
IIB3. Rural, Reconstruction, Other (Intersections, Signals, etc.).
IIB4. Rural, Reconstruction, Bridge.
IIB5. Rural, Reconstruction, Resurfacing (all Categories).

III. Non-Let (PR County Contracts).

It was determined that the actual time it took to complete each project should be utilized as the project duration value.

It was also determined that the value for the number of employees working on the project should be broken down into six months intervals, and that for each six month interval the title of the employee and the percentage of time per day to the nearest quarter day the employee spent working on the project should be obtained.

A questionnaire asking for this information was prepared and sent to selected project and area engineers throughout the state. See appendix for an example of the questionnaire.

After all questionnaires were received, they were grouped into data sets according to project type and the data analysis was started.

IV. DATA ANALYSIS

Data analysis was performed on each project type data set separately. Project type IA1 data set (Urban, New Construction, Multi-Lane Roadway) is utilized in this chapter to demonstrate the data analysis process.

PROJECT TYPE IA1 (URBAN, NEW CONSTRUCTION, MULTI-LANE ROADWAY):

There were ten projects in this data set. It should be noted again that only completed projects were utilized in this study. The following table is a summarization of the raw data for the second set of data for project type IA1.

Table 1: Raw Data for Project Type IA1

Project Number	MS-5(11) & MR-8046(2) Muscogee		
Project Type	(IA1) Urban, New Construction, Multi-Lane Roadway		
Project Cost	$ 4,249,860.44		
Project Duration	15 Months		
Number of Employees			
Empl's Title	1st Six Months	2nd Six Months	3rd Six Months
E.T. II	1	1	1
T.E. I	1	1	1
Total Empl's	2	2	2
Total T.E.'s	1	1	1

From the information in Table 1 the following values were calculated as follows:

$$Project\ Cost/Month = \frac{Project\ Cost}{Project\ Duration} = \frac{\$4,249,860.44}{15\ Months}$$

$$= \frac{\$283,324.00}{Month}$$

$$Total\ Empl's\ /\ Month = \frac{\sum((Empl's\ per\ Interval)\ X\ (Months\ Active\ per\ Interval))}{Project\ Duration}$$

$$= \frac{(2\ Empl's\ X\ 6\ Months) + (2\ Empl's\ X\ 6\ Months) + (2\ Empl's\ X\ 3\ Months)}{15\ Months}$$

$$= 2\ Empl's/Month$$

$$\text{Total T.E.'s/Month} = \frac{\sum((\text{T.E.'s per Interval}) \times (\text{Months Active per Interval}))}{\text{Project Duration}}$$

$$= \frac{(1\ \text{T.E.'s} \times 6\ \text{Months}) + (1\ \text{T.E.'s} \times 6\ \text{Months}) + (1\ \text{T.E.'s} \times 3\ \text{Months})}{15\ \text{Months}}$$

$$= 1\ \text{T.E.'s/Month}$$

These computed values for each construction project in project type IA1 data set are given in Table 2.

Table 2: Computed Data for Project Type IA1

PROJECT	Cost($)	Duration (Months)	Cost($) per Month	Empl's per Month	T.E.'s per Month
1	2,311,106	18	128,395	1	0
2	4,249,860	15	283,324	2	1
3	1,197,040	12	99,753	1	1
4	1,407,429	16	87,964	1	0.2
5	7,923,271	24	330,136	5.31	2.1
6	767,793	24	31,991	2.19	1.2
7	23,912,792	37	646,292	7.84	3.3
8	10,000,000	24	416,667	4.75	1.0
9	5,057,434	18	280,969	2.67	1.3
10	5,191,828	18	288,435	3.67	1.4

As shown in Table 2, project duration varies from project to project. For the purpose of data analysis, project cost per month was utilized to avoid the variability in project duration. Similar normalization was performed on the data for total employees and total transportation engineers (T.E.'s).

Two sets of linear regressions were performed to determine the correlations between employees per month versus project cost per month and T.E.'s per month versus project cost per month.

Employees per month versus project cost per month regression had a coefficient of determination (R^2) of 0.83 . This regression equation is shown below.

$$Employees/Month = 0.245 + (1.12 \times 10^{-5}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 1$$

T.E.'s per month versus project cost per month regression had a coefficient of determination (R^2) of 0.60 . This relationship is given in Equation 2.

$$T.E.'s/Month = 0.242 + (3.9 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 2$$

Figure 1(a) shows the data points and the two discussed regression lines.

In general, personnel requirements on a construction project varies during the project duration. The following data analysis procedure was utilized to study the variability of personnel needs during a construction project. Once again the second set of data (Table 2) in project type IA1 was utilized for demonstration purposes.

$$Months\ per\ Quarter\ for\ Project = \frac{(Total\ Months\ Project\ Active)}{4}$$

$$= \frac{15\ Months}{4}$$

$$= 3.75\ Months$$

$$Total\ Empl.\text{-}Months\ for\ Project = \sum ((Empl's\ per\ Interval) \times (Months\ Active\ per\ Interval)$$

$$= (2\ Empl's \times 6\ Months) + (2\ Empl's \times 6\ Months) + (2\ Empl's \times 3\ Months)$$

$$= 30\ Employee\text{-}Months$$

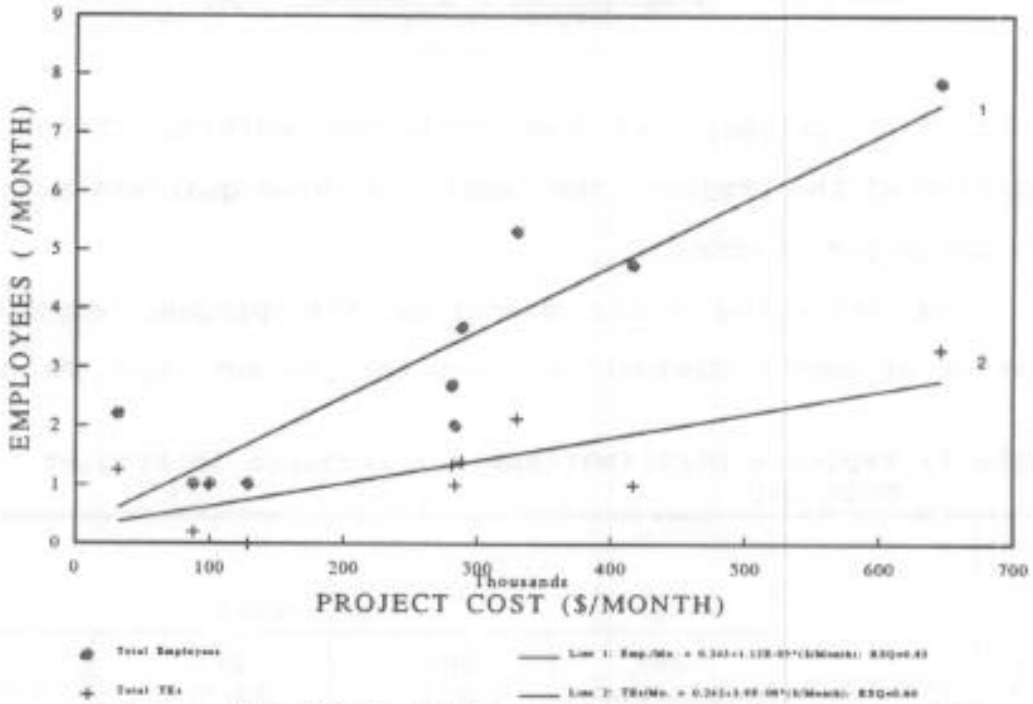


Figure 1(a): Project Type IA1 Linear Regression Lines.

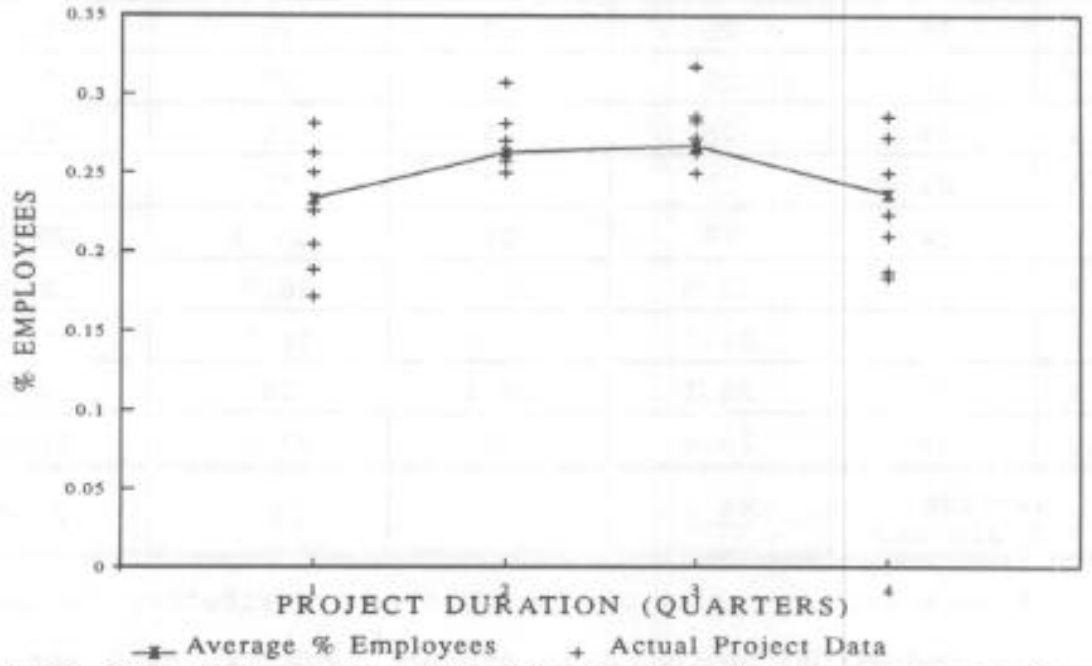


Figure 1(b): Project Type IA1 Distribution of Employees per Quarter.

$$\text{Percent Employees per Quarter} = \frac{(\text{Months per Quarter for Project}) \times (\text{Empl's per Quarter})}{(\text{Total Empl.-Months for Project})}$$

$$= \frac{(3.75\ \text{Months}) \times (2\ \text{Employees})}{(30\ \text{Employee-Months})} \times 100$$

$$= 25\%$$

Since this project had two employees working throughout the duration of the project, the remaining three quarters also had 25% employees per quarter.

The following table summaries the percent employees per quarter of each individual project for project type IA1 data set.

Table 3: Employee Distributions for Projects in Project Type IA1 Data Set

PROJECT	Duration (Months)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	18	25	25	25	25
2	15	25	25	25	25
3	12	25	25	25	25
4	16	25	25	25	25
5	24	19	27	32	22
6	24	17	26	28.5	28.5
7	37	22.5	30.7	28.3	18.4
8	24	26.3	26.3	26.3	21.1
9	18	28.1	28.1	25	18.8
10	18	20.4	25	27.3	27.3
Average % Employees		23.4	26.3	26.7	23.6

Figure 1(b) is a plot of the employee distribution per quarter for the individual projects in project type IA1 data set. This figure also shows the average percent employees per quarter. The

average percent employee distribution curve indicates that for project type IA1 the employee requirement for the first and fourth quarters are lower than the employee requirement for the middle two quarters.

PROJECT TYPE IA3 (URBAN, NEW CONSTRUCTION, OTHER):

There were five projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of this chapter. Table 4 gives the computed values from the raw data for each individual construction project.

Table 4:Computed Data for Project Type IA3

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl's per Month	T.E.'s per Month
1	1,151,406	36	31,984	0.625	0.25
2	454,840	24	18,951	0.4375	0
3	577,182	12	48,098	1	0
4	43,930	1	43,930	0.25	0
5	7,000,384	27	259,273	2.75	1

The linear regression between employees per month and project cost per month had a coefficient of determination (R^2) 0.94 . Line 1 in Figure 2(a) represents this regression line. The regression equation is shown below.

$$Employees/Month = 0.231 + (9.7 \times 10^{-6}) \times \left(\frac{Cost\ (\$)}{Month}\right) \qquad Equation\ 3$$

The linear regression between T.E.'s per month and project

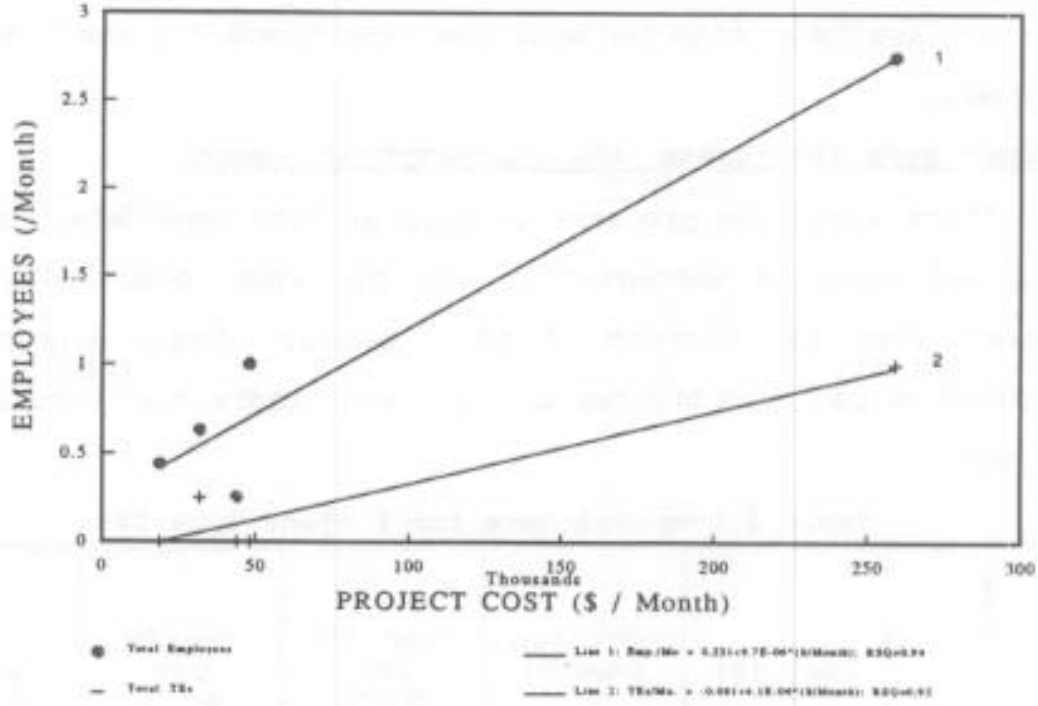


Figure 2(a): Project Type IA3 Linear Regression Lines.

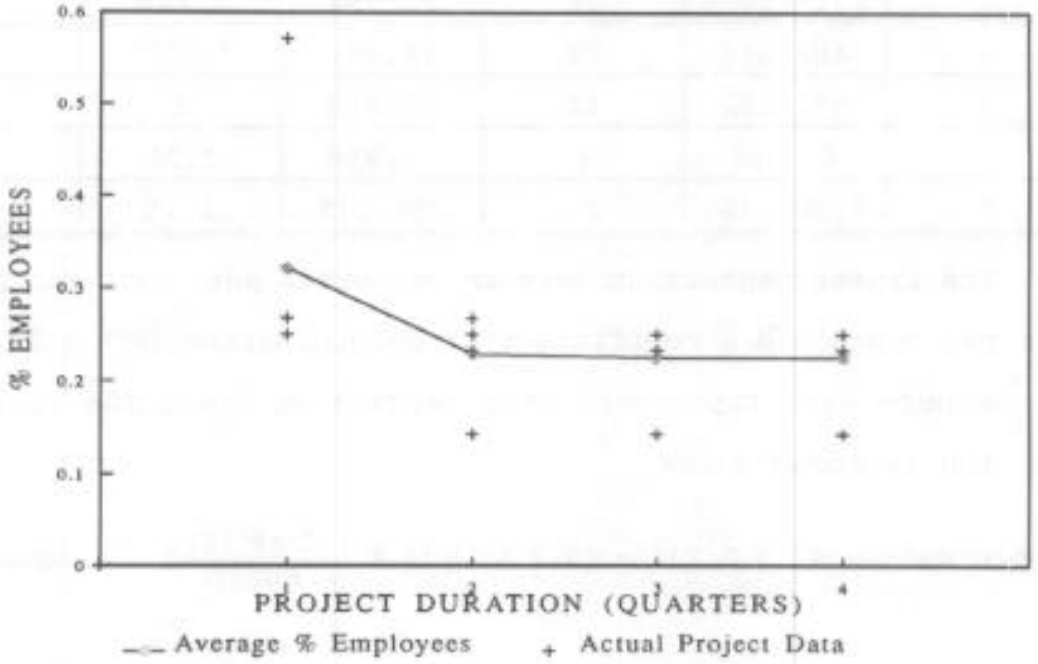


Figure 2(a): Projecet Type IA3 Distribution of Employees per Quarter.

cost per month had a coefficient of determination (R^2) 0.92 . Line 2 in Figure 2(a) represents this regression line. The relationship is given in Equation 4.

$$T.E.'s/Month = -0.081 + (4.1 + 10^{-6}) \; X \; (\frac{Cost(\$)}{Month}) \qquad Equation\ 4$$

The distribution of employees per quarter for project type IA3 data set is given in Table 5.

Table 5: Employee Distributions for Projects in Project Type IA3 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	26	26.7	26.7	23.3	23.3
2	24	57.1	14.3	14.3	14.3
3	12	25.0	25.0	25.0	25.0
4	1	25.0	25.0	25.0	25.0
5	27	26.8	23.2	25.0	25.0
Average % Employees		32.1	22.9	22.5	22.5

This data is graphically presented in Figure 2(b). Figure 2(b) also shows the average distribution of percent employees per quarter for project type IA3 data set.

PROJECT TYPE IB1 (URBAN, RECONSTRUCTION, MULTI-LANE ROADWAY):

There were thirteen projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of this chapter. Table 6 gives the computed values from the raw data for each individual construction

project.

Table 6: Computed Data for Project Type IB1

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl's per Month	T.E.'s per Month
1	2,991,139	24	124,630	1.25	1
2	14,563,490	20	728,174	7.78	2
3	1,159,192	21	55,199	1.39	0.39
4	2,296,952	18	127,608	3.33	2.67
5	1,914,243	24	79,760	1.25	0
6	567,344	7	81,049	1.36	0
7	7,789,097	12	649,091	3.25	0.15
8	1,325,567	18	73,642	2.42	0.21
9	8,242,489	18	457,916	3.58	0.09
10	1,305,582	17	76,798	1.82	1
11	2,877,202	21	137,009	2.50	0
12	3,991,081	21	190,051	2.04	1.61
13	6,676,692	18	370,927	4.17	2

The linear regression between employees per month and project cost per month had a coefficient of determination (R^2) 0.68 . Line 1 in Figure 3(a) represents this regression line. The regression equation is shown below.

$$Employees/Month = 1.243 + (6.3 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 5$$

The linear regression between T.E.'s per month and project cost per month had a coefficient of determination (R^2) 0.04 . Line 2 in Figure 3(a) represents this regression line. The relationship is given in Equation 6.

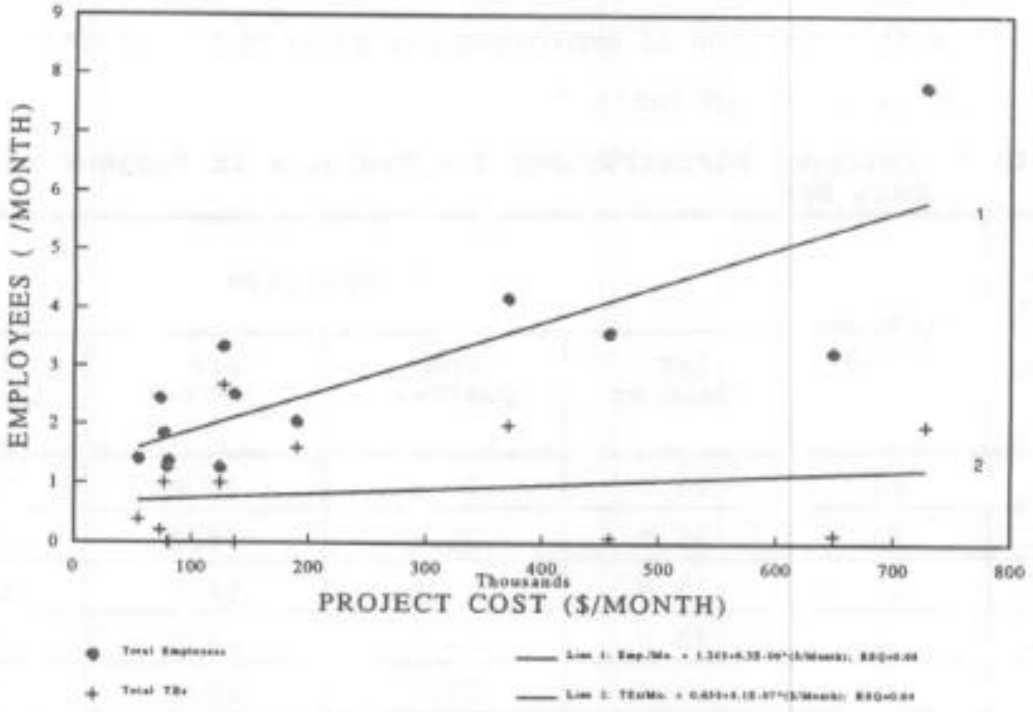


Figure 3(a): Project Type IB1 Linear Regression Lines.

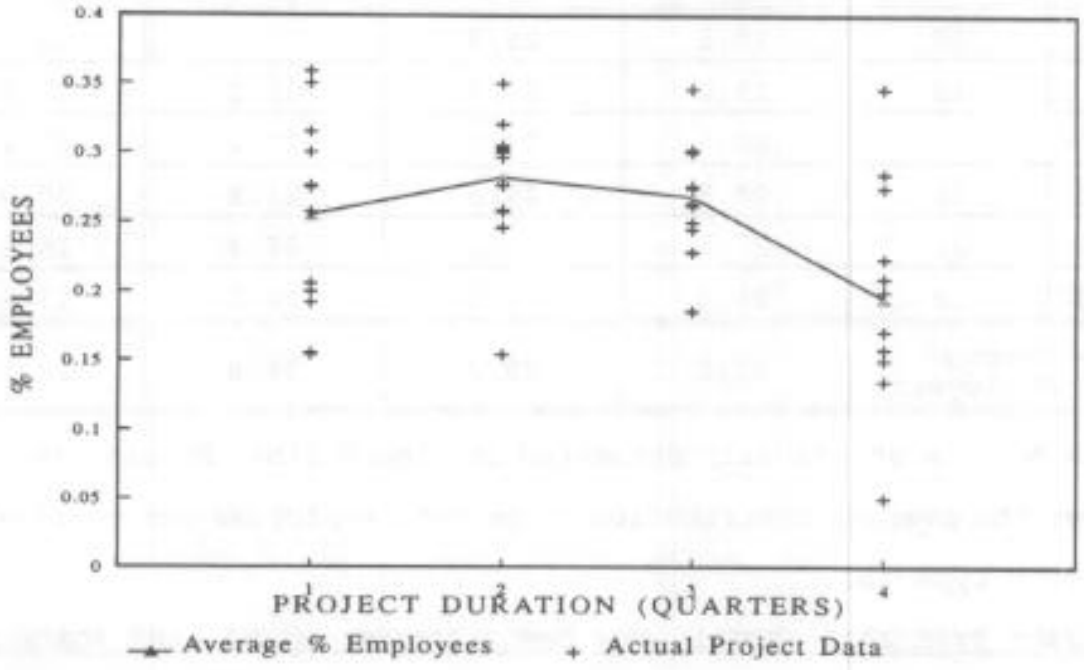


Figure 3(b): Project Type IB1 Distribution of Employees per Quarter.

$$T.E.'s/Month = 0.658 + (8.1 \times 10^{-7}) \times \left(\frac{Cost\ (\$)}{Month}\right) \qquad Equation\ 6$$

The distribution of employees per quarter for project type IB1 data set is given in Table 7.

Table 7: Employee Distributions for Projects in Project Type IB1 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	24	20.0	30.0	30.0	20.0
2	20	25.7	25.7	26.2	22.4
3	21	35.9	32.0	18.6	13.5
4	18	30.0	30.0	25.0	15.0
5	24	35.0	35.0	25.0	5.0
6	7	27.6	27.6	27.6	17.2
7	12	15.4	15.4	34.6	34.6
8	18	15.5	25.9	30.2	28.4
9	18	19.2	29.7	30.2	20.9
10	17	20.6	24.6	27.4	27.4
11	21	27.5	29.6	22.9	20.0
12	21	27.6	30.3	26.3	15.8
13	18	31.5	30.5	24.5	13.5
Average % Employees		25.5	28.2	26.8	19.5

This data is graphically presented in Figure 3(b). Figure 3(b) also shows the average distribution of percent employees per quarter for project type IB1.

PROJECT TYPE IIA1 (RURAL, NEW CONSTRUCTION, MULTI-LANE ROADWAY):

There were eight projects in this project type data set. This data was analyzed according to the procedure described in the

Project Type IA1 Section of this chapter. Table 8 gives the computed values from the raw data for each individual construction project.

Table 8: Computed Data for Project Type IIA1

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl's per Month	T.E.'s per Month
1	3,427,670	15	228,511	2.15	0.20
2	8,348,390	33	252,981	2.55	1.18
3	5,147,565	26	197,983	4.15	1.00
4	10,363,889	15	690,925	6.40	1.80
5	12,046,573	21	573,646	5.43	1.36
6	5,350,054	25	214,002	1.63	0.97
7	35,969,000	36	999,138	7.50	1.00
8	8,181,871	31	263,931	2.21	0.49

The linear regression between employees per month and project cost per month had a coefficient of determination (R^2) 0.85 . Line 1 in Figure 4(a) represents this regression line. The regression equation is shown below.

$$Employees/Month = 1.051 + (6.9 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 7$$

The linear regression between T.E.'s per month and project cost per month had a coefficient of determination (R^2) 0.22 . Line 2 in Figure 4(a) represents this regression line. The relationship is given in Equation 8.

$$T.E.'s/Month = 0.664 + (7.8 \times 10^{-7}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 8$$

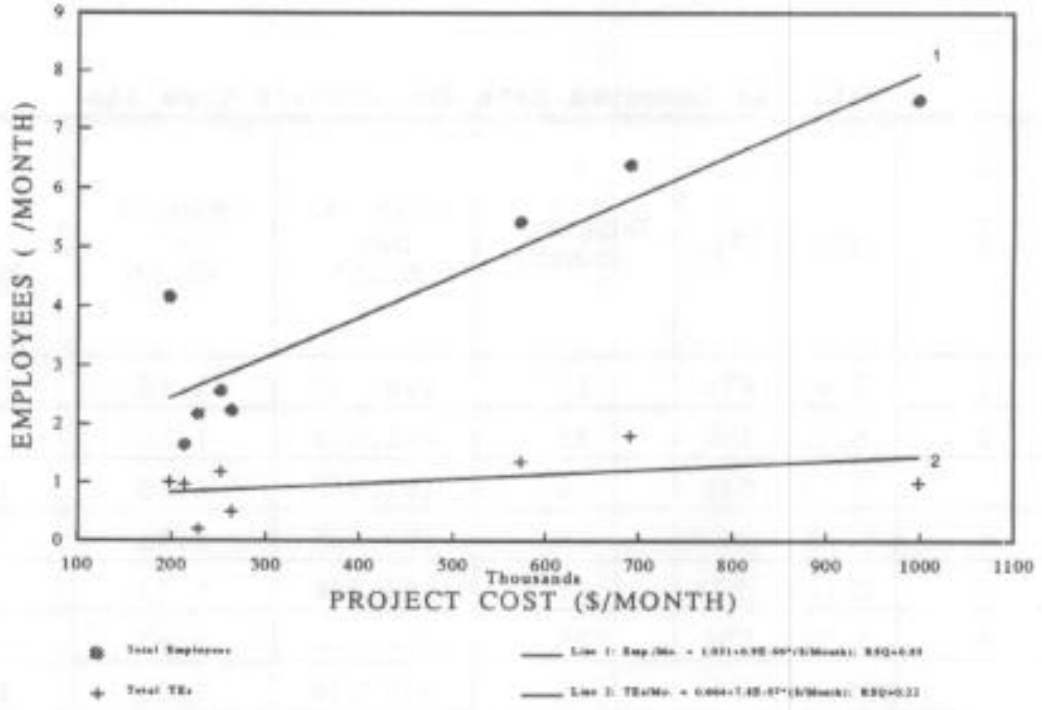


Figure 4(a): Project Type IIA1 Linear Regression Lines.

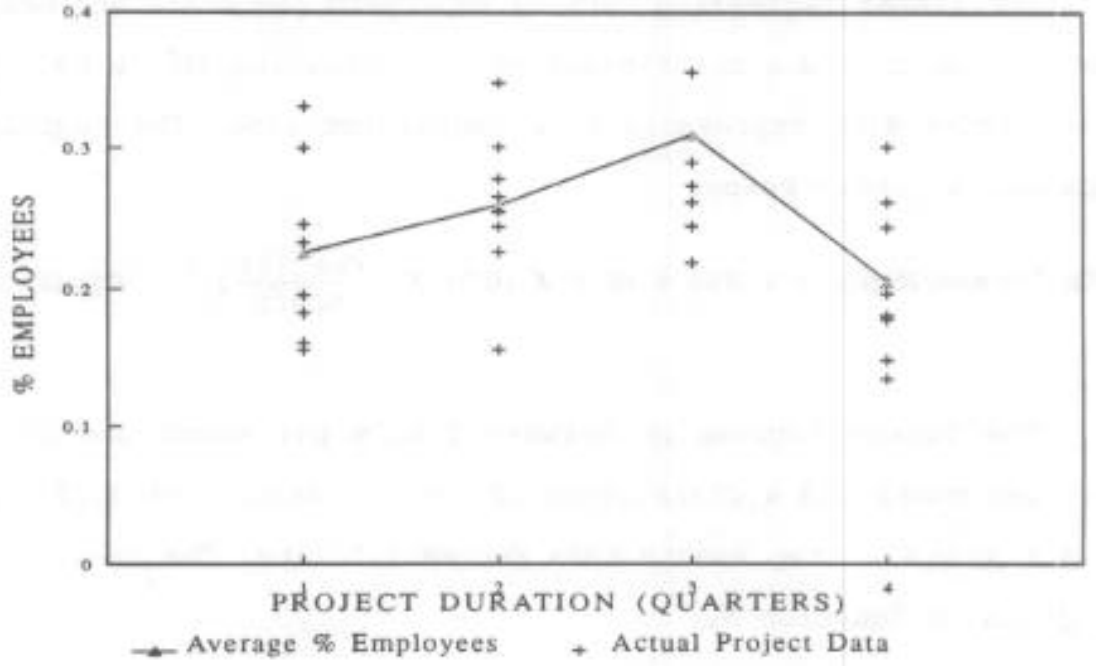


Figure 4(b): Project Type IIA1 Distribution of Employees per Quarter.

The distribution of employees per quarter for project type IIA1 data set is given in Table 9.

Table 9: Employee Distributions for Projects in Project Type IIA1 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	15	23.2	24.4	26.2	26.2
2	33	33.0	25.4	21.9	19.6
3	26	24.5	30.1	27.3	18.1
4	15	15.6	26.6	43.0	14.8
5	21	19.6	15.6	40.5	24.3
6	25	16.1	34.8	35.6	13.5
7	36	30.0	27.8	24.4	17.8
8	31	18.3	22.6	29.0	30.1
Average % Employees		22.5	25.9	31.0	20.6

This data is graphically presented in Figure 4(b). Figure 4(b) also shows the average distribution of percent employees per quarter for project type IIA1.

PROJECT TYPE IIA2 (RURAL, NEW CONSTRUCTION, TWO-LANE ROADWAY):

There were four projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of this chapter. Table 10 gives the computed values from the raw data for each individual construction project.

The linear regression between employees per month and project cost per month had a coefficient of determination (R^2) 0.83 . Line 1 in Figure 5(a) represents this regression line. The regression

Table 10: Computed Data for Project Type IIA2

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl's per Month	T.E.'s per Month
1	31,655	2	15,827	0.5	0
2	3,168,137	18	176,007	1	1
3	5,271,705	24	219,654	0.4	1
4	7,442,717	24	310,113	.07	0.25

relationship is given in Equation 9.

$$Employees/Month = -0.021 + (1.1 \times 10^{-5}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 9$$

The linear regression between T.E.'s per month and project cost per month had a coefficient of determination (R^2) 0.12. Line 2 in Figure 5(a) represents this regression line. The regression equation is shown below.

$$T.E.'s/Month = 0.296 + (1.5 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 10$$

The distribution of employees per quarter for project type IIA1 data set is given in Table 11. This data is graphically presented in Figure 5(b). Figure 5(b) also shows the average distribution of percent employees per quarter for project type IIA2.

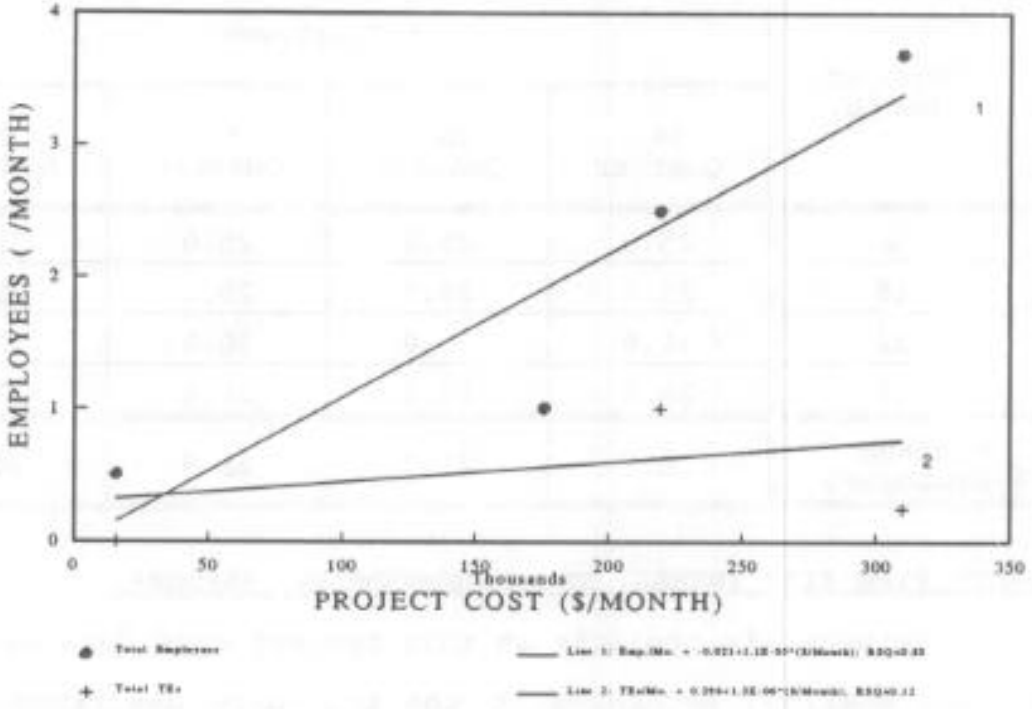


Figure 5(a): Project Type IIA2 Linear Regression Lines.

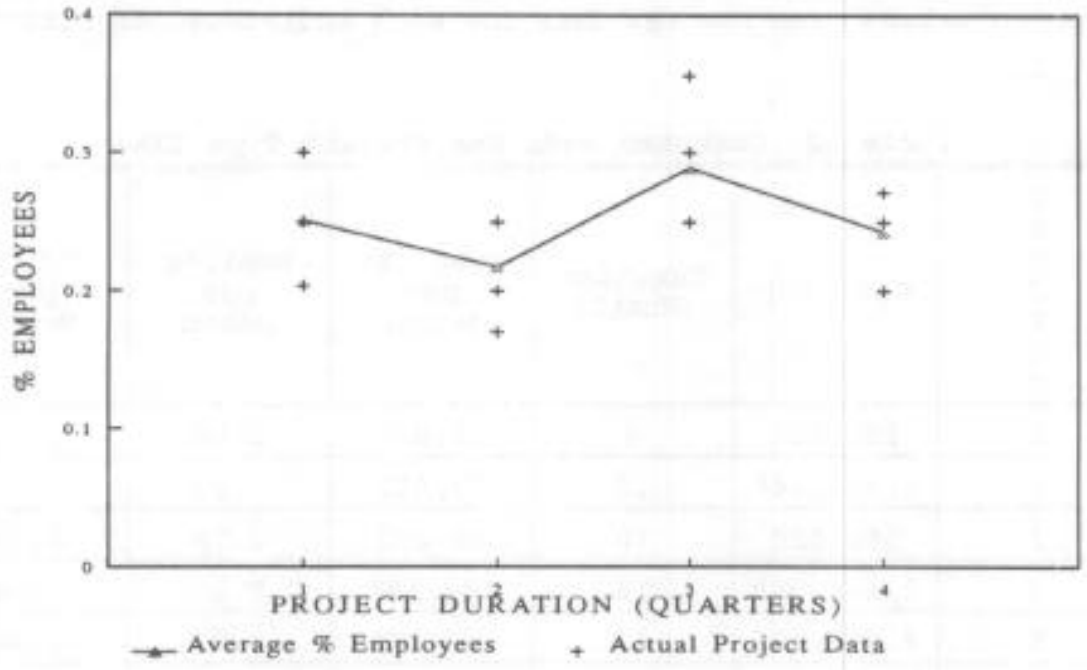


Figure 5(b): Project Type IIA2 Distribution of Employees per Quarter.

Table 11: Employee Distributions for Projects in Project Type IIA2 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	2	25.0	25.0	25.0	25.0
2	18	25.0	25.0	25.0	25.0
3	24	30.0	20.0	30.0	20.0
4	24	20.3	17.0	35.6	27.1
Average % Employees		25.1	21.7	28.9	24.3

PROJECT TYPE IIA4 (RURAL, NEW CONSTRUCTION, BRIDGE):

There were six projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of this chapter. Table 12 gives the computed values from the raw data for each individual construction project.

Table 12: Computed Data for Project Type IIA4

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl.'s per Month	T.E.'s per Month
1	181,101	8	22,637	1.00	1.00
2	1,331,148	18	73,952	2.25	0.25
3	560,020	10	56,002	0.70	0.00
4	2,144,068	14	153,147	0.50	0.14
5	7,048,369	43	163,915	2.03	1.00
6	417,890	10	41,789	1.25	0.25

The linear regression between employees per month and project

cost per month had a coefficient of determination (R^2) 0.02 . Line 1 in Figure 6(a) represents this regression line. The regression equation is shown below.

$$Employees/Month = 1.138 + (1.8 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 11$$

The linear regression between T.E.'s per month and project cost per month had a coefficient of determination (R^2) 0.01 . Line 2 in Figure 6(a) represents this regression line. The relationship is given in Equation 12.

$$T.E.'s/Month = 0.382 + (6.9 \times 10^{-7}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 12$$

The distribution of employees per quarter for project type IIA4 data set is given in Table 13.

Table 13: Employee Distributions for Projects in Project Type IIA4 Data Set

PROJECT	Duration (Month)	% Employee			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	8	25.0	25.0	25.0	25.0
2	18	25.0	25.0	25.0	25.0
3	10	17.9	17.8	28.6	35.7
4	14	25.0	25.0	25.0	25.0
5	43	25.9	24.9	24.6	24.6
6	10	25.0	25.0	25.0	25.0
Average % Employees		23.2	23.2	25.9	27.7

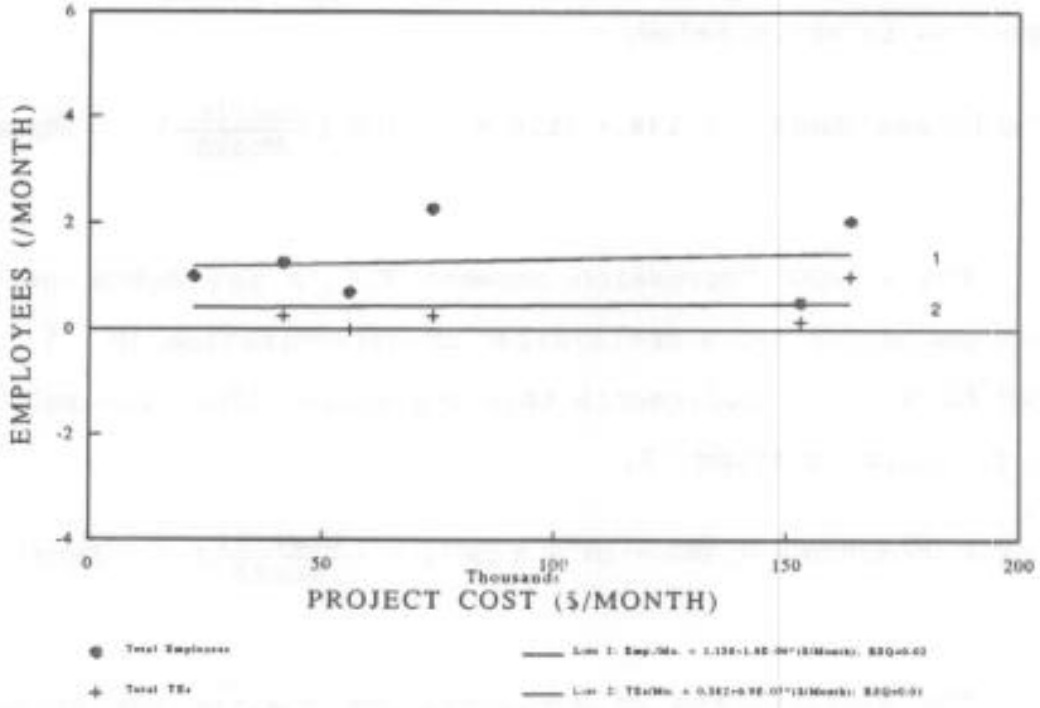


Figure 6(a): Project Type IIA4 Linear Regression Lines.

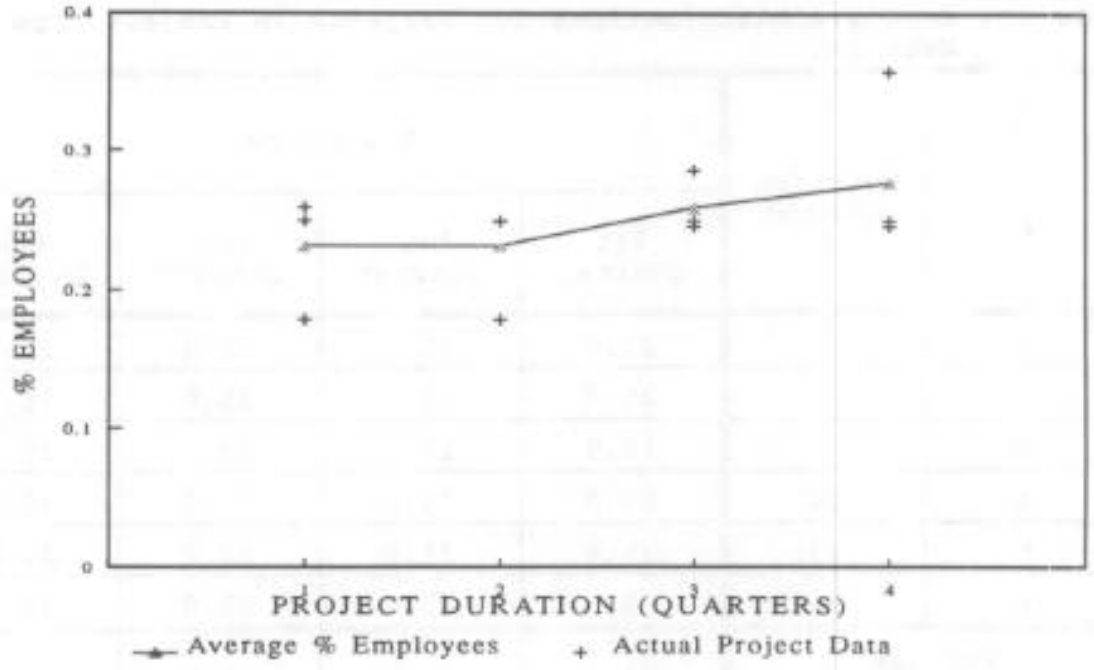


Figure 6(b): Project Type IIA4 Distribution of Employees per Quarter.

This data is graphically presented in Figure 6(b). Figure 6(b) also shows the average distribution of percent employees per quarter for project type IIA4.

PROJECT TYPE IIB1 (RURAL, RECONSTRUCTION, MULTI-LANE ROADWAY):

There were eleven projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of this chapter. Table 14 gives the computed values from the raw data for each individual construction project.

Table 14: Computed Data for Project Type IIB1

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl.'s per Month	T.E.'s per Month
1	6,812,327	26	262,012	1.81	0.00
2	2,014,574	17	118,504	1.15	1.00
3	4,073,890	18	226,327	3.33	0.67
4	666,226	10	66,622	1.65	0.25
5	2,431,939	20	121,597	2.18	0.00
6	18,738,159	31	604,456	6.52	1.58
7	13,127,817	30	437,593	3.50	1.00
8	1,944,021	12	162,001	2.50	0.00
9	1,115,507	8	139,438	1.69	0.50
10	2,146,014	17	126,236	2.04	0.32
11	8,069,554	30	268,985	3.4	1.00

The linear regression between employees per month and project cost per month had a coefficient of determination (R^2) 0.81 . Line 1 in Figure 7(a) represents this regression line. The regression relationship is shown in Equation 13.

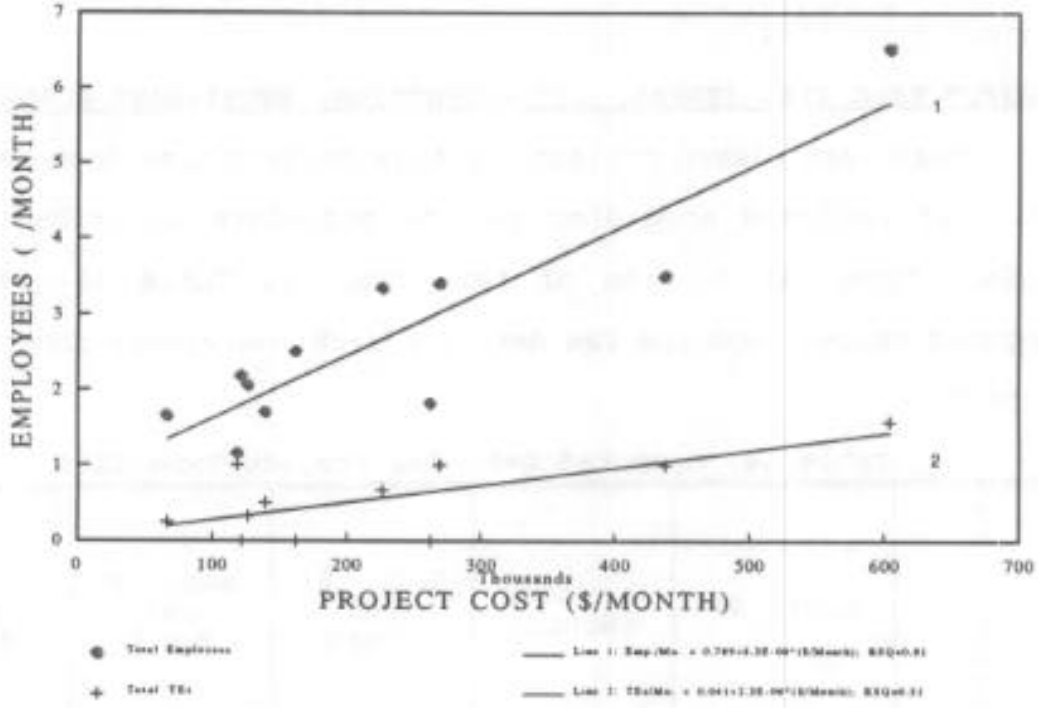


Figure 7(a): Project Type IIB1 Linear Regression Lines.

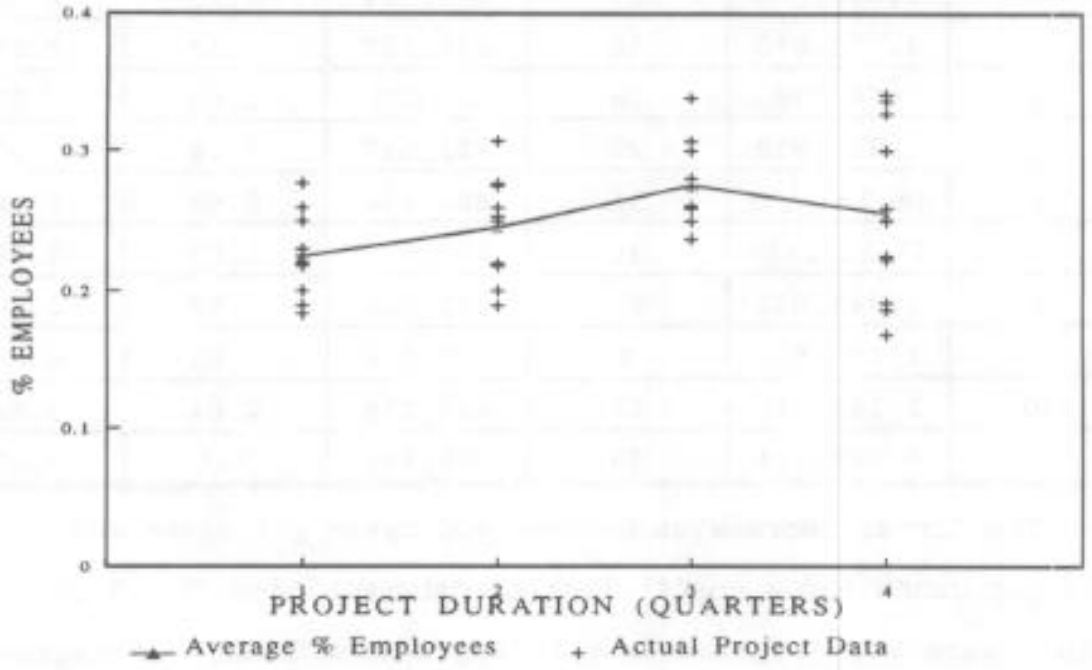


Figure 7(b): Project Type IIB1 Distribution of Employees per Quarter.

$$Employees/Month = 0.789 + (8.3 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 13$$

The linear regression between T.E.'s per month and project cost per month had a coefficient of determination (R^2) 0.22 . Line 2 in Figure 7(a) represents this regression line. The regression equation is shown below.

$$T.E.'s/Month = 0.041 + (2.3 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 14$$

The distribution of employees per quarter for project type IIB1 data set is given in Table 15.

Table 15: Employee Distributions for Projects in Project Type IIB1 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	26	27.7	27.6	26.1	18.6
2	17	21.8	21.8	23.7	32.7
3	18	22.5	27.5	27.5	22.5
4	10	18.9	18.9	28.1	34.1
5	20	22.9	25.3	25.9	25.9
6	31	21.8	30.7	30.7	16.8
7	30	25.0	25.0	25.0	25.0
8	12	20.0	20.0	30.0	30.0
9	8	25.9	25.9	25.9	22.3
10	17	18.3	21.9	26.1	33.6
11	30	22.1	25.0	33.8	19.1
Average %Employees		22.5	24.5	27.5	25.5

This data is graphically presented in Figure 7(b). Figure 7(b) also shows the average distribution of percent employees per quarter for project type IIB1.

PROJECT TYPE IIB2 (RURAL, RECONSTRUCTION, TWO-LANE ROADWAY):

There were five projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of this chapter. Table 16 gives the computed values from the raw data for each individual construction project.

Table 16: Computed Data for Project Type IIB2

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl.'s per Month	T.E.'s per Month
1	181,101	8	22,637	1.00	1.00
2	297,549	9	33,061	1.00	0.00
3	512,002	22	23,272	1.25	0.00
4	6,481,369	26	249,283	5.79	1.37
5	2,931,279	27	108,565	1.97	0.31

The linear regression between employees per month and project cost per month had a coefficient of determination (R^2) 0.96 . Line 1 in Figure 8(a) represents this regression line. The regression equation is shown below.

$$Employees/Month = 0.405 + (2.1 \times 10^{-5}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 15$$

The linear regression between T.E.'s per month and project cost per month had a coefficient of determination (R^2) 0.46 . Line

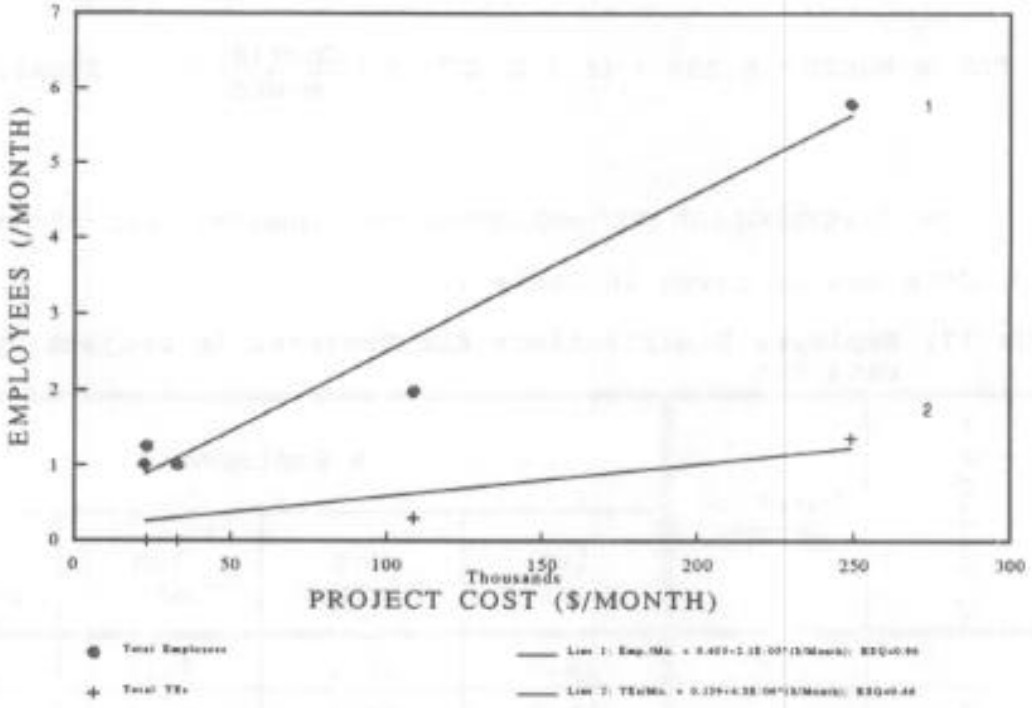


Figure 8(a): Project Type IIB2 Linear Regression Lines.

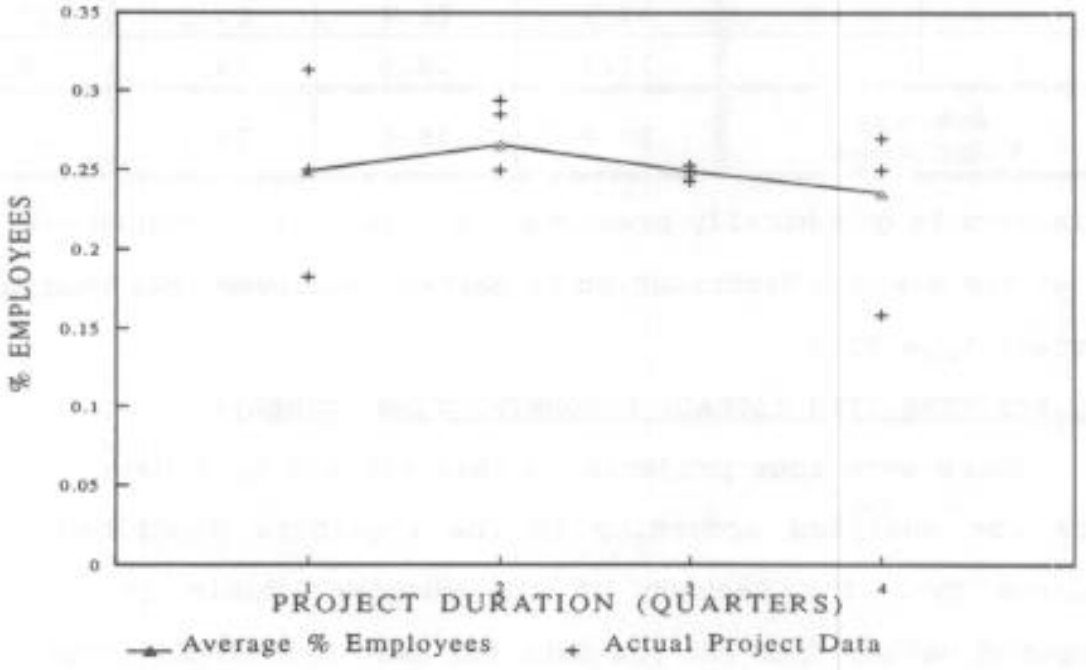


Figure 8(b): Project Type IIB2 Distribution of Employees per Quarter.

2 in Figure 8(a) represents this regression line. The regression relationship is given in Equation 16.

$$T.E./s/Month = 0.159 + (4.3 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 16$$

The distribution of employees per quarter for project type IIB2 data set is given in Table 17.

Table 17: Employee Distributions for Projects in Project Type IIB2 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	8	25.0	25.0	25.0	25.0
2	9	25.0	25.0	25.0	25.0
3	22	25.0	25.0	25.0	25.0
4	26	18.3	29.4	25.3	27.0
5	27	31.3	28.5	24.3	15.9
Average % Employees		24.9	26.6	24.9	23.6

This data is graphically presented in Figure 8(b). Figure 8(b) also shows the average distribution of percent employees per quarter for project type IIB2.

PROJECT TYPE IIB3 (RURAL, RECONSTRUCTION, OTHER):

There were four projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of the chapter. Table 18 gives the computed values from the raw data for each individual construction project.

Table 18: Computed Data for Project Type IIB3

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl.'s per Month	T.E.'s per Month
1	23,473	2	11,736	0.50	0.00
2	123,184	3	41,061	1.00	0.50
3	127,022	3	42,340	1.00	0.00
4	646,000	9	71,777	1.00	0.00

The linear regression between employees per month and project cost per month had a coefficient of determination (R^2) 0.67 . Line 1 in Figure 9(a) represents this regression line. The regression equation is shown below.

$$Employees/Month = 0.528 + (8.3 \; X \; 10^{-6}) \; X \; (\frac{Cost(\$)}{Month}) \qquad Equation \; 17$$

The linear regression between T.E.'s per month and project cost per month could not be performed on this project type data set. Three of the four projects had no T.E.'s working on them. Thus, there was not enough data to perform the regression analysis.

The distribution of employees per quarter for project type IIB3 data set is given in Table 19. This data is graphically presented in Figure 9(b). Figure 9(b) also shows the average distribution of percent employees per quarter for project type IIB3.

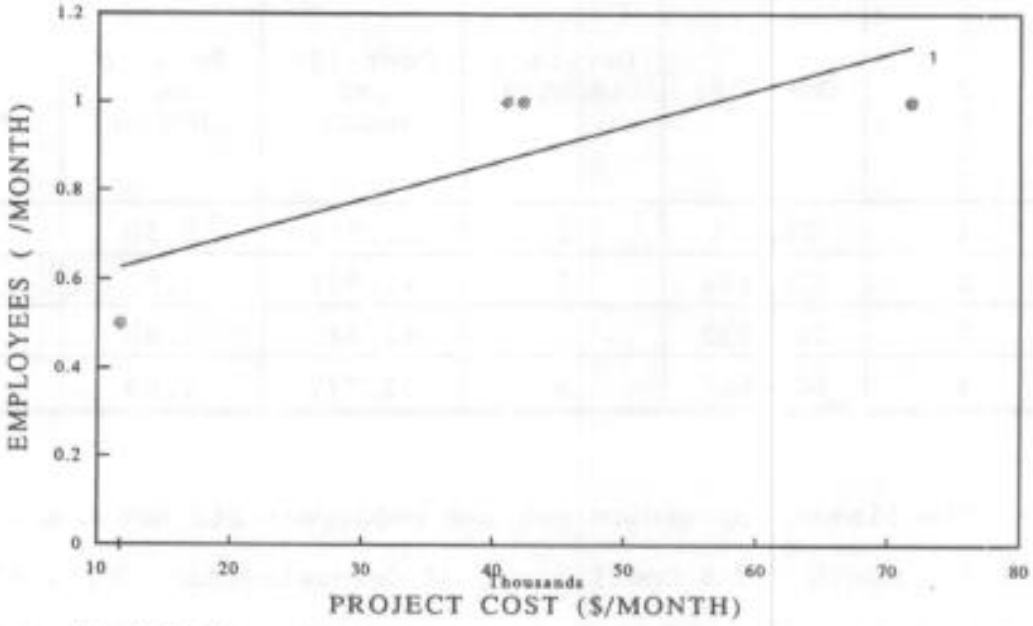


Figure 9(a): Project Type IIB3 Linear Regression Line.

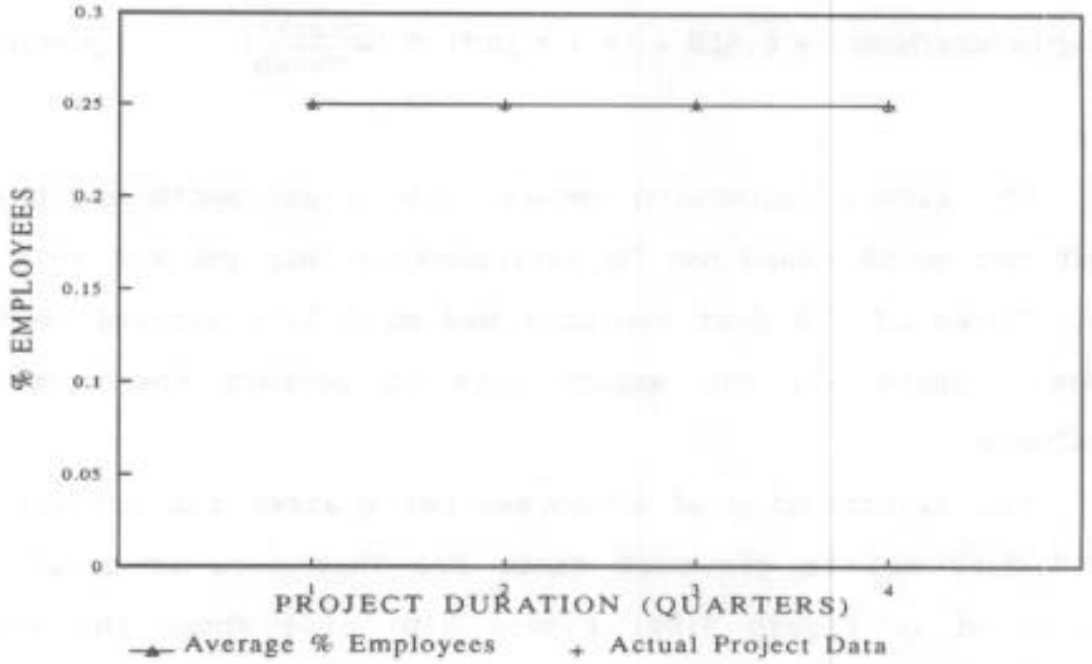


Figure 9(b): Project Type IIB3 Distribution of Employees per Quarter.

Table 19: Employee Distributions for Projects in Project Type IIB3 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	2	25.0	25.0	25.0	25.0
2	3	25.0	25.0	25.5	25.0
3	3	25.0	25.0	25.5	25.0
4	9	25.0	25.0	25.0	25.0
Average % Employees		25.0	25.0	25.0	25.0

PROJECT TYPE IIB4 (RURAL, RECONSTRUCTION, BRIDGE):

There were six projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of this chapter. Table 20 gives the computed values from the raw data for each individual construction project.

Table 20: Computed Data for Project Type IIB4

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl.'s per Month	T.E.'s per Month
1	1,293,309	9	143701	1.00	0.00
2	652,366	12	54363	1.00	0.00
3	1,530,590	18	85032	1.54	1.04
4	1,543,234	18	85735	1.21	0.21
5	1,406,370	16	87898	1.25	0.25
6	1,679,432	17	98790	1.60	0.60

The linear regression between employees per month and project

cost per month had a coefficient of determination (R^2) 0.66 . Line 1 in Figure 10(a) represents this regression line. The regression equation is shown below.

$$Employees/Month = 0.317 + (1.2 \times 10^{-5}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 18$$

The linear regression between T.E.'s per month and project cost per month had a coefficient of determination (R^2) 0.30 . Line 2 in Figure 10(a) represents this regression line. The regression relationship is given in Equation 19.

$$T.E.'s/Month = 0.682 + (1.3 \times 10^{-5}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 19$$

The distribution of employees per quarter for project type IIB4 data set is given in Table 21.

Table 21: Employee Distributions for Projects in Project Type IIB4 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	9	25.0	25.0	25.0	25.0
2	12	25.0	25.0	25.0	25.0
3	18	20.3	31.1	30.4	18.2
4	18	25.9	25.8	25.0	23.3
5	16	25.0	25.0	25.0	25.0
6	17	27.3	27.3	25.9	19.5
Average % Employees		24.7	26.5	26.1	22.7

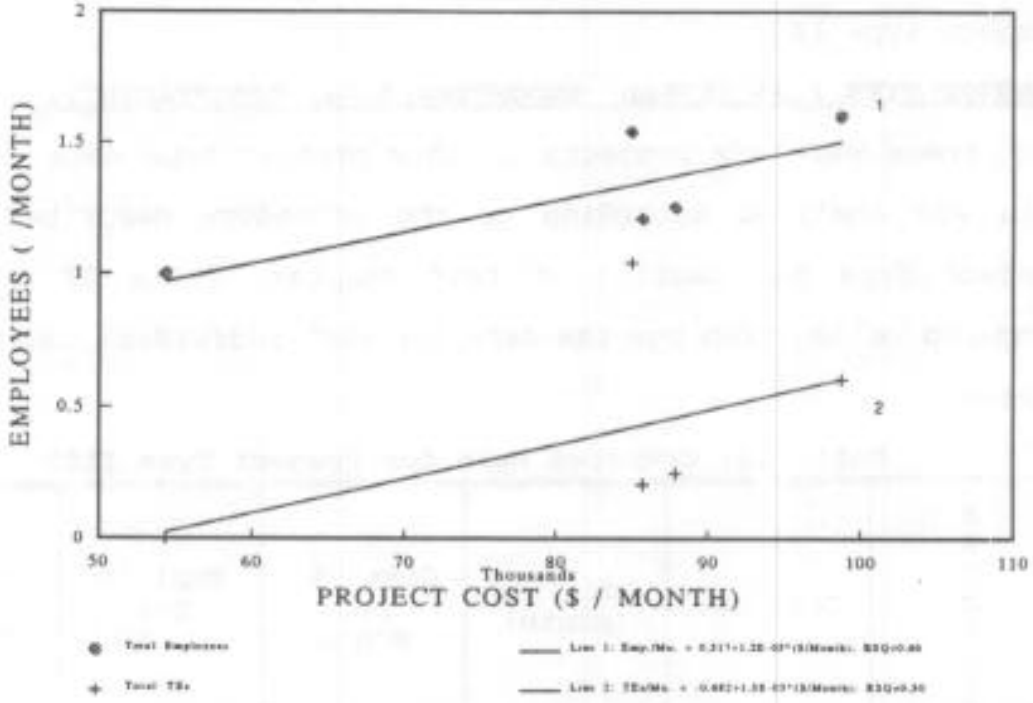


Figure 10(a): Project Type IIB4 Linear Regression Lines.

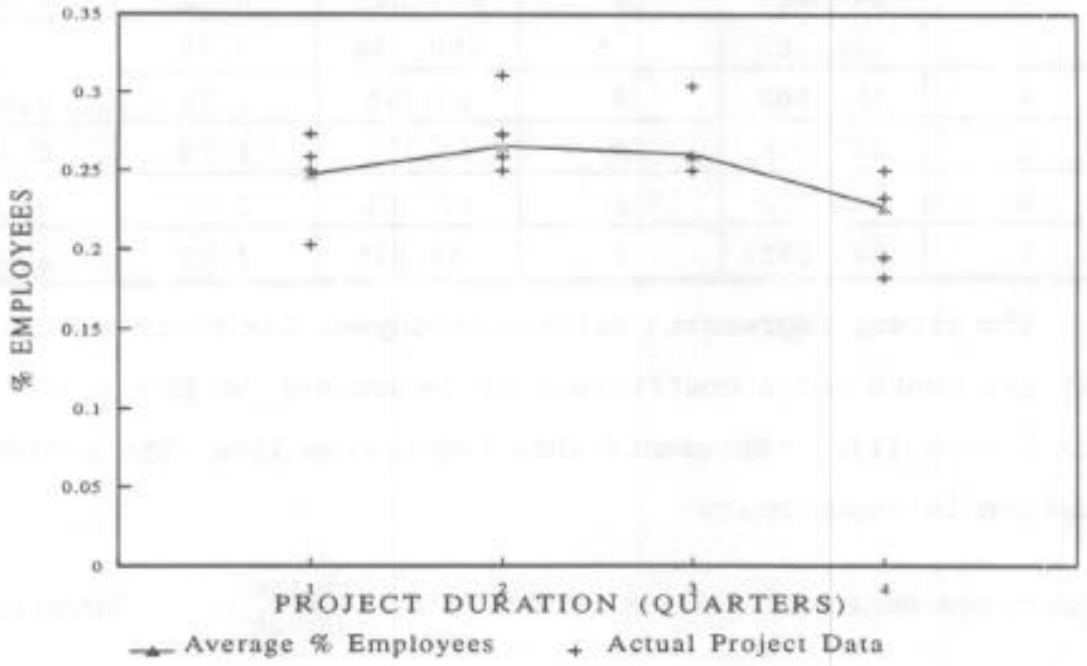


Figure 10(b): Project Type IIB4 Distribution of Employees per Quarter.

This data is graphically presented in Figure 9(b). Figure 9(b) also shows the average distribution of percent employees per quarter for project type IIB4.

PROJECT TYPE IIB5 (RURAL, RECONSTRUCTION, RESURFACING):

There were six projects in this project type data set. This data was analyzed according to the procedure described in the Project Type IA1 Section of this chapter. Table 22 gives the computed values from the raw data for each individual construction project.

Table 22: Computed Data for Project Type IIB5

PROJECT	Cost ($)	Duration (Month)	Cost ($) per Month	Empl.'s per Month	T.E.'s per Month
1	12,012	0.1	120,120	1.00	0.00
2	246,219	1	246,219	0.75	0.00
3	226,180	1.5	150,786	0.75	0.00
4	351,502	4	87,875	1.25	0.00
5	482,578	8	60,322	1.19	0.44
6	524,172	6	87,361	1.25	0.25
7	399,071	2	199,535	3.00	2.00

The linear regression between employees per month and project cost per month had a coefficient of determination (R^2) 0.03 . Line 1 in Figure 11(a) represents this regression line. The regression equation is shown below.

$$Employees/Month = 1.097 + (1.9 \times 10^{-6}) \times \left(\frac{Cost(\$)}{Month}\right) \qquad Equation\ 20$$

The linear regression between T.E.'s per month and project

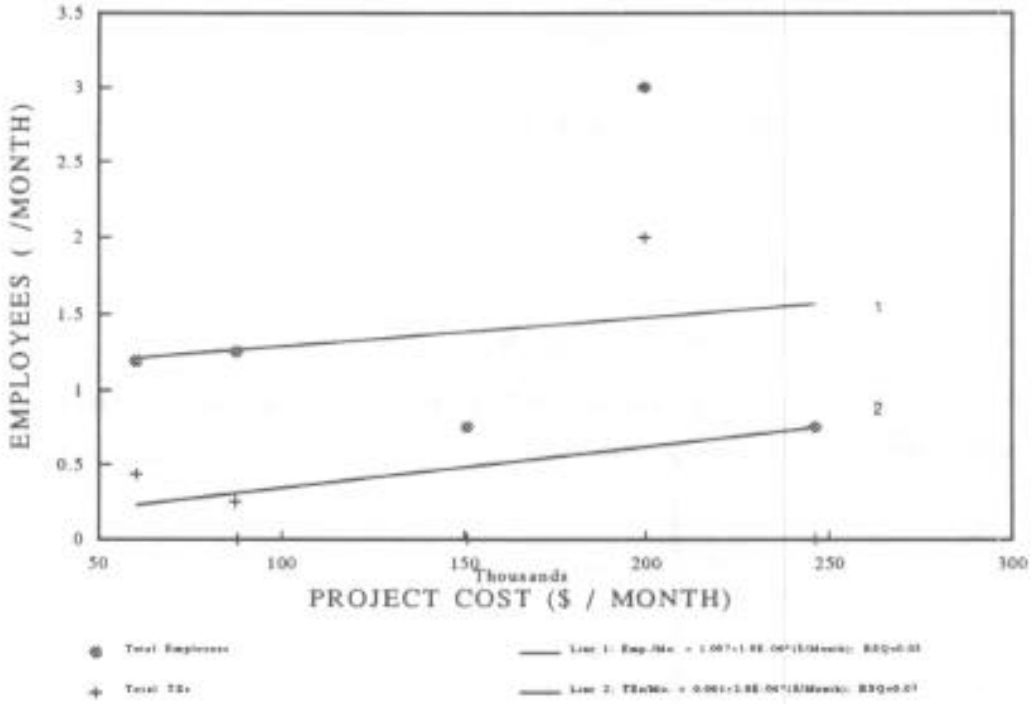


Figure 11(a): Project Type IIB5 Linear Regression Lines.

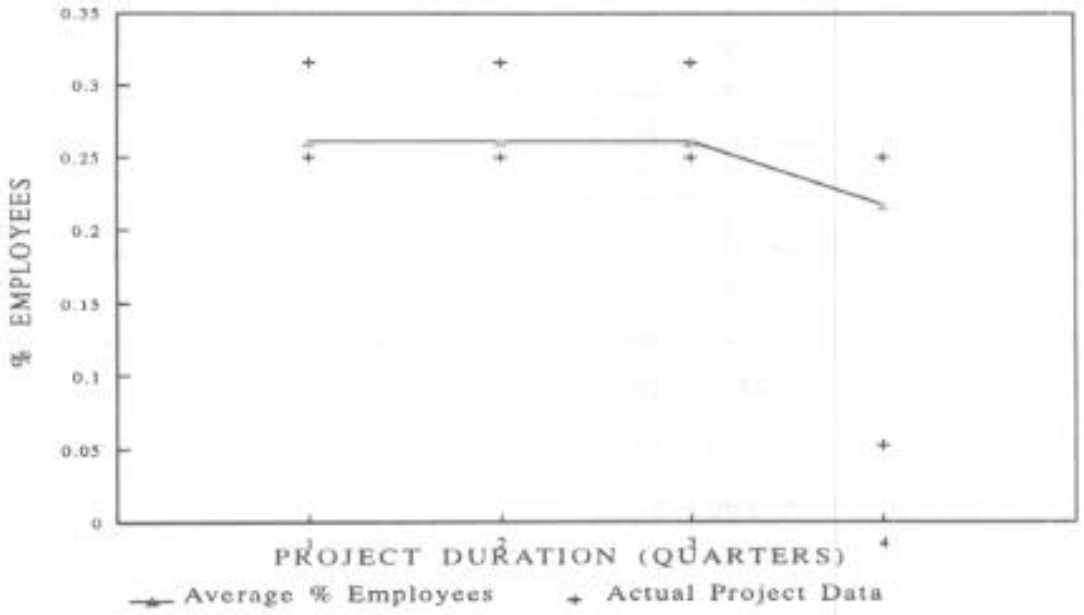


Figure 11(b): Project Type IIB5 Distribution of Employees per Quarter.

cost per month had a coefficient of determination (R^2) 0.07 . Line 2 in Figure 11(a) represents this regression line. The regression relationship is given in Equation 21.

$$T.E.'s/Month = 0.061 + (2.8 \times 10^{-6}) \times (\frac{Cost(\$)}{Month}) \qquad Equation\ 21$$

The distribution of employees per quarter for project type IIB5 data set is given in Table 23.

Table 23: Employee Distributions for Projects in Project Type IIB5 Data Set

PROJECT	Duration (Month)	% Employees			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	0.1	--	--	--	--
2	1	25.0	25.0	25.0	25.0
3	1.5	25.0	25.0	25.0	25.0
4	4	25.0	25.0	25.0	25.0
5	8	31.6	31.6	31.6	5.2
6	6	25.0	25.0	25.0	25.0
7	2	25.0	25.0	25.0	25.0
Average % Employees		26.1	26.1	26.1	21.7

This data is graphically presented in Figure 11(b). Figure 11(b) also shows the average distribution of percent employees per quarter for project type IIB5.

V. RESULTS OF DATA ANALYSIS

The following project types IA2, IA4, IB2, IB3, IB4, IB5, and IIA3 had less than four construction projects in their data sets. Thus, data analysis could not be performed on these project types due to the insufficient data.

For the project type III (Non-Let, PR County Contracts), there were eight projects. However, most of these projects had durations that were less than six months and had less than one employee working on them. Thus, the linear regression results for this project type were very poor. The system developed in this study is inadequate for this project type. Further studies need to be performed on projects under the type III category.

The linear regression results, the number of projects in each project type, and the project types are given in Table 24. Employees and T.E.'s per month were utilized as the dependent variable (Y) and project cost per month was utilized as the independent variable (X) in the linear regression process.

As given in Table 24, the employees per month versus project cost per month linear regression correlations were high. All project types except IIA4 and IIB5 had high R^2 values and low values for the standard error of estimate for Y. This indicates that there was a good correlation between employees per month and project cost per month. Therefore, the manpower prediction procedure developed in this study utilizing employees per month and project cost per month data will predict manpower needs satisfactorily and could be utilized on future construction projects. Table 24 also indicates that the linear regression correlations between T.E.'s per month versus project cost per month

Table 24: Linear Regression Results

Project Type	Linear Regression	Number of Projects	Coefficient of Determination R^2	Standard Error of Estimate for Y
IA1	Employees	10	0.831	0.985
	T.E.'s	10	0.600	0.625
IA3	Employees	5	0.935	0.297
	T.E.'	5	0.915	0.146
IB1	Employees	13	0.680	1.057
	T.E.'s	13	0.041	0.953
IIA1	Employees	8	0.847	0.937
	T.E.'s	8	0.221	0.470
IIA2	Employees	4	0.834	0.724
	T.E.'s	4	0.125	0.590
IIA4	Employees	6	0.022	0.787
	T.E.'s	6	0.008	0.493
IIB1	Employees	11	0.813	0.679
	T.E.'s	11	0.511	0.385
IIB2	Employees	5	0.960	0.471
	T.E.'s	5	0.457	0.526
IIB3	Employees	4	0.665	0.177
	T.E.'s	4	0.001	0.306
IIB4	Employees	6	0.657	0.169
	T.E.'s	6	0.295	0.397
IIB5	Employees	6	0.028	0.920
	T.E.'s	6	0.068	0.843

were poor. Most of the projects had lower R^2 values indicating poor correlations between the X and Y data. T.E.II trainees in construction projects could be a possible cause for this poor correlation. Although they are accounted for as T.E.'s, they do not carry responsibilities of regular T.E.'s. Thus, the manpower prediction procedure developed in this study utilizing T.E.'s per month and project cost per month data should be utilized cautiously.

VI. CASE STUDY

The manpower prediction procedure developed in this study can be utilized on new construction projects during their planning stage to help management predict manpower needs. If this procedure is utilized correctly (used as an aid in estimating manpower needs and not substituting it for good engineering judgements) it could be a helpful tool for the GADOT. The following case study describes the use of the developed procedure.

A new multi-lane roadway construction project [F-171-1(1)01] was completed in Chatham County. The cost of this project was $23,912,792.15 and the duration was thirty seven months. The intention of this case study is to utilize the project information listed above in conjunction with the manpower prediction system developed earlier in this study to determine the project manpower requirement. The following step by step procedure demonstrates the use of this system.

Step 1: Identify the project type.

The project described above falls under the project type IA1 category.

Step 2: Calculate the project cost per month.

$$Total\ Cost/Project\ Duration = \frac{\$23,912,792.15}{37\ Months}$$

$$= \$646,292\ per\ Month$$

Step 3: Use Equation 1 or Line 1 in Figure 1(a) to determine the employees per month. In this case utilize Equation 1.

$$Employees/Month = 0.245 + (1.12 \times 10^{-5}) \times (646,292)$$

$$= 7.48\ Employees\ per\ Month$$

Step 4: Use Equation 2 or Line 2 in Figure 2(a) to determine the T.E.'s per month. In this case utilize Equation 2.

$$T.E.'s/Month = 0.242 + (3.9 \times 10^{-6}) \times (646,292)$$

$$= 2.76\ T.E.'s\ per\ Month$$

Step 5: Determine T.E.'s / employees per month Ratio.

$$T.E's/Employees\ per\ Month\ Ratio = \frac{T.E.'s\ per\ Month}{Employees\ per\ Month}$$

$$= \frac{2.76}{7.48} = 0.37$$

Step 6: Determine employees per month for each quarter. Utilize the average percent employees value from Figure 1(b) or Table 3.

$$Employees/Month\ (1st\ Quarter) = (Employees/Month) \times (Average\ \%\ Empl.'s) \times (No.\ of\ Quarters)$$

$$= 7.48 \times 0.23 \times 4 = 6.88$$

$$Employees/Month\ (2nd\ Quarter) = 7.48 \times 0.26 \times 4 = 7.78$$

$$Employees/Month\ (3rd\ Quarter) = 7.48 \times 0.27 \times 4 = 8.08$$

$$Employees/Month\ (4th\ Quarter) = 7.48 \times 0.24 \times 4 = 7.18$$

Step 7: Determine T.E.'s per month for each quarter.

T.E.'s/Month (1st Quarter) = [Empl.'s/Month (1st Quarter)] X (T.E.'s/Empl.'s per Month Ratio)
= 6.88 X 0.37 = 2.55

T.E.'s/Month (2ndQuarter) = 7.78 *X* 0.37 = 2.88
T.E.'s/Month (3rdQuarter) = 8.08 *X* 0.37 = 2.99
T.E.'s/Month (4thQuarter) = 7.18 *X* 0.37 = 2.66

Step 8: Final estimate of employee requirement.

Final employee estimates are given in Table 25. As shown in the table these estimates are recorded only to one decimal point.

Table 25: Final Estimate of Employees Obtained from Manpower System for Project in Case Study

Project Duration in Quarters	1	2	3	4
Project Duration in Months	0 - 9.25	9.25 - 18.5	18.5 - 27.75	27.75 - 37
Employees per Month	6.9	7.8	8.1	7.2
T.E.'s per Month	2.5	2.9	3.0	2.7

Table 26 shows the actual employee distribution for the project in this case study.

Table 26: Actual Employee Distribution for Project in Case Study

Months	1st Six	2nd Six	3rd Six	4th Six	5th Six	6th Six	7th Six
Empl.'s per Month	6.25	7.75	10	8.5	8.5	5	2
T.E.'s per Month	2.75	4.5	3.5	3	3.5	2	1

A comparison of the actual employee distribution and the estimated employee distribution obtained from the manpower system for the project in this case study is shown in Figure 12.

VI. CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

1. A manpower management system based primarily on construction dollars was developed for GDOT.
2. This system is able to estimate the number of employees and engineers required for different construction projects.
3. The developed system is presented in a simple computer program "MANPOWER" and a set of charts. This computer program and charts will be helpful in the implementation of the findings of this study.

Recommendations:

1. It is recommended that the manpower management system developed in this study be utilized on future construction projects during their planning stage to help management predict manpower needs.

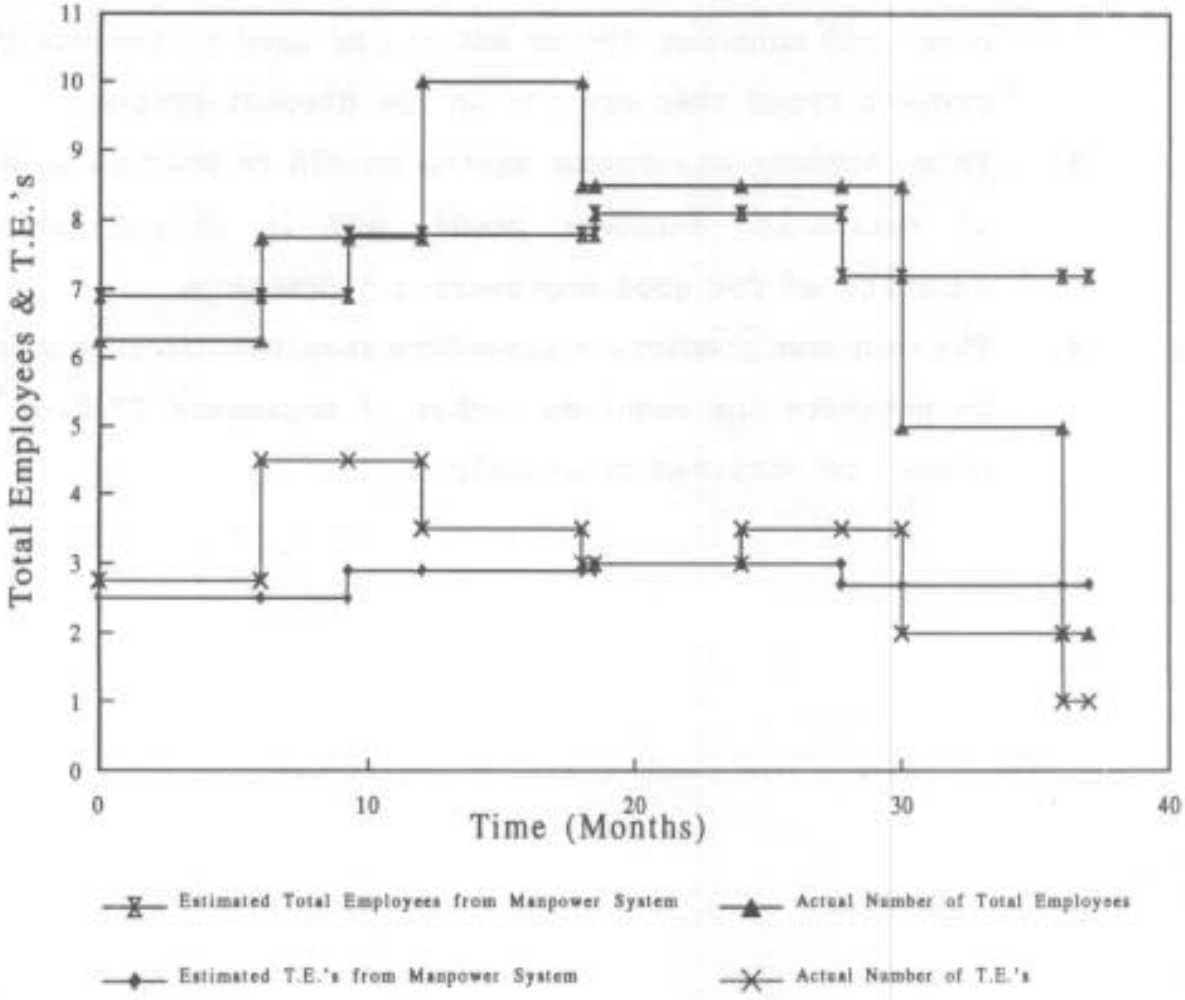


Figure 12: Actual and Estimated Total Employee and T.E. Distributions in the Case Study

2. It is recommended that a database of personnel use be maintained in the future on all project types. After a few years, the new database can be used to upgrade the developed manpower system and can be used to include the project types that are not in the present system.
3. This manpower management system should be used as an aid in estimating manpower needs, and it should not be substituted for good engineering judgements.
4. The manpower prediction procedure developed in this study to estimate the required number of engineers (T.E.'s) should be utilized cautiously.

Appendix A

A User Guide for Manpower program

MANPOWER PROGRAM
VERSION 1.0 AUGUST 1993

A. GENERAL

The MANPOWER program is a tool to predict personnel needs for construction projects in the Georgia Department of Transportation. This procedure was developed using data collected from the completed construction projects. This program is capable of providing accurate estimates for personnel needs in construction projects. But these estimates are not intended to replace good engineering judgements. It is very important to maintain good records such as number of employees in construction projects and their devoted time to each project in the future. These data will enable to evaluate the developed manpower prediction procedure and also to revise it, if necessary.

B. RUNNING THE MANPOWER PROGRAM

The MANPOWER program is located in DTD1MR directory in the main frame (VAX) computer system. Log on to your regular directory in VAX system. To copy MANPOWER program to your directory type ***COPY[DTD1MR] MANPOWER.EXE*** and press ***ENTER*** key. The following section explains the steps in running the program using an example. Assume that you are required to estimate the personnel needs for the following project. A new multi-lane roadway project in Chatham county is scheduled to complete in 37 months. The estimated cost of the project is $ 23,912,792.15 and the project number is F-171-1(1) 01.

To run the MANPOWER program type ***RUN MANPOWER*** and press ***ENTER*** key. Now the following screen will appear.

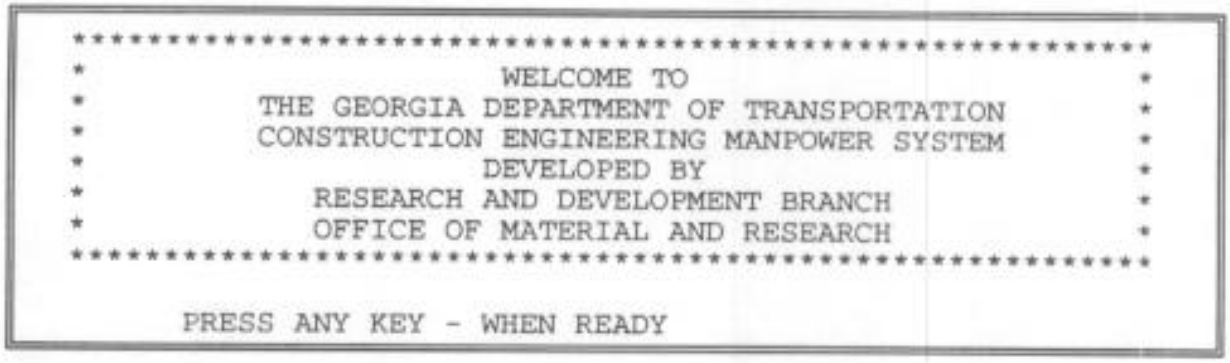


Figure A1

Now press ***any key***. The following screen will scroll up to the screen.

```
        PLEASE IDENTIFY THE PROJECT TYPE FROM
                THE FOLLOWING LIST

    Project Type                                    Identification

URBAN-NEW CONSTRUCTION - MULTI LANE ROADWAY              IA1
          (INCLUDING BRIDGES)
URBAN-NEW CONSTRUCTION - OTHERS                          IA3
URBAN-RECONSTRUCTION   - MULTI LANE ROADWAY              IB1
          (INCLUDING BRIDGES)
RURAL-NEW CONSTRUCTION - MULTI LANE ROADWAY              IIA1
          (INCLUDING BRIDGES)
RURAL-NEW CONSTRUCTION - TWO LANE ROADWAY                IIA2
RURAL-NEW CONSTRUCTION - BRIDGES                         IIA4
RURAL-RECONSTRUCTION   - MULTI LANE ROADWAY              IIB1
          (INCLUDING BRIDGES)
RURAL-RECONSTRUCTION   - TWO LANE ROADWAY                IIB2
RURAL-RECONSTRUCTION   - OTHERS                          IIB3
   (INTERSECTIONS, SIGNALS, LANDSCAPE, ETC.)
RURAL-RECONSTRUCTION   - BRIDGES                         IIB4
RURAL-RECONSTRUCTION   - RESURFACING (ALL TYPES)         IIB5

 PLEASE ENTER YOUR PROJECT IDENTIFICATION NUMBER
```

Figure A2

Please read these project types and identify the project identification number which represents the project you want to analyze. Then type project identification number and press enter key. Project type for our example problem is IA1. Now type ***IA1*** and press ***ENTER*** key. The following statement will appear on the screen.

```
PLEASE ENTER ESTIMATED TOTAL PROJECT COST
(Example for $ 6,000,000.50 Project Enter 6000000.50)
```

Figure A3

Project cost of our example problem is $ 23,912,792.15. Therefore, type ***23912792.15*** and press ***ENTER*** key. As soon as project cost is entered the computer ask for the project duration with the following statement.

```
PLEASE ENTER ESTIMATED PROJECT DURATION IN MONTHS
```

Figure A4

Answer to this by typing project duration in months and press enter key. This value for our example problem is 37. Type ***37*** and press ***ENTER*** key. Now the program does the computation and the results will appear on the screen. The results of the our example problem is given below.

```
**********************************************************************
*            MANPOWER PREDICTION FOR THE PROJECT                     *
**********************************************************************

  Average Total Employees Per Month = 7.5
  Average Transportation Engineers Per Month = 2.8

     $$$$-Employee Distribution in Project Quarters-$$$$
                  AVERAGE TOTAL EMPLOYEES
   1st Quarter     2nd Quarter     3rd Quarter     4th Quarter
       6.9             7.8             8.1             7.2

              AVERAGE TRANSPORTATION ENGINEERS
   1st Quarter     2nd Quarter     3rd Quarter     4th Quarter
       2.5             2.9             3.0             2.7

 PROJECT DURATION (MONTHS)              EACH QUARTER (MONTHS)
          37                                    9.25
                  TOTAL PROJECT COST ($)
                       23912792.15

  DO YOU WANT TO SAVE THESE RESULTS (ENTER Y OR N)
```

Figure A5

If you do not want to save these results type ***N*** and press ***ENTER*** key to end the program. If you wish to save these results type ***Y*** and press ***ENTER*** key. Now program ask for a name for output file by displaying:

```
  ENTER A NAME FOR OUTPUT FILE
```

Figure A6

Type a name for output file. Let's type ***EXAMPLE.OUT*** and press ***ENTER*** key. Program ask for a project title by displaying:

```
  ENTER A PROJECT TITLE
```

Figure 7A

You can enter a project title up to 60 characters. For our example problem type ***F-171-1(1)01 in Chatham County*** and press ***ENTER*** key. Now you will see the massage 'MANPOWER PREDICTION ENDS'. Now you are out of the program. You can print EXAMPLE.OUT file to obtain a hard copy of your results. Figure 8A shows a hard copy of EXAMPLE.OUT file. If you like to run the program again type ***RUN MANPOWER*** and press ***ENTER*** key.

```
  PROJECT: F-171-1(1)01 in Chatham County
  PROJECT TYPE: IA1

**************************************************************
*            MANPOWER PREDICTION FOR THE PROJECT             *
**************************************************************

  Average Total Employees Per Month = 7.5
  Average Transportation Engineers Per Month = 2.8

     $$$$-Employee Distribution in Project Quarters-$$$$
                  AVERAGE TOTAL EMPLOYEES
   1st Quarter    2nd Quarter    3rd Quarter    4th Quarter
       6.9            7.8            8.1            7.2

              AVERAGE TRANSPORTATION ENGINEERS
   1st Quarter    2nd Quarter    3rd Quarter    4th Quarter
       2.5            2.9            3.0            2.7

 PROJECT DURATION (MONTHS)          EACH QUARTER (MONTHS)
          37                               9.25
                  TOTAL PROJECT COST ($)
                       23912792.15
```

Figure 8A

Appendix B

A Listing of Manpower program

```
*****************************************************************
*            GEORGIA DEPARTMENT OF TRANSPORTATION               *
*               MANPOWER PREDICTION PROGRAM                     *
*                  DEVELOPED AND WRITTEN                        *
*                        BY                                     *
*                  B. Lanka Santha, P.E.                        *
*             OFFICE OF MATERIALS AND RESEARCH                  *
*               UNDER  RESEARCH PROJECT 9212                    *
*****************************************************************
      INTEGER  J,K
      REAL TOTAL$, TIME, MONTH$, EMPM, TEPM, R, EMQ1,EMQ2,EMQ3,EMQ4
      REAL TEQ1, TEQ2, TEQ3, TEQ4, QUARTER
      CHARACTER PROJECTID*4, XX*1, YorN*1, OPNAME*30, PROJECTNAME*60
       EMPM = 0.0
       TEPM = 0.0
       EMQ1 = 0.0
       EMQ2 = 0.0
       EMQ3 = 0.0
       EMQ4 = 0.0
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)'*****************************************************'
      WRITE(*,*)'*                    WELCOME TO                     *'
      WRITE(*,*)'*     THE GEORGIA DEPARTMENT OF TRANSPORTATION      *'
      WRITE(*,*)'*     CONSTRUCTION ENGINEERING MANPOWER SYSTEM      *'
      WRITE(*,*)'*                  DEVELOPED BY                     *'
      WRITE(*,*)'*         RESEARCH AND DEVELOPMENT BRANCH           *'
      WRITE(*,*)'*        OFFICE OF MATERIALS AND RESEARCH           *'
      WRITE(*,*)'*****************************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          PRESS ANY KEY - WHEN READY'
      READ (*,21)XX
  200 WRITE(*,*)'       PLEASE IDENTIFY THE PROJECT TYPE FROM'
      WRITE(*,*)'              THE FOLLOWING LIST'
      WRITE(*,*)
      WRITE(*,*)'       Project Type                    Identification'
      WRITE(*,*)
      WRITE(*,*)'URBAN-NEW CONSTRUCTION - MULTI LANE ROADWAY      IA1'
      WRITE(*,*)'             (INCLUDING BRIDGES)'
      WRITE(*,*)'URBAN-NEW CONSTRUCTION - OTHERS                  IA3'
      WRITE(*,*)'URBAN-RECONSTRUCTION   - MULTI LANE ROADWAY      IB1'
      WRITE(*,*)'             (INCLUDING BRIDGES)'
      WRITE(*,*)'RURAL-NEW CONSTRUCTION - MULTI LANE ROADWAY     IIA1'
      WRITE(*,*)'             (INCLUDING BRIDGES)'
      WRITE(*,*)'RURAL-NEW CONSTRUCTION - TWO LANE ROADWAY       IIA2'
      WRITE(*,*)'RURAL-NEW CONSTRUCTION - BRIDGES                IIA4'
      WRITE(*,*)'RURAL-RECONSTRUCTION   - MULTI LANE ROADWAY     IIB1'
      WRITE(*,*)'             (INCLUDING BRIDGES)'
      WRITE(*,*)'RURAL-RECONSTRUCTION   - TWO LANE ROADWAY       IIB2'
      WRITE(*,*)'RURAL-RECONSTRUCTION   - OTHERS                 IIB3'
      WRITE(*,*)'   (INTERSECTIONS, SIGNALS, LANDSCAPE, ETC.)'
      WRITE(*,*)'RURAL-RECONSTRUCTION   - BRIDGES                IIB4'
      WRITE(*,*)'RURAL-RECONSTRUCTION   - RESURFACING (ALL TYPES)IIB5'
      WRITE(*,*)'  '
      WRITE(*,*)' PLEASE ENTER YOUR PROJECT IDENTIFICATION NUMBER'
      READ(*,21)PROJECTID
  21  FORMAT(A4)
      WRITE(*,*)' PLEASE ENTER ESTIMATED TOTAL PROJECT COST'
     WRITE(*,*)' (Example for $ 6,000,000.50 Project Enter 6000000.50)'
      READ(*,19) TOTAL$
  19  FORMAT(F14.2)
```

```
      WRITE(*,*)' PLEASE ENTER ESTIMATED PROJECT DURATION IN MONTHS'
      READ(*,*) TIME
        MONTH$ = TOTAL$/TIME
      CALL REGDATA(MONTH$, EMPM, TEPM, PROJECTID,EMQ1,EMQ2,EMQ3,EMQ4)
        IF (EMPM .LT. 0.0) EMPM = 0.0
        IF (TEPM .LT. 0.0) TEPM = 0.0
        IF (EMPM .LE. TEPM) TEPM = EMPM
        IF (EMPM .EQ. 0.0 .AND. TEPM .EQ. 0.0) GOTO 200
        R = TEPM/EMPM
        TEQ1 = R*EMQ1
        TEQ2 = R*EMQ2
        TEQ3 = R*EMQ3
        TEQ4 = R*EMQ4
        QUARTER = TIME/4
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)' ************************************************'
      WRITE(*,*)' *     MANPOWER PREDICTION FOR THE PROJECT      *'
      WRITE(*,*)' ************************************************'
      WRITE(*,*)
      WRITE(*,45) EMPM
   45 FORMAT(' Average Total Employees Per Month = ',F4.1)
      WRITE(*,46) TEPM
   46 FORMAT(' Average Transportation Engineers Per Month = ',F4.1)
      WRITE(*,*)
      WRITE(*,*)'$$$$-Employee Distribution in Project Quarters-$$$$'
      WRITE(*,*)'                AVERAGE TOTAL EMPLOYEES'
      WRITE(*,*)'1st Quarter  2nd Quarter  3rd Quarter  4th Quarter'
      WRITE(*,50) EMQ1, EMQ2, EMQ3, EMQ4
   50 FORMAT(6X,F4.1,8X,F4.1,8X,F4.1,8X,F4.1)
      WRITE(*,*)
      WRITE(*,*)'        AVERAGE TRANSPORTATION ENGINEERS'
      WRITE(*,*)'1st Quarter  2nd Quarter  3rd Quarter  4th Quarter'
      WRITE(*,50) TEQ1, TEQ2, TEQ3, TEQ4
      WRITE(*,*)
      WRITE(*,*)'PROJECT DURATION (MONTHS)      EACH QUARTER (MONTHS)'
      WRITE(*,60)TIME, QUARTER
   60 FORMAT(8X, F4.1, 25X, F5.2)
      WRITE(*,*)'                TOTAL PROJECT COST ($)'
      WRITE(*,70)TOTAL$
   70 FORMAT(18X, F14.2)
      WRITE(*,*)
  290 WRITE(*,*)'DO YOU WANT TO SAVE THESE RESULTS (ENTER Y or N)'
      READ(*,22)YorN
   22 FORMAT(A1)
      IF (YorN .EQ. 'Y' .OR. YorN .EQ. 'y') THEN
        WRITE(*,*)'ENTER A NAME FOR OUTPUT FILE'
        READ(*,23)OPNAME
   23   FORMAT(A30)
        OPEN(UNIT=3, FILE=OPNAME, STATUS='UNKNOWN')
        WRITE(*,*)' ENTER A PROJECT TITLE'
        READ(*,24)PROJECTNAME
   24   FORMAT(A60)
        WRITE(3,31)PROJECTNAME
   31   FORMAT(4X, 'PROJECT:', A60)
        WRITE(3,32) PROJECTID
   32   FORMAT(4X, 'PROJECT TYPE:', A4)
        WRITE(3,33)
   33   FORMAT(' ************************************************')
        WRITE(3,34)
   34   FORMAT(' *     MANPOWER PREDICTION FOR THE PROJECT      *')
```

```
      WRITE(3,33)
      WRITE(3,*)
      WRITE(3,35) EMPM
 35   FORMAT(' Average Total Employees Per Month = ',F4.1)
      WRITE(3,36) TEPM
 36   FORMAT(' Average Transportation Engineers Per Month = ',F4.1)
      WRITE(3,*)
     WRITE(3,*)'$$$$-Employee Distribution in Project Quarters-$$$$'
      WRITE(3,*)'                AVERAGE TOTAL EMPLOYEES'
    WRITE(3,*)'1ST QUARTER  2ND QUARTER  3RD QUARTER  4TH QUARTER'
      WRITE(3,50)EMQ1, EMQ2, EMQ3, EMQ4
      WRITE(3,*)
      WRITE(3,*)'       AVERAGE TRANSPORTATION ENGINEERS'
    WRITE(3,*)'1ST QUARTER  2ND QUARTER  3RD QUARTER  4TH QUARTER'
      WRITE(3,50)TEQ1, TEQ2, TEQ3, TEQ4
      WRITE(3,*)
      WRITE(3,*)'PROJECT DURATION (MONTHS)    EACH QUARTER (MONTHS)'
      WRITE(3,60)TIME, QUARTER
      WRITE(3,*)'                TOTAL PROJECT COST ($)'
      WRITE(3,70) TOTAL$
      CLOSE(3)
    ELSE IF (YorN .EQ. 'N' .OR. YorN .EQ. 'n') THEN
      GOTO 300
    ELSE
      GOTO 290
    END IF
300 WRITE(*,*)'MANPOWER PREDICTION ENDS'
    STOP
    END
    SUBROUTINE REGDATA(MON$, EPM, TPM, PID, EQ1, EQ2, EQ3, EQ4)
    REAL EPM, MON$, TPM, EQ1, EQ2, EQ3, EQ4
    CHARACTER PID*4
    IF (PID .EQ. 'IA1' .OR. PID .EQ. 'ia1')THEN
       EPM = 0.245 + 0.0000112*MON$
       TPM = 0.242 + 0.0000039*MON$
       EQ1 = EPM*0.23*4
       EQ2 = EPM*0.26*4
       EQ3 = EPM*0.27*4
       EQ4 = EPM*0.24*4
    END IF
    IF (PID .EQ. 'IA3' .OR. PID .EQ. 'ia3')THEN
       EPM = 0.231 + 0.0000097*MON$
       TPM =-0.081 + 0.0000041*MON$
       EQ1 = EPM*0.32*4
       EQ2 = EPM*0.23*4
       EQ3 = EPM*0.23*4
       EQ4 = EPM*0.22*4
    END IF
    IF (PID .EQ. 'IB1' .OR. PID .EQ. 'ib1')THEN
       EPM = 1.243 + 0.0000063*MON$
       TPM = 0.658 + 0.00000081*MON$
       EQ1 = EPM*0.25*4
       EQ2 = EPM*0.28*4
       EQ3 = EPM*0.27*4
       EQ4 = EPM*0.20*4
    END IF
    IF (PID .EQ.'IIA1' .OR. PID .EQ. 'iia1')THEN
       EPM = 1.051 + 0.0000069*MON$
       TPM = 0.664 + 0.00000078*MON$
       EQ1 = EPM*0.22*4
       EQ2 = EPM*0.26*4
       EQ3 = EPM*0.31*4
       EQ4 = EPM*0.21*4
    END IF
    IF (PID .EQ.'IIA2' .OR. PID .EQ. 'iia2')THEN
       EPM =-0.021 + 0.000011*MON$
```

```
    TPM = 0.296 + 0.0000015*MON$
    EQ1 = EPM*0.25*4
    EQ2 = EPM*0.22*4
    EQ3 = EPM*0.29*4
    EQ4 = EPM*0.24*4
END IF
IF (PID .EQ.'IIA4' .OR. PID .EQ. 'iia4')THEN
    EPM = 1.138 + 0.0000016*MON$
    TPM = 0.382 + 0.00000069*MON$
    EQ1 = EPM*0.23*4
    EQ2 = EPM*0.23*4
    EQ3 = EPM*0.26*4
    EQ4 = EPM*0.28*4
END IF
IF (PID .EQ.'IIB1' .OR. PID .EQ. 'iib1')THEN
    EPM = 0.789 + 0.0000083*MON$
    TPM = 0.041 + 0.0000023*MON$
    EQ1 = EPM*0.22*4
    EQ2 = EPM*0.25*4
    EQ3 = EPM*0.28*4
    EQ4 = EPM*0.25*4
END IF
IF (PID .EQ.'IIB2' .OR. PID .EQ. 'iib2')THEN
    EPM = 0.405 + 0.000021*MON$
    TPM = 0.159 + 0.0000043*MON$
    EQ1 = EPM*0.25*4
    EQ2 = EPM*0.27*4
    EQ3 = EPM*0.25*4
    EQ4 = EPM*0.23*4
END IF
IF (PID .EQ.'IIB3' .OR. PID .EQ. 'iib3')THEN
    EPM = 0.528 + 0.0000083*MON$
    TPM = 0
    EQ1 = EPM
    EQ2 = EPM
    EQ3 = EPM
    EQ4 = EPM
END IF
IF (PID .EQ.'IIB4' .OR. PID .EQ. 'iib4')THEN
    EPM = 0.317 + 0.000012*MON$
    TPM =-0.682 + 0.000013*MON$
    EQ1 = EPM*0.24*4
    EQ2 = EPM*0.27*4
    EQ3 = EPM*0.26*4
    EQ4 = EPM*0.23*4
END IF
IF (PID .EQ.'IIB5' .OR. PID .EQ. 'iib5')THEN
    EPM = 1.097 + 0.0000019*MON$
    TPM = 0.061 + 0.0000028*MON$
    EQ1 = EPM*0.26*4
    EQ2 = EPM*0.26*4
    EQ3 = EPM*0.26*4
    EQ4 = EPM*0.22*4
END IF
RETURN
END
```

```
   PROJECT:F-171-1(1)01 in Chatham County
   PROJECT TYPE:IA1
**********************************************
*     MANPOWER PREDICTION FOR THE PROJECT     *
**********************************************

Average Total Employees Per Month =  7.5
Average Transportation Engineers Per Month =  2.8

$$$$-Employee Distribution in Project Quarters-$$$$
            AVERAGE TOTAL EMPLOYEES
1ST QUARTER  2ND QUARTER  3RD QUARTER  4TH QUARTER
      6.9          7.8          8.1          7.2

       AVERAGE TRANSPORTATION ENGINEERS
1ST QUARTER  2ND QUARTER  3RD QUARTER  4TH QUARTER
      2.5          2.9          3.0          2.7

PROJECT DURATION (MONTHS)     EACH QUARTER (MONTHS)
       37.0                             9.25
                TOTAL PROJECT COST ($)
                    23912792.00
```

Appendix C

Manpower Analysis Using Charts

CHART BASED MANPOWER ANALYSIS

The developed manpower engineering system is represented by 11 charts given in this Appendix. Application of these charts is demonstrated by an example. Assume that you are required to estimate the personnel needs for the following project. A new multi-lane roadway project in Chatham county is scheduled to complete in 37 months. The estimated cost of the project is $ 23,912,792.15 and the project number is F-171-1(1) 01. In order to estimate personnel needs for this project first identify the correct chart which describe the project category. In this case chart titled "IA1 - Urban, New Construction, Multi-Lane Roadway" represents the project type of the above project. Now calculate the project cost per month for the project dividing $23,912,792.15 by 37. This value is $646,291.68. Now go to chart IA1 and locate this value on Project Cost per Month axis (horizontal axis) and read the corresponding values from Total Employee Line and T.E. Line. These values are 7.5 and 2.8. These values represents the required average total employees and average transportation engineers for the project, respectively.

Estimates for average employees and average T.E.s for each quarter of the project can be found using Employee Distribution Factors given in the chart.

These computations are as follows:

A project quarter = 37/4 = 9.25 months

First Quarter: 0 - 9.25 months

Average total employees	= 7.5 x 0.23 x 4	= 6.9
Average T.E.s	= 2.8 x 0.23 x 4	= 2.5

Second Quarter: 9.25 - 18.5 months

Average total employees	= 7.5 x 0.26 x 4	= 7.8
Average T.E.s	= 2.8 x 0.26 x 4	= 2.9

Third Quarter: 18.5 - 27.75 months

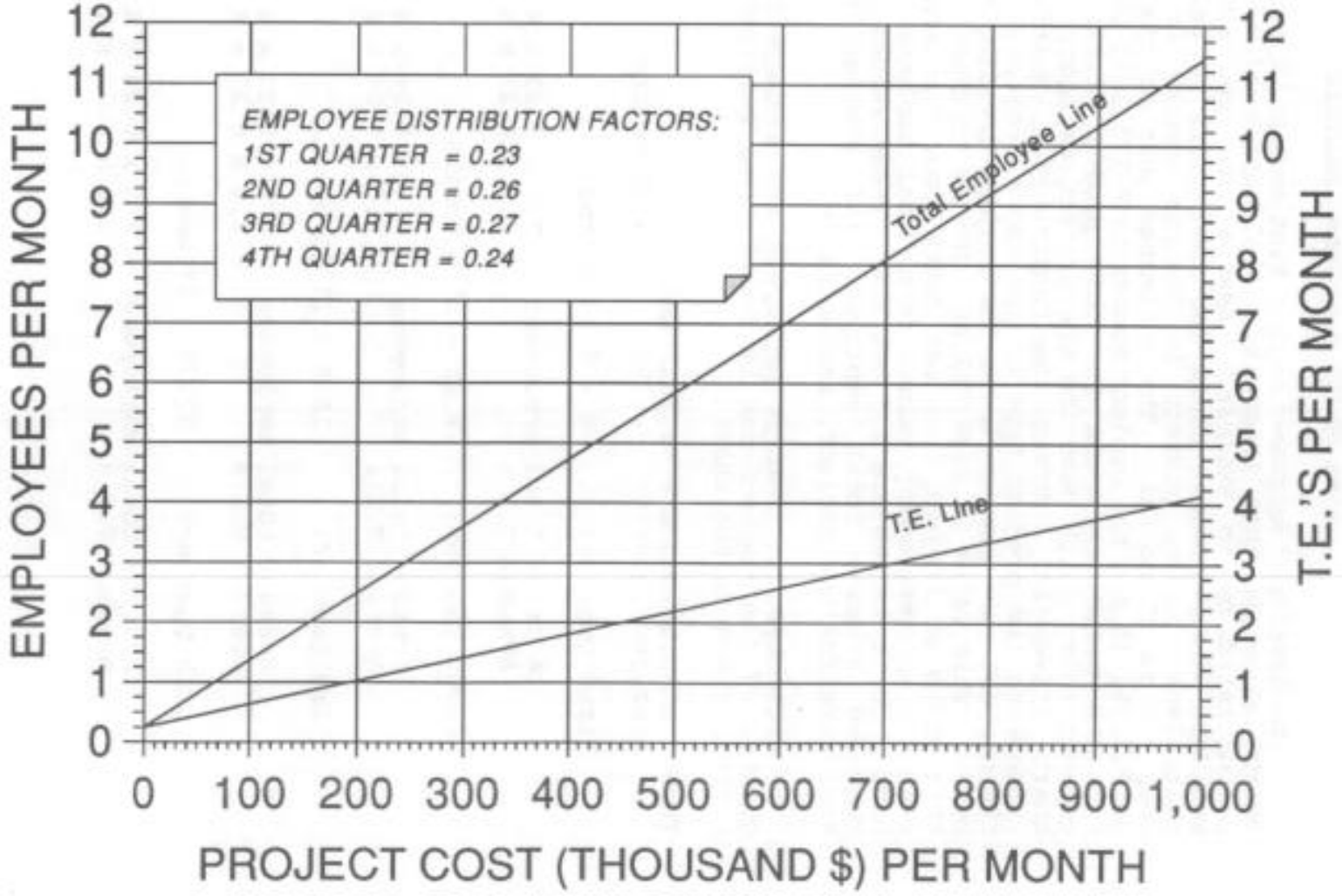
Average total employees	= 7.5 x 0.27 x 4	= 8.1
Average T.E.s	= 2.8 x 0.27 x 4	= 3.0

Fourth Quarter: 27.75 - 37 months

Average total employees	= 7.5 x 0.24 x 4	= 7.2
Average T.E.s	= 2.8 x 0.24 x 4	= 2.7

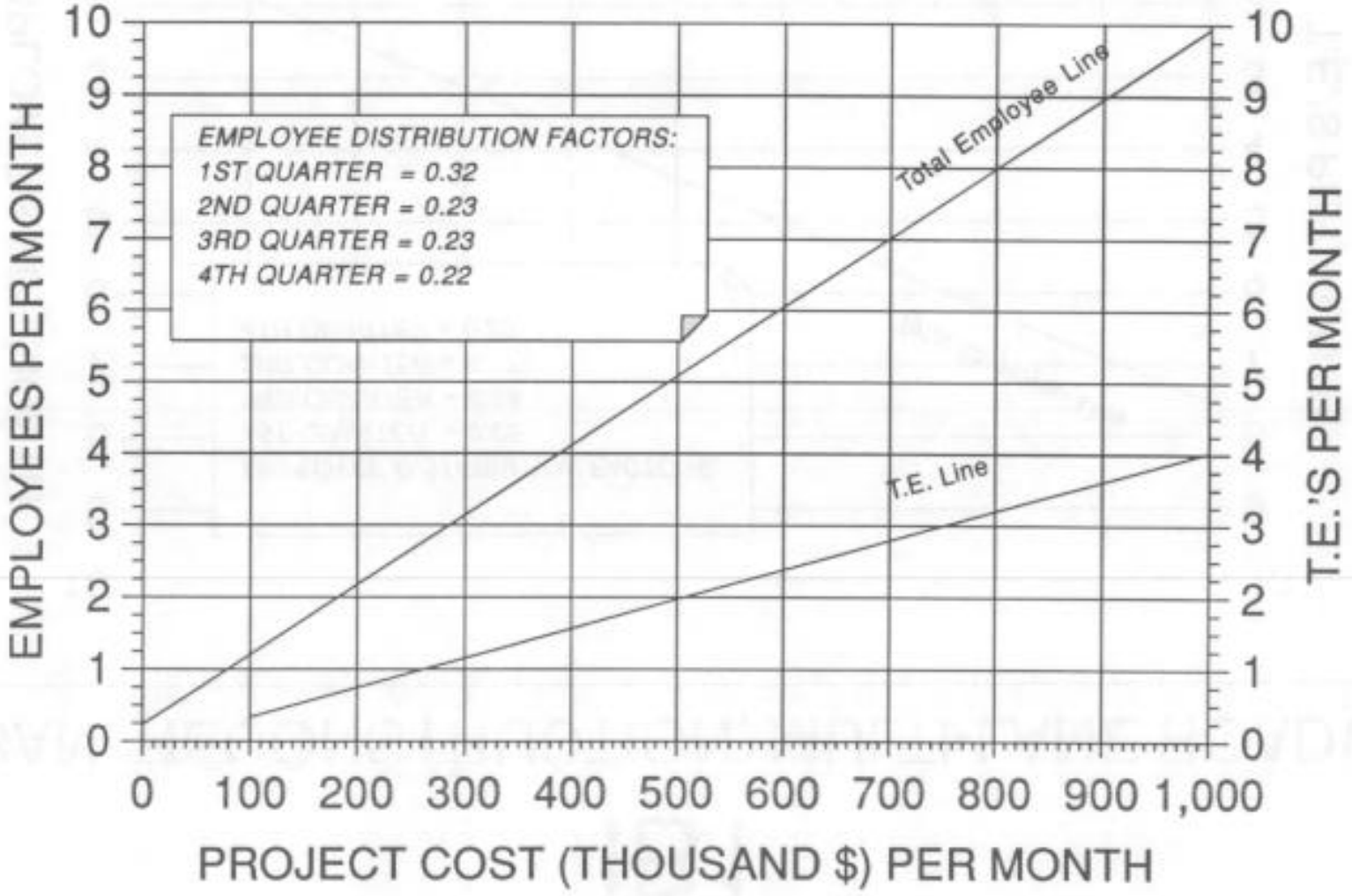
IA1

URBAN, NEW CONSTRUCTION, MULTI-LANE ROADWAY



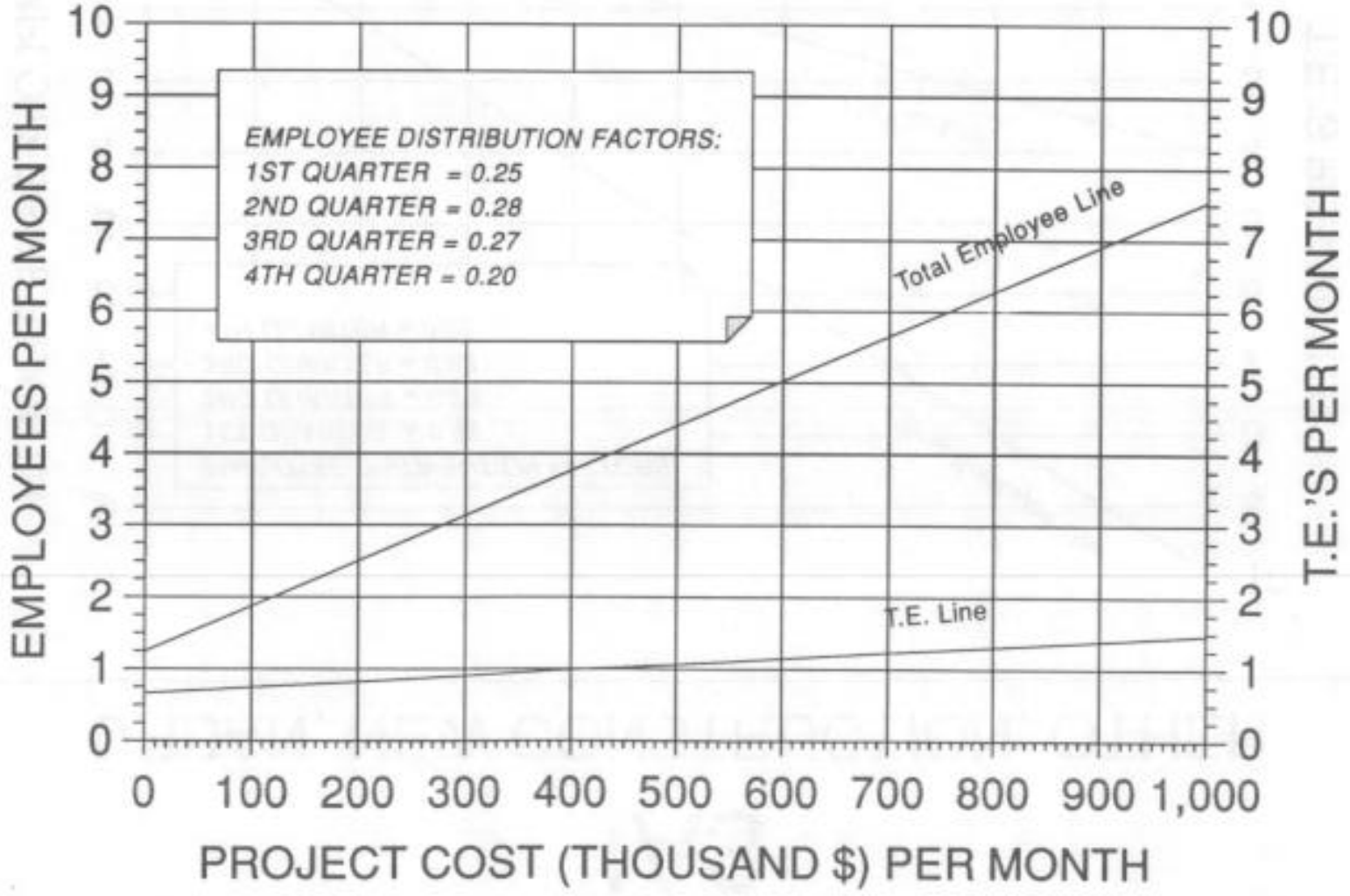
IA3

URBAN, NEW CONSTRUCTION, OTHER



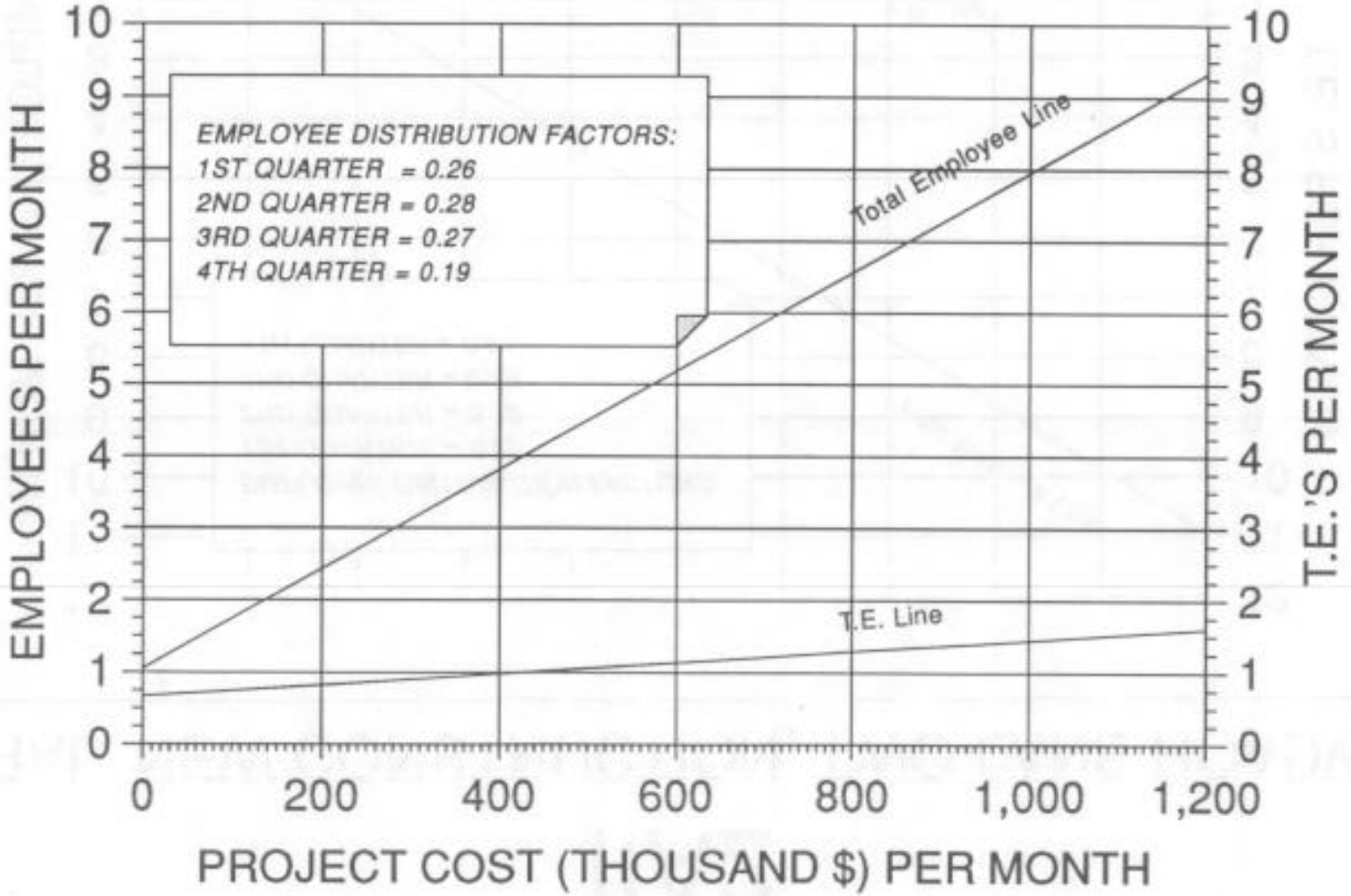
IB1

URBAN, RECONSTRUCTION, MULTI-LANE ROADWAY



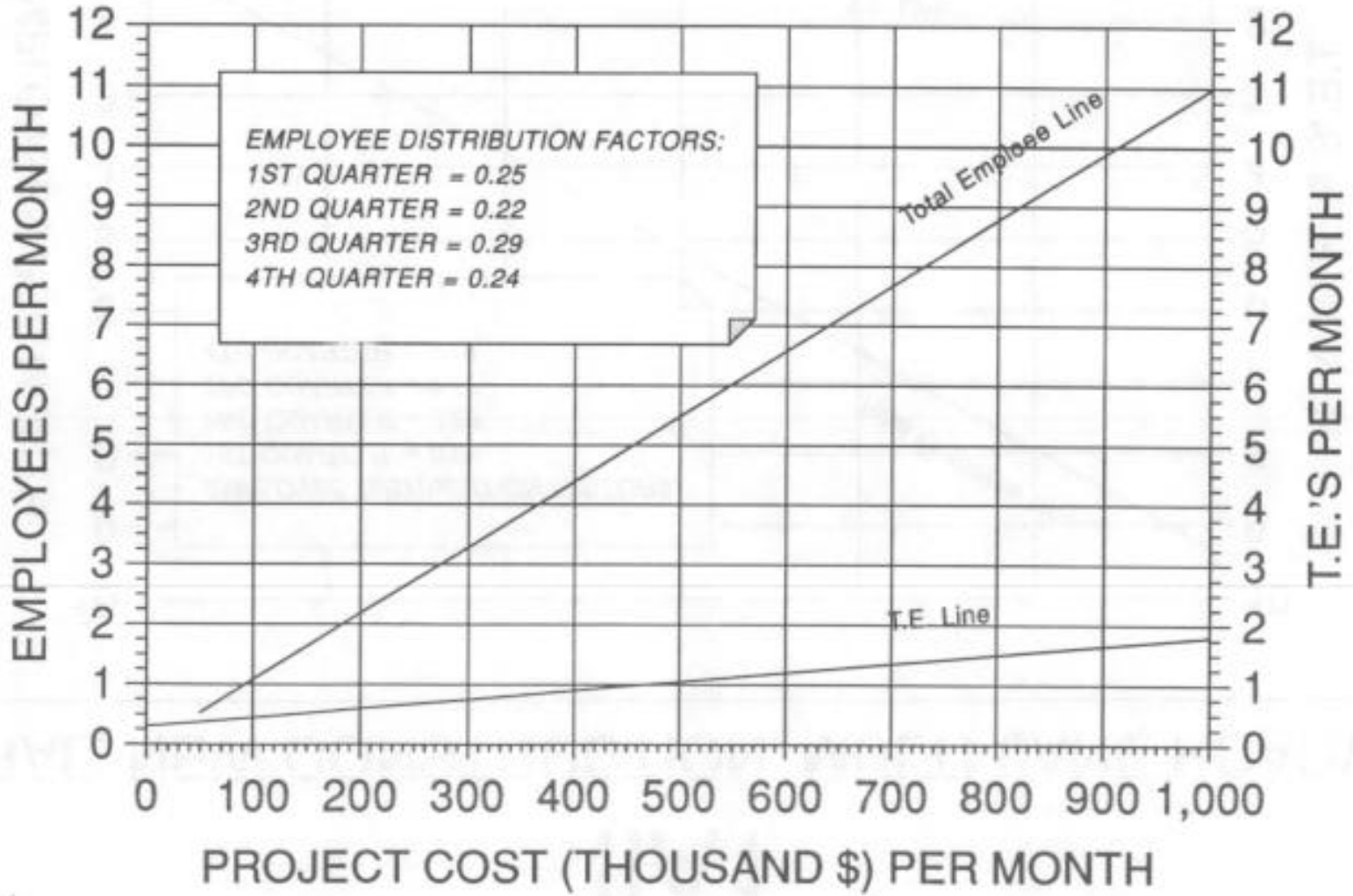
IIA1

RURAL, NEW CONSTRUCTION, MULTI-LANE ROADWAY



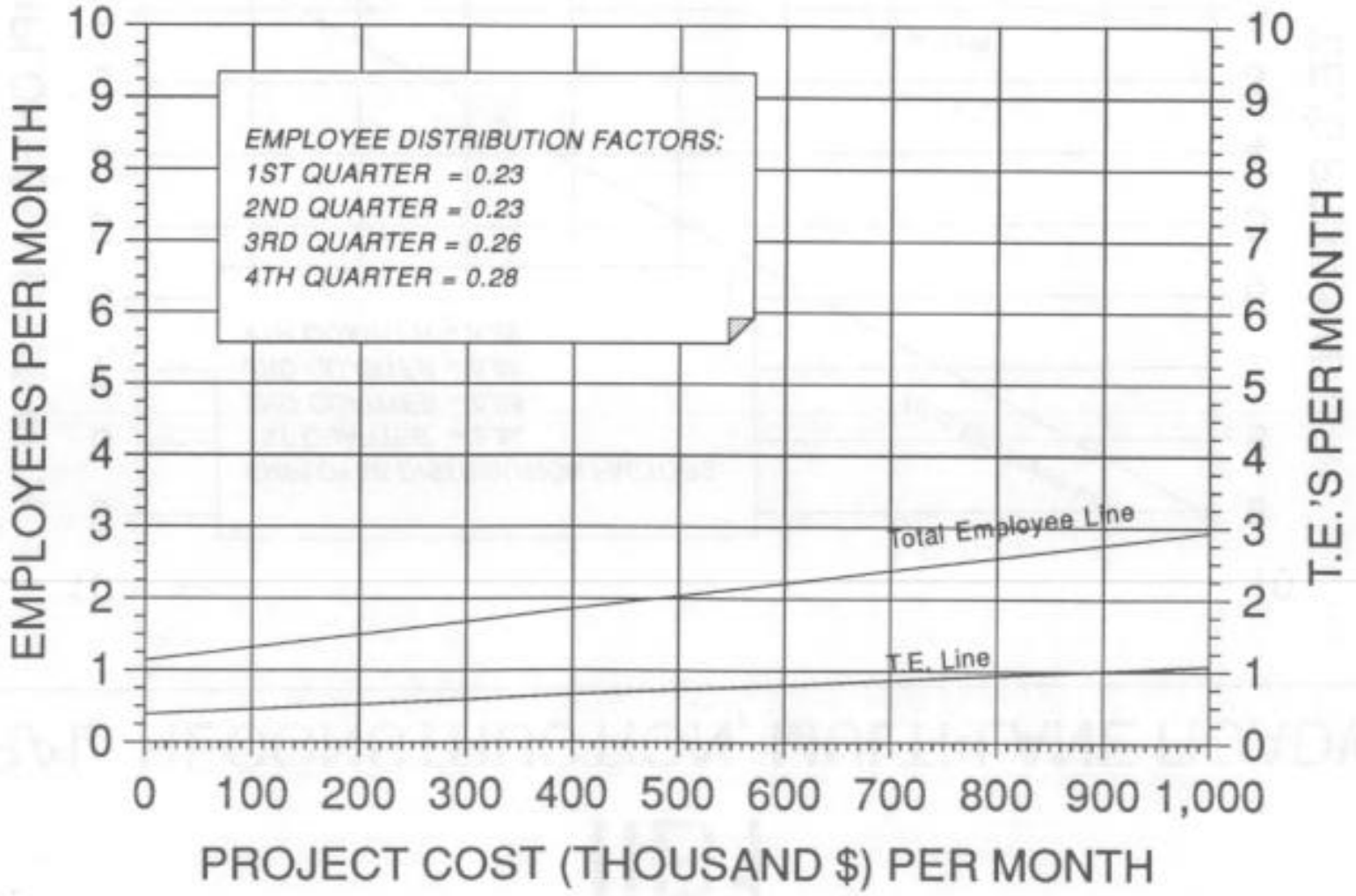
IIA2

RURAL, NEW CONSTRUCTION, TWO-LANE ROADWAY



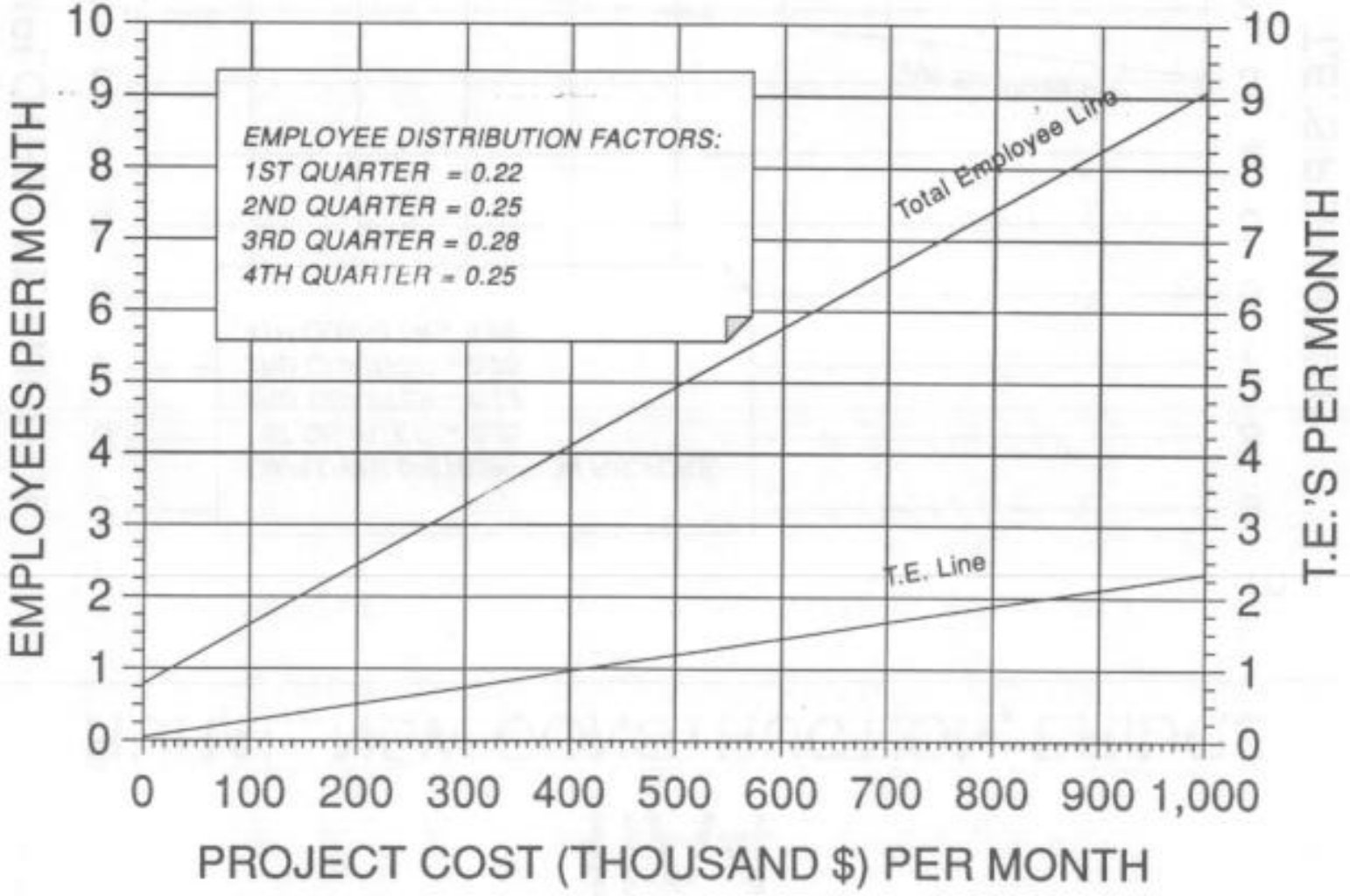
IIA4

RURAL, NEW CONSTRUCTION, BRIDGE



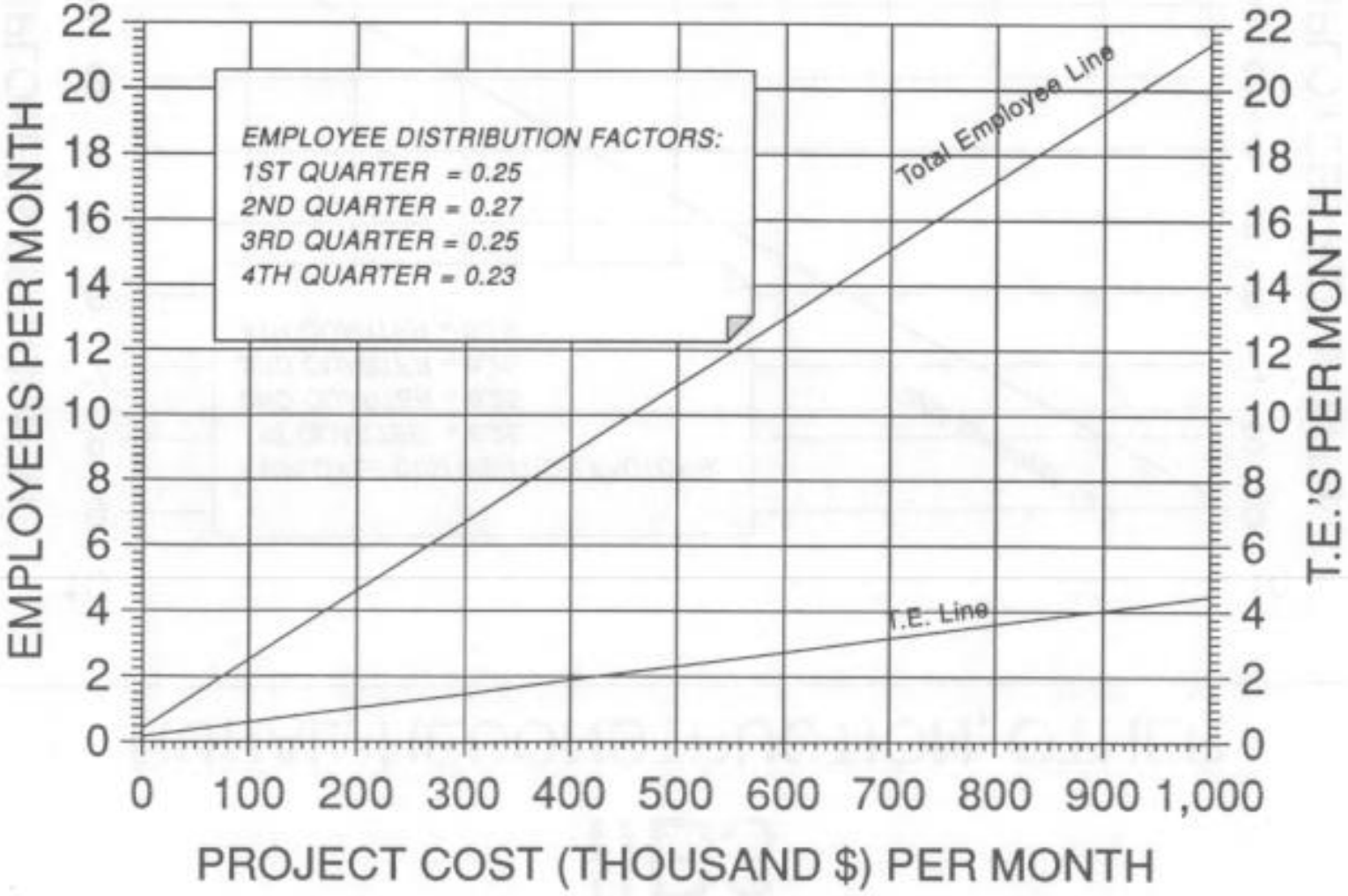
IIB1

RURAL, RECONSTRUCTION, MULTI-LANE ROADWAY



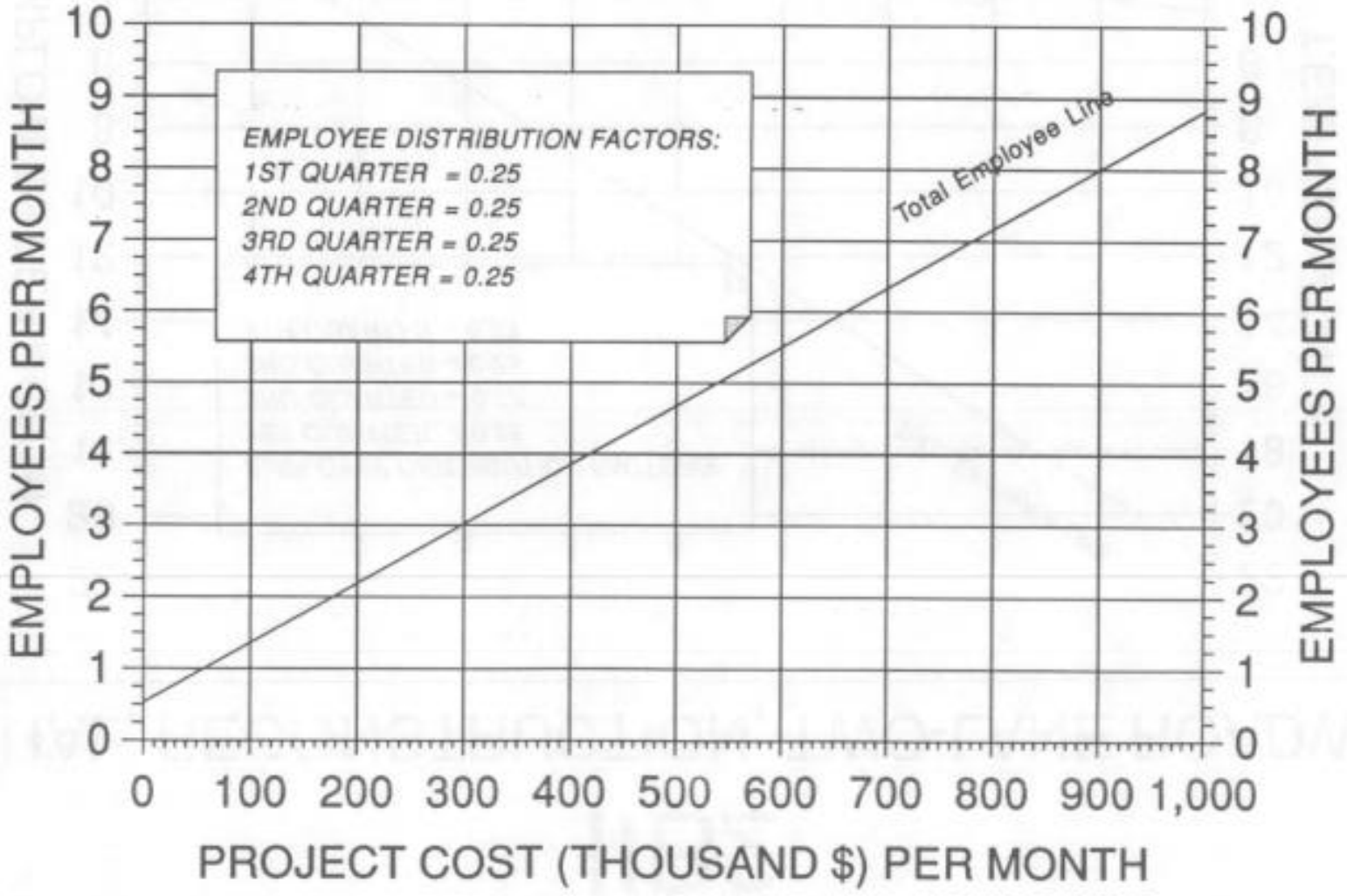
IIB2

RURAL, RECONSTRUCTION, TWO-LANE ROADWAY



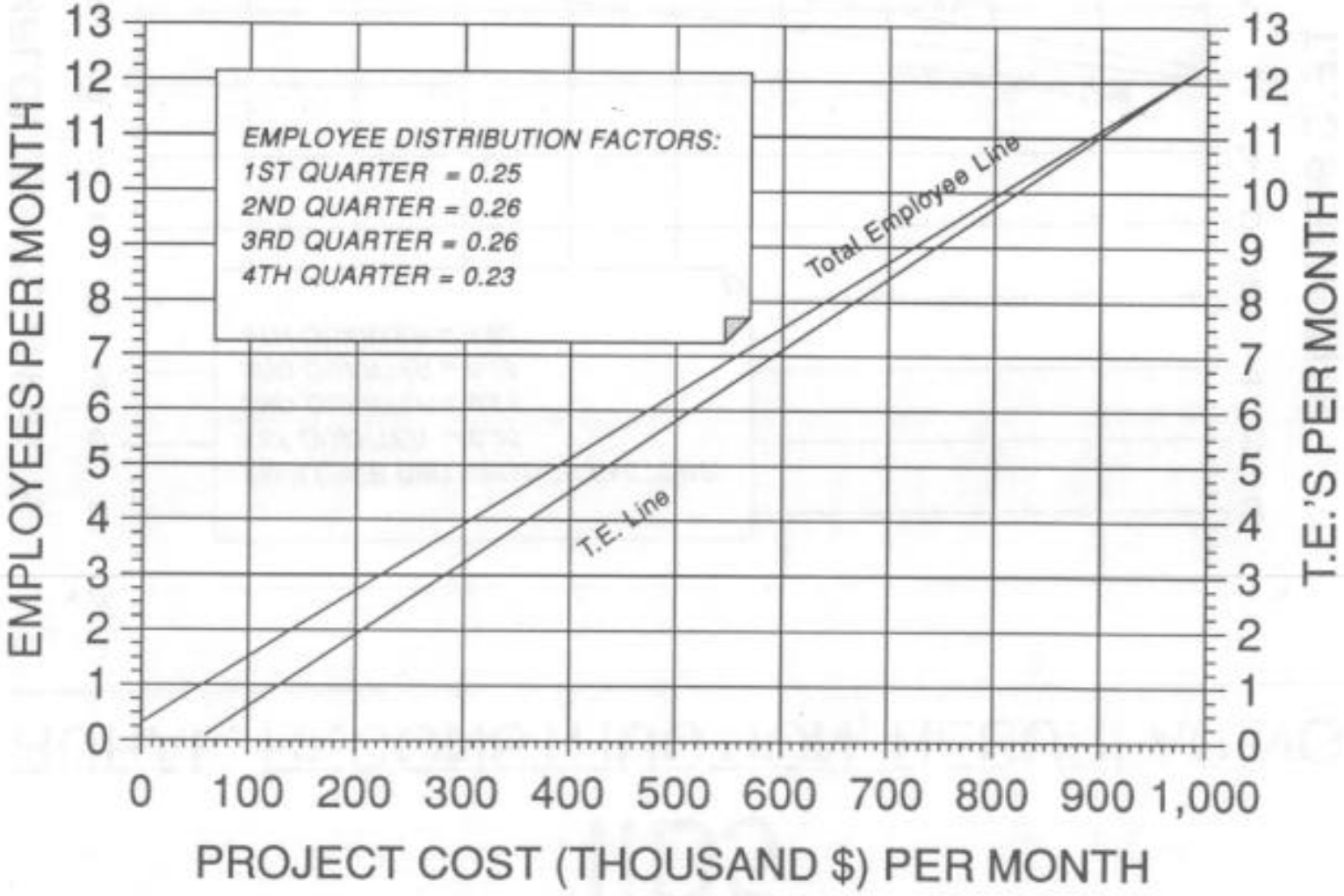
IIB3

RURAL, RECONSTRUCTION, OTHER



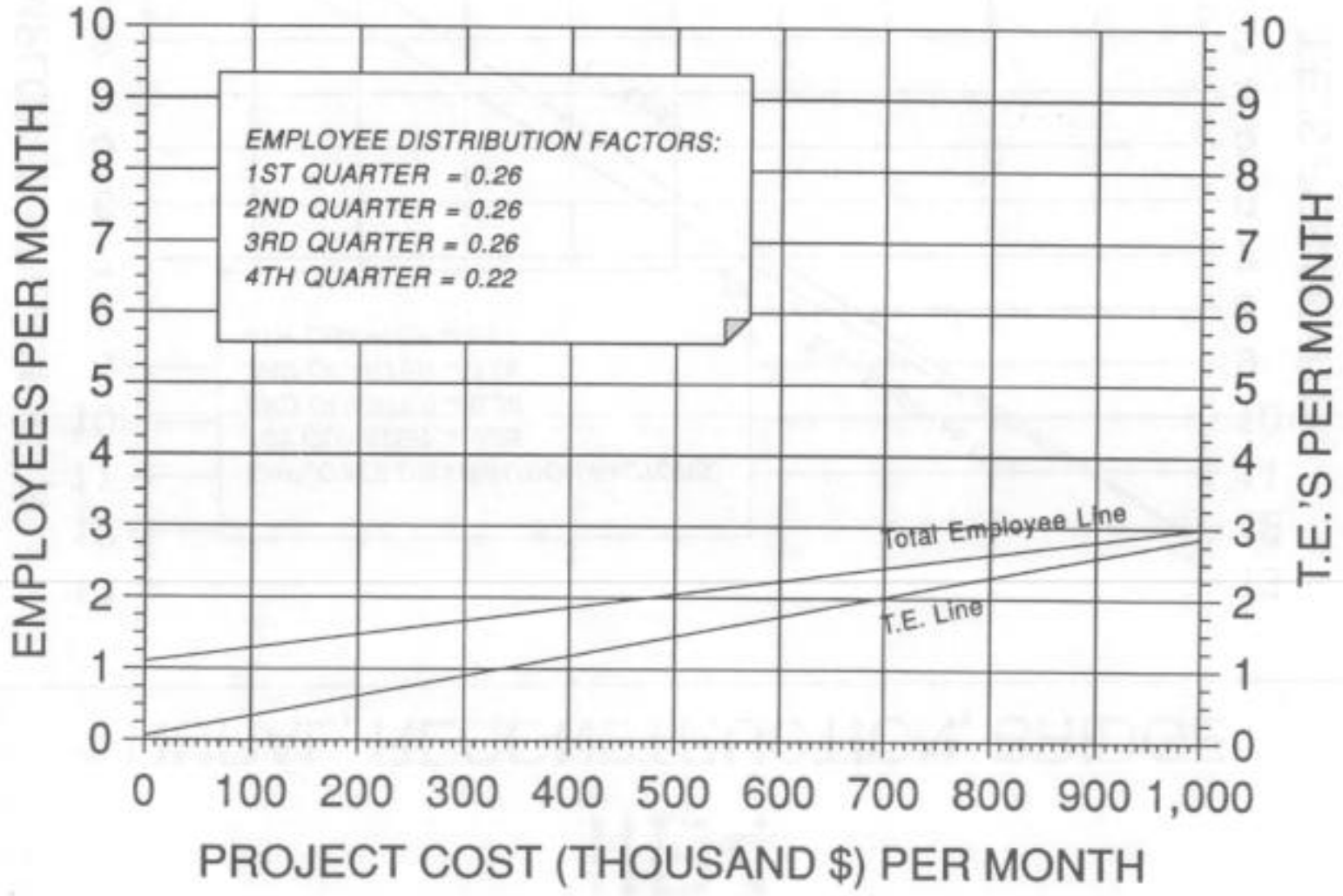
IIB4

RURAL, RECONSTRUCTION, BRIDGE



IIB5

RURAL, RECONSTRUCTION, RESURFACING



Appendix D

Manpower Study Questionnaire

MANPOWER STUDY
QUESTIONNAIRE

Project Number: _____

Project Type Number: _____ (See back for instructions)

Project Cost: _____ (From Detailed Cost Estimate)

Project Duration: _____ (Actual Time)

Number of Employees Working on Project: (Complete Table below)

(6 MONTH INTERVALS)

EMPL.'S TITLE	"TIME" (1ST 6 MONTHS)	"TIME" (2ND 6 MONTHS)	"TIME" (3RD 6 MONTHS)	"TIME" (4TH 6 MONTHS)	"TIME" (5TH 6 MONTHS)	"TIME" (6TH 6 MONTHS)	"TIME" (7TH 6 MONTHS)	"TIME" (8TH 6 MONTHS)
E.T. I								
E.T. II								
E.T. III								
E.T. IV								
E.T. V								
C.E.T.								
T.E. I								
T.E. II								
*								
*								
*								

INSTRUCTIONS:

1. Under "TIME" enter approximate number of employees assigned to project for each title to the nearest 1/4 (i.e. 1 3/4, 1/2, 3 1/2).

* If employee's title is not listed above, enter their title.

PROJECT TYPE NUMBERS

Project Type List:

I. Urban
   A. New Construction
      1. Multi-Lane Roadway (including Bridges)
      2. Two-Lane Roadway
      3. Other (Intersections, Signals, Landscape, etc.)
      4. Bridge
   B. Reconstruction
      1. Multi-Lane Roadway (including Bridges)
      2. Two-Lane Roadway
      3. Other (Intersections, Signals, Landscape, etc.)
      4. Bridge
      5. Resurfacing (all Categories)

II. Rural
   A. New Construction
      1. Multi-Lane Roadway (including Bridges)
      2. Two-Lane Roadway
      3. Other (Intersections, Signals, Landscape, etc.)
      4. Bridge
   B. Reconstruction
      1. Multi-Lane Roadway (including Bridges)
      2. Two-Lane Roadway
      3. Other (Intersections, Signals, Landscape, etc.)
      4. Bridge
      5. Resurfacing (all Categories)

III. Non-Let (PR County Contracts)

EXAMPLES:

1. An urban (I), new construction (A), two-lane roadway project would have a "**IA2**" project type number.

2. A rural (II), reconstruction (B), bridge (4) project would have a "**IIB4**" project type number.

3. A non-let PR County contract project would have a "**III**" project type number.