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ESTIMATING PROGRAM OFFICE SIZE

THROUGH ATTRIBUTE DATA

by

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ABSTRACT

In times of tight budgets, an ability to forecast personnel requirements for new DND commitments is critically needed. This research note illustrates a battery of analytical techniques that were used to determine parametric equations for the size of Program Management Offices (PMOs). These equations, once thoroughly developed, can provide Senior Management with timely manpower planning guidance in this departmentally significant area.

RÉSUMÉ

En période de restrictions budgétaires, il devient impératif de bien prévoir quel est le personnel requis pour la gestion de nouveaux projets du ministère de la Defense. Cette note de recherche décrit un éventail de méthodes statistiques qui relient, sous forme d'équations, les différents paramètres régissant la taille des bureaux de projet. Une fois qu'elles seront mises au point, ces équations deviendront, pour la haute direction, un puissant outil de planification du personnel.

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INTRODUCTION

1.   An ability to forecast personnel requirements for new DND commitments is critically needed in times of tight manpower budgets. While any commitment undertaken addresses one or more departmental objectives, their resource requirements often conflict with those of other DND commitments. This note illustrates a battery of analytical techniques that were used in determining parametric equations for the size of Program Management Offices (PMO). These equations, once thoroughly developed, can provide Senior Management with timely manpower planning guidance in a departmentally significant area.

BACKGROUND

2.   Earlier this year, the Project Management Secretariat (PM Sec) of the Department of National Defence requested that the Directorate of Logistics Analysis investigate what project-specific factors could be used to predict PMO size. PM Sec provided the program size and attribute data for forty-one combinations of programs and Defence Services Program (DSP) phases. The number of programs in each phase is shown below:

    a.   Development   - 11;
    b.   Definition   - 10; and
    c.   Implementation   - 20.

3.   The right hand column of Table I identifies the program attributes available for this study. The left hand column gives their corresponding abbreviations. These identify the attributes used in the analysis reports and in the remainder of this discussion.

Table I - Study Attributes

Variable	Meaning
TOTCOS	TOTAL COST
PHASE	PHASE
PHASEC	PHASE COST
RANK	RANK/LEVEL OF PM
STRATGY	PROCUREMENT STRATEGY
MAINTC	MAINTENANCE CONCEPT
TECHT	TECHNOLOGY TYPE
TECHC	TECH.COMPLEXITY
TECHR	TECHNOLOGICAL RISK
INTERF	INTERFACES
PMOLOC	PMO LOCATION
OFFSUP	OFFICE SUPPORT
EST	ESTABLISHMENT
DURA	PHASE DURATION
AVEPMPY	AVERAGE PMPY
OPI	PM SEC OPI

4.   With several exceptions, program attributes were given by integer ratings on scales appropriate to the attribute. For example, Phase Costs were described by an integer ranging from one to seven. Each integer is associated with a specific cost range. The meaning of each integer rank for each program attribute is shown below.

OUTLINE OF ANALYSIS PROCEDURE

5.   We examined the PM Sec data using the SYSTAT Statistical analysis package. First, we applied Kendall's TAU-B to measure the associations between measured variables. A TAU-B coefficient is similar to the well-known correlation measure but is more appropriate for the ranked data given. TAU-B coefficients were generated for each program phase. The coefficients for the Development, Definition and Implementation phases are shown on Pages 10 through 12. In all cases, average PMPY correlates quite strongly with RANK and ESTABLISHMENT. This result is not unexpected. Phase duration in nearly constant across projects. Therefore, larger ESTABLISHMENTS result in higher AVEPMPY's. Larger PMO's also have a broader span of control and therefore require management by higher ranking officers. With this observation in mind, we removed these two elements from further consideration in the analysis.

Table II

TOTAL COST			TECH TYPE	
1	1-10		1	OFF SHELF
2	10-100		2	MODIFIED
3	100-500		3	DESIGN
4	500-2,000		4	MIL SPEC
5	2,000+			

PHASE			TECH COMPLEXITY	
			1	LOW
1	DEVELOPMENT		2	MEDIUM
2	DEFINITION		3	HIGH
3	IMPLEMENTATION			

PHASE COST			TECH RISK	
			1	HIGH
1	0-1		2	MEDIUM
2	1-5		3	LOW
3	5-10			
4	10-100		INTERFACES	
5	100-500			
6	500-2,000		1	OGD
7	2,000+		2	INTERNATIONAL

RANK/LEVEL			PMO LOCATION	
1	BGEN		1	CO LOCATED
2	COL		2	SEPARATE
3	LCOL		3	MIX RATIO
4	MAJ			
5	CAPT		OFFICE SUPPORT	

PROC STRATEGY			1	CONTRACTED
			2	SELF CONTAINED
1	DND PRIME			
2	CONTRACTOR PRIME		ESTABLISHMENT	
			1	MIL
			2	CIV
MAINT CONCEPT			3	TOTAL
1	IN HOUSE			
2	CONTRACTED			

6.   Next, we examined the spread in the data for some underlying simplification. We applied principal components analysis against the data.   Principal components analysis aims at finding combinations of data attributes that 'explain' much of the spread in the data. In some cases, the principal component method can identify specific attributes that are essential to building a predictive model. The analyses for each program phase are shown on Pages 13 through 15. Note that for all program phases, approximately 80%

of the data spread can be 'explained' by a four component model. Identifying attributes that strongly associate with these components could significantly reduce the number of attributes needed from the 15 factors originally considered.

7. The study of the four dominant factor vectors for clues in deciding which model attributes include or eliminate from a prediction equation proved inconclusive. In all cases, one of TOTCOS or PHASEC or both appeared to dominate some of the factor vectors. Note that in each program phase, these terms are strongly correlated (see Kendall coefficients). Therefore a prediction model should consider one or the other but not both to be important factors.

8. Other items noted during this analysis:

    a. <u>Development Phase</u> - Domination of MAINTC and one of DURA or INTERF in two of the factors.

    b. <u>Definition Phase</u> - Strength of MAINTC in at least two of the factors.

    c. <u>Implementation Phase</u> - The strength of MAINTC in one and PMOLOC in the other of two of the factors.

9. Finally, we applied step-wise regression of the program attributes to PMO size. Normally, this technique is applied with continuously-valued attributes. In our case, we wished to determine how much of AVEPMPY can be explained by the given variables. A low measure of regression strength, measured by R^2, might indicate that other attributes not included in the analysis might play a part in determing PMO size. Furthermore, its outcome might be useful in confirming some of the observations made in the preceding discussion. The results of the stepwise regression for each phase are shown on Pages 16, 19 and 21.

10.   Note that we have used the natural logarithm of AVEPMPY, LNPMPY as the dependent variable. We did this to regularize the scales used for TOTCOS and PHASEC with the AVEPMPY data. Evidence of this linearity is shown by Figures 1 to 3.

11.   From the stepwise regression, we concluded that the following variables could appear significant in developing a PMO sizing model

     a.   Development Phase -
                    INTERF
                    MAINTC
                    TECHC
                    TECHT
                    TOTCOS

     b.   Definition Phase -
                    MAINTC
                    PHASEC

     c.   Implementation Phase -
                    STRATGY
                    TOTCOS

For the Development Phase, the regression strength measured by R^2 is extremely high. Thus, these variables taken together provide a very good fit to the observed data. For the second and third cases the regression strength measure is weaker. This suggests that factors not considered in the study, such as normal versus accelerated activity rate, may play a part in estimating Definition and Implementation Phase PMPY's.

12.   We used SYSTAT to generate plots of LNPMPY against one of PHASEC or TOTCOS. These are shown as Figures 1 - 3. The plots confirm the linear tendency we had assumed in these variates. Furthermore, the broad confidence bands about the trend line show that other input factors must play a significant role in any prediction equation developed.

13.   Next we compared the actual data to the predictions implied by the three regression model. These are shown for the three program phases in Figure 4, Figure 5 and Figure 6 respectively.

CONCLUSION

14.   The strong linear fits seen in the stepwise regression results suggest that models of the form:

$$AVEPMPY = CONSTANT * (ATTRIBUTE\_INDEX_1)^{FACTOR_1} * ... \\ * (ATTRIBUTE\_INDEX_N)^{FACTOR_N}$$

could be useful in predicting PMO sizes. In particular, we apply this equation to those attributes found significant in the stepwise regression for each phase and given in Paragraph 11. The factor and constant coefficients for each equation can be easily found from the step-wise regression summaries on Pages 18, 21 and 22. These prediction equation associated with this data set are given below:

Development Phase

$$AVEPMPY = 1.48 \times INTERF^{.307} \times MAINTC^{.717} \\ \times TECHC^{-.517} \times TECHT^{-.161} \times TOTCOS^{.448}$$

Definition Phase

$$AVEPMPY = .460 \times MAINTC^{.842} \times PHASEC^{.668}$$

Implementation Phase

$$AVEPMPY = 3.10 \times STRATGY^{-.679} \times TOTCOS^{1.06}$$

15.   Referring to Figure 4, we note that the prediction model provides a good fit to the observed data. One the other hand, Figure 5 suggests that Definition Phase model overestimates smaller PMO sizes and underestimates larger ones. The figure suggests that a better prediction model may be had by filtering the larger PMOs from the definition phase sample. From Figure 6, we observe that the Implementation Phase model is appropriate to the prediction of PMOs of less than 100 people. Beyond this range, the equation grossly underestimates PMO size.

16.   These partial results have been encouraging. Nevertheless, given the scarcity of available analyst effort, direct tasking for further effort is required. Further, directorate effort in this area should concentrate on resolving the following issues:

    a.   validating the linear tendency seen for LNPMPY against the exact program cost figures,

b.   regularizing these phase dependent prediction equations, and

c.   investigating the residual errors for the effects of autocorrelation.

17.   The rationale for each of these activities is described in the following three paragraphs.

18.   The substitution of an index for a known value for the model significant TOTCOS and PHASEC attributes added unneccesary noise to the given. This might be particularly significant for the larger PMOs whose costs might be concentrated at the maximum of these scales.

19.   We should develop a single prediction equation applicable to all program phases. Having three equations, each unique to phase, makes this sizing model slightly more difficult to use in practice.

20.   The study of residuals for autocorrelation is a routine procedure in developing reliable parametric models. The discovery of autocorrelation could force us to include cross and higher order terms into the prediction equations.

21.   This note has demonstrated the statistical methodologies involved in determining a parametric estimation model. The tools used, accessible to the working analyst thorough Personal Computer software, enabled the timely determination of several key determinants of PMO size. The resulting PMO size prediction models have some shortcomings. Nevertheless these can be addressed by expanding the working data base, expanding the list of project attributes consideted and by substituting, where possible, continuous ordinal for categorical data.

22.   The parametric models derived here should be used with caution. As shown in Figures 5 and 6, these equations break down badly for larger sized program offices. At best they give very conservative lower bounds for the size of program staffs. In such cases, a proper needs analysis is the only recourse for gauging PMO size.

MATRIX OF KENDALL TAU-B COEFFICIENTS (Development Phase)

	AVEPMPY	DURA	EST	INTERF	MAINTC
AVEPMPY	1.000				
DURA	-0.147	1.000			
EST	0.561	0.390	1.000		
INTERF	0.306	-0.620	-0.052	1.000	
MAINTC	0.542	0.029	0.481	-0.069	1.000
OFFSUP	.	.	.	.	.
OPI	0.570	-0.132	0.328	0.128	0.802
PHASE	.	.	.	.	.
PHASEC	0.324	-0.348	0.071	0.648	0.000
PMOLOC	-0.085	0.444	0.132	-0.418	0.346
RANK	-0.561	-0.413	-0.681	0.179	-0.311
STRATGY	0.445	0.515	0.588	-0.356	0.430
TECHC	0.092	0.187	0.214	0.065	0.157
TECHR	0.315	-0.168	0.075	-0.068	0.328
TECHT	-0.484	-0.024	-0.347	-0.059	-0.399
TOTCOS	0.325	0.188	0.376	0.142	0.083

	OFFSUP	OPI	PHASE	PHASEC	PMOLOC
OFFSUP	.				
OPI	.	1.000			
PHASE	.	.	.		
PHASEC	.	0.203	.	1.000	
PMOLOC	.	0.214	.	-0.271	1.000
RANK	.	-0.256	.	0.000	-0.239
STRATGY	.	0.478	.	0.000	0.149
TECHC	.	-0.029	.	-0.088	-0.163
TECHR	.	0.455	.	-0.246	0.454
TECHT	.	-0.396	.	-0.027	-0.296
TOTCOS	.	0.178	.	0.155	-0.334

	RANK	STRATGY	TECHC	TECHR	TECHT
RANK	1.000				
STRATGY	-0.624	1.000			
TECHC	-0.065	0.243	1.000		
TECHR	-0.272	0.169	-0.339	1.000	
TECHT	0.620	-0.147	0.429	-0.477	1.000
TOTCOS	-0.456	0.497	0.621	-0.217	0.094

	TOTCOS
TOTCOS	1.000

NUMBER OF OBSERVATIONS: 11

MATRIX OF KENDALL TAU-B COEFFICIENTS (Definition Phase)

	AVEPMPY	DURA	EST	INTERF	MAINTC
AVEPMPY	1.000				
DURA	-0.176	1.000			
EST	0.911	-0.076	1.000		
INTERF	0.248	-0.394	0.248	1.000	
MAINTC	0.507	-0.101	0.507	0.333	1.000
OFFSUP	-0.522	-0.085	-0.522	-0.667	-0.500
OPI	0.234	-0.265	0.182	0.058	0.174
PHASE	.	.	.	.	.
PHASEC	0.596	-0.113	0.596	0.222	0.333
PMOLOC	0.522	0.085	0.522	0.667	0.500
RANK	-0.738	-0.030	-0.791	-0.295	-0.460
STRATGY	-0.348	0.225	-0.248	-0.111	-0.333
TECHC	0.130	0.235	0.182	0.406	0.487
TECHR	0.000	-0.415	-0.056	-0.252	0.000
TECHT	-0.083	0.565	-0.028	-0.495	-0.297
TOTCOS	0.553	0.000	0.553	0.509	0.218

	OFFSUP	OPI	PHASE	PHASEC	PMOLOC
OFFSUP	1.000				
OPI	-0.087	1.000			
PHASE	.	.	.		
PHASEC	-0.500	-0.232	.	1.000	
PMOLOC	-1.000	0.087	.	0.500	1.000
RANK	0.619	0.154	.	-0.825	-0.619
STRATGY	0.167	-0.464	.	0.000	-0.167
TECHC	-0.609	-0.364	.	0.348	0.609
TECHR	0.567	0.461	.	-0.252	-0.567
TECHT	0.371	-0.226	.	-0.124	-0.371
TOTCOS	-0.764	-0.114	.	0.727	0.764

	RANK	STRATGY	TECHC	TECHR	TECHT
RANK	1.000				
STRATGY	0.177	1.000			
TECHC	-0.400	0.406	1.000		
TECHR	0.301	-0.504	-0.757	1.000	
TECHT	0.066	0.433	-0.032	-0.070	1.000
TOTCOS	-0.733	-0.218	0.266	-0.330	-0.324

	TOTCOS
TOTCOS	1.000

NUMBER OF OBSERVATIONS: 10

MATRIX OF KENDALL TAU-B COEFFICIENTS (Implementation Phase)

	AVEPMPY	DURA	EST	INTERF	MAINTC
AVEPMPY	1.000				
DURA	0.236	1.000			
EST	0.821	0.422	1.000		
INTERF	-0.296	-0.015	-0.267	1.000	
MAINTC	0.104	0.162	0.193	0.167	1.000
OFFSUP	-0.121	0.038	-0.048	-0.068	-0.408
OPI	-0.090	-0.282	-0.163	0.229	-0.017
PHASE	.	.	.	.	.
PHASEC	0.593	0.172	0.507	-0.215	-0.095
PMOLOC	0.403	0.539	0.433	-0.043	-0.257
RANK	-0.638	-0.271	-0.564	-0.087	-0.087
STRATGY	-0.068	-0.262	-0.160	0.171	-0.257
TECHC	0.057	0.429	0.196	-0.134	0.348
TECHR	-0.181	-0.440	-0.315	-0.142	-0.302
TECHT	0.226	0.076	0.153	-0.266	-0.413
TOTCOS	0.638	0.239	0.564	-0.174	-0.044

	OFFSUP	OPI	PHASE	PHASEC	PMOLOC
OFFSUP	1.000				
OPI	-0.221	1.000			
PHASE	.	.	.		
PHASEC	-0.056	-0.168	.	1.000	
PMOLOC	0.105	0.035	.	0.283	1.000
RANK	0.328	-0.099	.	-0.626	-0.510
STRATGY	0.454	0.139	.	0.353	-0.099
TECHC	0.262	-0.508	.	0.177	0.000
TECHR	-0.169	0.230	.	-0.280	-0.155
TECHT	0.028	0.035	.	0.333	0.318
TOTCOS	-0.043	-0.163	.	0.964	0.340

	RANK	STRATGY	TECHC	TECHR	TECHT
RANK	1.000				
STRATGY	-0.090	1.000			
TECHC	-0.007	0.027	1.000		
TECHR	0.300	-0.155	-0.582	1.000	
TECHT	-0.309	0.168	-0.029	-0.249	1.000
TOTCOS	-0.693	0.305	0.231	-0.355	0.302

	TOTCOS
TOTCOS	1.000

NUMBER OF OBSERVATIONS: 20

DEVELOPMENT PHASE PRINCIPAL COMPONENTS ANALYSIS

LATENT ROOTS (EIGENVALUES)

1	2	3	4	5
2.695	2.309	1.435	0.924	0.676

6	7	8	9
0.460	0.331	0.129	0.041

COMPONENT LOADINGS

	1	2	3	4
PMOLOC	-0.744	0.396	0.195	-0.114
TECHR	-0.742	-0.181	0.166	0.498
TOTCOS	0.664	0.377	0.424	0.007
TECHT	0.624	0.312	-0.316	0.313
TECHC	0.620	0.544	0.405	0.272
DURA	-0.178	0.827	0.083	-0.471
INTERF	0.414	-0.721	0.265	0.042
PHASEC	0.253	-0.613	0.426	-0.480
MAINTC	-0.331	0.066	0.817	0.193

VARIANCE EXPLAINED BY COMPONENTS

1	2	3	4
2.695	2.309	1.435	0.924

PERCENT OF TOTAL VARIANCE EXPLAINED

1	2	3	4
29.943	25.652	15.945	10.266

FACTOR SCORE COEFFICIENTS

	1	2	3	4
PMOLOC	-0.276	0.171	0.136	-0.123
TECHR	-0.275	-0.078	0.116	0.539
TOTCOS	0.246	0.163	0.296	0.008
TECHT	0.232	0.135	-0.220	0.338
TECHC	0.230	0.236	0.282	0.295
DURA	-0.066	0.358	0.058	-0.510
INTERF	0.153	-0.312	0.185	0.045
PHASEC	0.094	-0.266	0.297	-0.519
MAINTC	-0.123	0.029	0.569	0.208

DEFINITION PHASE PRINCIPAL COMPONENTS ANALYSIS

LATENT ROOTS (EIGENVALUES)

	1	2	3	4	5
	4.821	2.566	1.206	0.993	0.709
	6	7	8	9	10
	0.504	0.135	0.066	0.000	-0.000
	11				
	-0.000				

COMPONENT LOADINGS

	1	2	3	4
OFFSUP	-0.960	0.022	-0.078	-0.066
PMOLOC	0.960	-0.022	0.078	0.066
TOTCOS	0.803	0.122	0.443	-0.339
TECHC	0.727	-0.484	-0.393	0.212
INTERF	0.693	0.309	-0.394	-0.189
PHASEC	0.682	0.045	0.423	-0.276
TECHR	-0.570	0.766	0.120	0.111
MAINTC	0.567	0.272	-0.119	0.672
DURA	0.007	-0.773	0.447	0.345
STRATGY	-0.083	-0.767	-0.433	-0.351
TECHT	-0.455	-0.609	0.303	0.086

VARIANCE EXPLAINED BY COMPONENTS

	1	2	3	4
	4.821	2.566	1.206	0.993

PERCENT OF TOTAL VARIANCE EXPLAINED

	1	2	3	4
	43.829	23.323	10.960	9.031

FACTOR SCORE COEFFICIENTS

	1	2	3	4
OFFSUP	-0.199	0.009	-0.064	-0.067
PMOLOC	0.199	-0.009	0.064	0.067
TOTCOS	0.167	0.048	0.368	-0.341
TECHC	0.151	-0.189	-0.326	0.213
INTERF	0.144	0.121	-0.327	-0.190
PHASEC	0.141	0.017	0.351	-0.278
TECHR	-0.118	0.299	0.099	0.112
MAINTC	0.118	0.106	-0.099	0.676
DURA	0.001	-0.301	0.371	0.347
STRATGY	-0.017	-0.299	-0.359	-0.353
TECHT	-0.094	-0.237	0.251	0.086

IMPLEMENTATION PHASE PRINCIPAL COMPONENTS ANALYSIS

LATENT ROOTS (EIGENVALUES)

1	2	3	4	5
3.118	2.177	1.522	1.134	0.875

6	7	8	9	10
0.507	0.300	0.200	0.154	0.013

COMPONENT LOADINGS

	1	2	3	4
TOTCOS	0.855	0.203	0.257	-0.103
PHASEC	0.795	0.334	0.298	-0.170
TECHR	-0.656	0.508	-0.181	-0.189
DURA	0.597	-0.510	-0.464	0.192
TECHC	0.538	-0.591	0.096	-0.300
PMOLOC	0.538	0.127	-0.604	0.404
TECHT	0.526	0.505	-0.263	0.024
MAINTC	-0.021	-0.797	0.273	-0.192
STRATGY	0.277	0.424	0.678	0.228
INTERF	-0.184	-0.266	0.375	0.824

VARIANCE EXPLAINED BY COMPONENTS

1	2	3	4
3.118	2.177	1.522	1.134

PERCENT OF TOTAL VARIANCE EXPLAINED

1	2	3	4
31.177	21.772	15.216	11.339

FACTOR SCORE COEFFICIENTS

	1	2	3	4
TOTCOS	0.274	0.093	0.169	-0.091
PHASEC	0.255	0.153	0.196	-0.150
TECHR	-0.210	0.233	-0.119	-0.167
DURA	0.192	-0.234	-0.305	0.170
TECHC	0.173	-0.271	0.063	-0.265
PMOLOC	0.173	0.058	-0.397	0.356
TECHT	0.169	0.232	-0.173	0.021
MAINTC	-0.007	-0.366	0.179	-0.169
STRATGY	0.089	0.195	0.446	0.201
INTERF	-0.059	-0.122	0.247	0.727

DEVELOPMENT PHASE STEPWISE REGRESSION

DEPENDENT VARIABLE   LNPMPY

MINIMUM TOLERANCE FOR ENTRY INTO MODEL =   .010000

STEP #   0 R= .000 RSQUARE=   .000

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						

OUT	PART. CORR					
---						
2 DURA	-0.095	.	.	.1E+01	0.082	0.781
3 INTERF	0.323	.	.	.1E+01	1.046	0.333
4 MAINTC	0.587	.	.	.1E+01	4.733	0.058
5 PHASEC	0.428	.	.	.1E+01	2.020	0.189
6 PMOLOC	-0.049	.	.	.1E+01	0.021	0.887
7 STRATGY	0.503	.	.	.1E+01	3.053	0.115
8 TECHC	0.061	.	.	.1E+01	0.034	0.859
9 TECHR	0.299	.	.	.1E+01	0.887	0.371
10 TECHT	-0.511	.	.	.1E+01	3.188	0.108
11 TOTCOS	0.432	.	.	.1E+01	2.067	0.184

STEP #   1 R= .587 RSQUARE=   .345
TERM ENTERED: MAINTC

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
4 MAINTC	0.683	0.314	0.587	.1E+01	4.733	0.058

OUT	PART. CORR					
---						
2 DURA	-0.158	.	.	0.99688	0.205	0.663
3 INTERF	0.450	.	.	0.99524	2.027	0.192
5 PHASEC	0.412	:	.	0.97128	1.634	0.237
6 PMOLOC	-0.332	.	.	0.88000	0.991	0.349
7 STRATGY	0.343	.	.	0.81481	1.067	0.332
8 TECHC	-0.062	.	.	0.96449	0.031	0.864
9 TECHR	0.127	.	.	0.88000	0.130	0.728
10 TECHT	-0.445	.	.	0.91972	1.970	0.198
11 TOTCOS	0.523	.	.	0.99978	3.014	0.121

STEP # 2 R= .724 RSQUARE= .524
TERM ENTERED: TOTCOS

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
4 MAINTC	0.675	0.284	0.581	0.99978	5.667	0.045
11 TOTCOS	0.220	0.127	0.424	0.99978	3.014	0.121
OUT	PART. CORR					
---						
2 DURA	-0.362	.	.	0.92619	1.055	0.339
3 INTERF	0.455	.	.	0.97974	1.823	0.219
5 PHASEC	0.444	.	.	0.96707	1.717	0.231
6 PMOLOC	-0.179	.	.	0.76381	0.231	0.646
7 STRATGY	0.079	.	.	0.57077	0.045	0.839
8 TECHC	-0.769	.	.	0.44669	10.107	0.016
9 TECHR	0.399	.	.	0.76381	1.324	0.288
10 TECHT	-0.719	.	.	0.84943	7.506	0.029

STEP # 3 R= .897 RSQUARE= .805
TERM ENTERED: TECHC

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
4 MAINTC	0.839	0.201	0.722	0.93378	17.483	0.004
8 TECHC	-0.745	-0.234	-0.793	0.44669	10.107	0.016
11 TOTCOS	0.517	0.127	0.995	0.46303	16.461	0.005
OUT	PART. CORR				.	
---						
2 DURA	-0.521	.	.	0.92492	2.240	0.185
3 INTERF	0.624	.	.	0.97443	3.823	0.098
5 PHASEC	0.291	.	.	0.84794	0.554	0.485
6 PMOLOC	-0.197	.	.	0.76021	0.243	0.640
7 STRATGY	-0.469	.	.	0.45433	1.692	0.241
9 TECHR	0.192	.	.	0.65906	0.230	0.649
10 TECHT	-0.542	.	.	0.57964	2.489	0.166

STEP # 4 R= .939 RSQUARE= .881
TERM ENTERED: INTERF

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
3 INTERF	0.336	0.172	0.279	0.97443	3.823	0.098
4 MAINTC	0.856	0.170	0.736	0.93141	25.454	0.002
8 TECHC	-0.716	-0.198	-0.763	0.44427	13.045	0.011
11 TOTCOS	0.488	0.109	0.938	0.45414	20.149	0.004
OUT	PART. CORR					
---						
2 DURA	-0.189	.	.	0.52460	0.184	0.685
5 PHASEC	-0.108	.	.	0.56590	0.059	0.817
6 PMOLOC	0.077	.	.	0.63620	0.030	0.870
7 STRATGY	-0.133	.	.	0.27927	0.091	0.775
9 TECHR	0.293	.	.	0.65681	0.470	0.524
10 TECHT	-0.608	.	.	0.57245	2.928	0.148

```
STEP #    5 R=  .962 RSQUARE=    .925
TERM ENTERED: TECHT
```

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
3 INTERF	0.307	0.150	0.255	0.96234	4.174	0.097
4 MAINTC	0.717	0.168	0.617	0.71615	18.170	0.008
8 TECHC	-0.517	-0.208	-0.550	0.30481	6.152	0.056
10 TECHT	-0.161	-0.094	-0.277	0.57245	2.928	0.148
11 TOTCOS	0.448	0.097	0.861	0.42813	21.165	0.006
OUT	**PART. CORR**					
---						
2 DURA	-0.506	.	.	0.47205	1.374	0.306
5 PHASEC	0.017	.	.	0.54324	0.001	0.974
6 PMOLOC	-0.112	.	.	0.59081	0.051	0.833
7 STRATGY	0.004	.	.	0.26522	0.000	0.994
9 TECHR	0.254	.	.	0.64109	0.275	0.628

```
THE SUBSET MODEL INCLUDES THE FOLLOWING PREDICTORS:

CONSTANT
INTERF
MAINTC
TECHC
TECHT
TOTCOS
```

```
DEP VAR: LNPMPY      N:      11  MULTIPLE R: 0.962  SQUARED MULTIPLE R: 0.925

ADJUSTED SQUARED MULTIPLE R:  .850     STANDARD ERROR OF ESTIMATE:       0.235
```

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.392	0.422	0.000	.	0.928	0.396
INTERF	0.307	0.150	0.255	0.962	2.043	0.097
MAINTC	0.717	0.168	0.617	0.716	4.263	0.008
TECHC	-0.517	0.208	-0.550	0.305	-2.480	0.056
TECHT	-0.161	0.094	-0.277	0.572	-1.711	0.148
TOTCOS	0.448	0.097	0.861	0.428	4.601	0.006

```
                     ANALYSIS OF VARIANCE
```

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	3.410	5	0.682	12.328	0.008
RESIDUAL	0.277	5	0.055		

```
WARNING: CASE    6 HAS LARGE LEVERAGE          (LEVERAGE =       .941)

DURBIN-WATSON D STATISTIC    1.439
FIRST ORDER AUTOCORRELATION   .059
```

DEFINITION PHASE STEPWISE REGRESSION ANALYSIS

DEPENDENT VARIABLE   LNPMPY

MINIMUM TOLERANCE FOR ENTRY INTO MODEL =   .010000

STEP #   0 R= .000 RSQUARE=   .000

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
OUT	PART. CORR					
---						
2 DURA	-0.053	.	.	.1E+01	0.022	0.885
3 INTERF	0.197	.	.	.1E+01	0.322	0.586
4 MAINTC	0.576	.	.	.1E+01	3.981	0.081
5 OFFSUP	-0.604	.	.	.1E+01	4.596	0.064
6 PHASEC	0.774	.	.	.1E+01	11.938	0.009
7 PMOLOC	0.604	.	.	.1E+01	4.596	0.064
8 STRATGY	-0.302	.	.	.1E+01	0.804	0.396
9 TECHC	0.238	.	.	.1E+01	0.481	0.507
10 TECHR	-0.099	.	.	.1E+01	0.079	0.786
11 TECHT	-0.080	.	.	.1E+01	0.052	0.825
12 TOTCOS	0.599	.	.	.1E+01	4.481	0.067

STEP #   1 R= .774 RSQUARE=   .599
TERM ENTERED: PHASEC

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
6 PHASEC	0.792	0.229	0.774	.1E+01	11.938	0.009
OUT	PART. CORR					
---						
2 DURA	-0.020	.	.	0.99738	0.003	0.958
3 INTERF	0.032	.	.	0.94771	0.007	0.935
4 MAINTC	0.523	.	.	0.88235	2.631	0.149
5 OFFSUP	-0.328	.	.	0.68934	0.847	0.388
7 PMOLOC	0.328	.	.	0.68934	0.847	0.388
8 STRATGY	-0.408	.	.	0.99673	1.397	0.276
9 TECHC	-0.031	.	.	0.88971	0.007	0.936
10 TECHR	0.221	.	.	0.90993	0.360	0.567
11 TECHT	0.154	.	.	0.94842	0.171	0.692
12 TOTCOS	-0.105	.	.	0.32213	0.079	0.787

```
STEP #    2 R=  .842 RSQUARE=   .708
TERM ENTERED: MAINTC
```

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
1 CONSTANT						
4 MAINTC	0.842	0.519	0.352	0.88235	2.631	0.149
6 PHASEC	0.668	0.222	0.653	0.88235	9.029	0.020
OUT	PART. CORR					
2 DURA	0.030	.	.	0.98977	0.005	0.944
3 INTERF	-0.139	.	.	0.87407	0.118	0.743
5 OFFSUP	-0.155	.	.	0.58125	0.148	0.714
7 PMOLOC	0.155	.	.	0.58125	0.148	0.714
8 STRATGY	-0.290	.	.	0.88519	0.551	0.486
9 TECHC	-0.354	.	.	0.70611	0.860	0.390
10 TECHR	0.190	.	.	0.89792	0.225	0.652
11 TECHT	0.390	.	.	0.85749	1.078	0.339
12 TOTCOS	-0.050	.	.	0.31746	0.015	0.906

THE SUBSET MODEL INCLUDES THE FOLLOWING PREDICTORS:

```
CONSTANT
MAINTC
PHASEC
```

```
DEP VAR:  LNPMPY     N:     10  MULTIPLE R: 0.842  SQUARED MULTIPLE R: 0.708
ADJUSTED SQUARED MULTIPLE R:  .625    STANDARD ERROR OF ESTIMATE:        0.771
```

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	-0.775	0.802	0.000	.	-0.966	0.366
MAINTC	0.842	0.519	0.352	0.882	1.622	0.149
PHASEC	0.668	0.222	0.653	0.882	3.005	0.020

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	10.098	2	5.049	8.502	0.013
RESIDUAL	4.157	7	0.594		

```
DURBIN-WATSON D STATISTIC     2.351
FIRST ORDER AUTOCORRELATION   -.201
```

IMPLEMENTATION PHASE STEPWISE REGRESSION ANALYSIS

DEPENDENT VARIABLE   LNPMPY

MINIMUM TOLERANCE FOR ENTRY INTO MODEL =   .010000

STEP #   0 R= .000 RSQUARE=   .000

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
OUT	PART. CORR					
---						
2 DURA	0.396	.		. .1E+01	3.338	0.084
3 INTERF	-0.301	.		. .1E+01	1.799	0.196
4 MAINTC	0.168	.		. .1E+01	0.521	0.480
5 PHASEC	0.696	.		. .1E+01	16.866	0.001
6 PMOLOC	0.418	.		. .1E+01	3.808	0.067
7 STRATGY	-0.012	.		. .1E+01	0.002	0.961
8 TECHC	0.175	.		. .1E+01	0.568	0.461
9 TECHR	-0.254	.		. .1E+01	1.245	0.279
10 TECHT	0.210	.		. .1E+01	0.827	0.375
11 TOTCOS	0.740	.		. .1E+01	21.770	0.000

STEP #   1 R= .740 RSQUARE=   .547
TERM ENTERED: TOTCOS

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
11 TOTCOS	0.933	0.200	0.740	.1E+01	21.770	0.000
OUT	PART. CORR					
---						
2 DURA	0.293	.		. 0.92223	1.595	0.224
3 INTERF	-0.295	.		. 0.97973	1.615	0.221
4 MAINTC	0.276	.		. 0.99944	1.397	0.254
5 PHASEC	-0.144	.		. 0.05675	0.359	0.557
6 PMOLOC	0.262	.		. 0.88358	1.249	0.279
7 STRATGY	-0.417	.		. 0.88358	3.588	0.075
8 TECHC	-0.049	.		. 0.92226	0.040	0.843
9 TECHR	0.035	.		. 0.86060	0.021	0.886
10 TECHT	-0.052	.		. 0.89239	0.046	0.832

STEP #   2 R= .791 RSQUARE=   .626
TERM ENTERED: STRATGY

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	F	'P'
IN						
---						
1 CONSTANT						
7 STRATGY	-0.679	-0.359	-0.299	0.88358	3.588	0.075
11 TOTCOS	1.061	0.199	0.842	0.88358	28.482	0.000
OUT	PART. CORR					
---						
2 DURA	0.156	.	.	0.78353	0.401	0.536
3 INTERF	-0.222	.	.	0.92507	0.828	0.376
4 MAINTC	0.188	.	.	0.92945	0.589	0.454
5 PHASEC	-0.024	.	.	0.05179	0.009	0.926
6 PMOLOC	0.181	.	.	0.83110	0.544	0.471
8 TECHC	-0.099	.	.	0.91339	0.158	0.696
9 TECHR	0.026	.	.	0.85989	0.010	0.920
10 TECHT	-0.011	.	.	0.88335	0.002	0.965

THE SUBSET MODEL INCLUDES THE FOLLOWING PREDICTORS:

CONSTANT
STRATGY
TOTCOS

DEP VAR: LNPMPY   N: 20 MULTIPLE R: 0.791 SQUARED MULTIPLE R: 0.626
ADJUSTED SQUARED MULTIPLE R: .582   STANDARD ERROR OF ESTIMATE: 0.719

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	1.106	0.748	0.000	.	1.477	0.158
STRATGY	-0.679	0.359	-0.299	0.884	-1.894	0.075
TOTCOS	1.061	0.199	0.842	0.884	5.337	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	14.733	2	7.366	14.244	0.000
RESIDUAL	8.792	17	0.517		

WARNING: CASE   7 IS AN OUTLIER (STUDENTIZED RESIDUAL =   4.590)

DURBIN-WATSON D STATISTIC   2.417
FIRST ORDER AUTOCORRELATION -.219
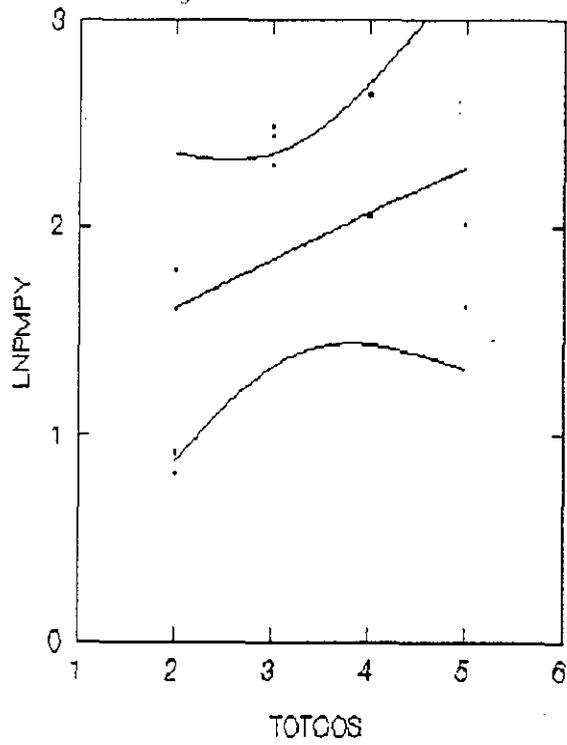
Figure 1 - LNPMPY VS TOTAL COST (Development)
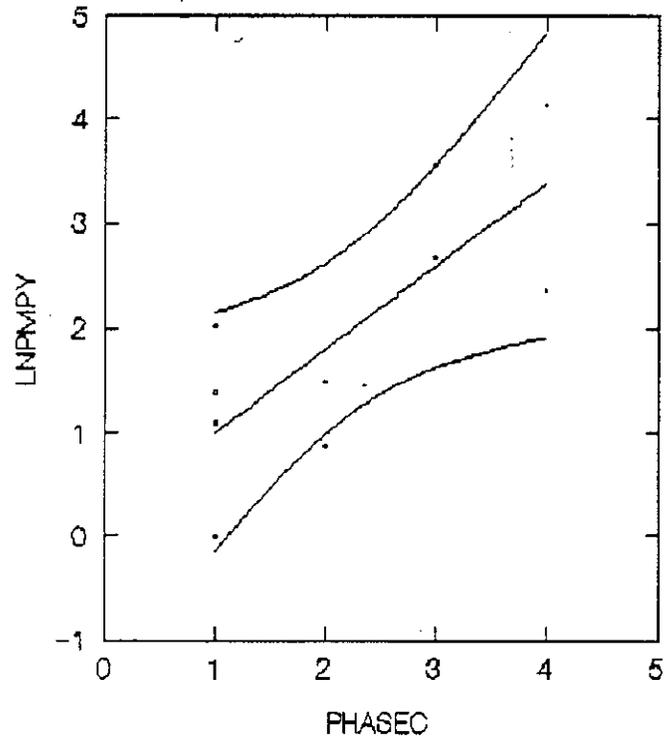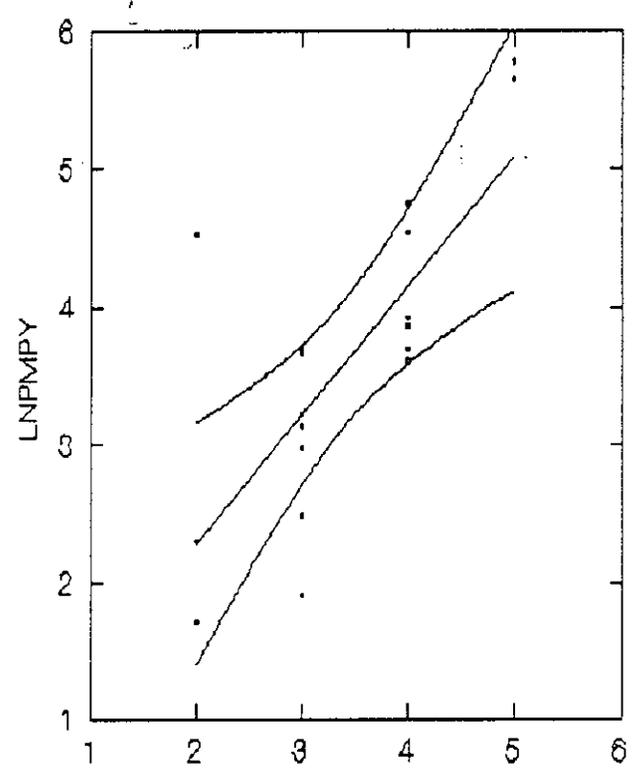
Figure 2 - LNPMPY VS PHASE COST (Definition)

Figure 3 - LNPMPY VS TOTAL COST (Implementation)
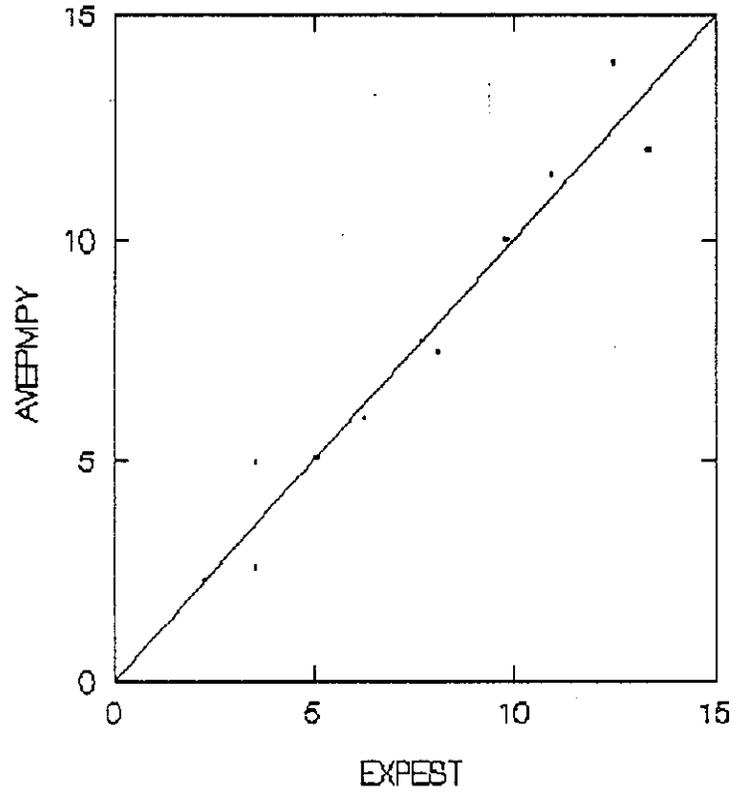
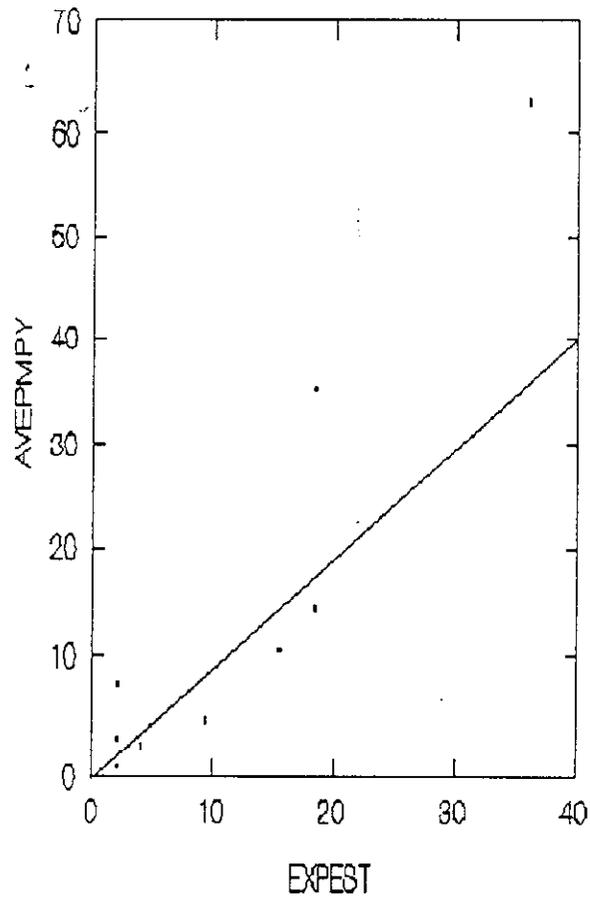**Figure 4** - ACTUAL SIZE VS PREDICTION (Development)

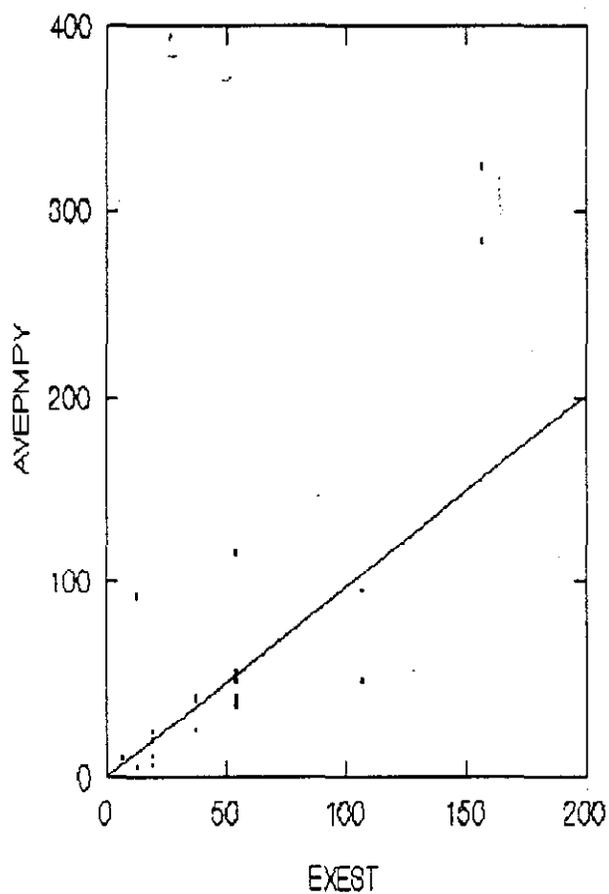Figure 5 - ACTUAL SIZE VS PREDICTION (Definition)
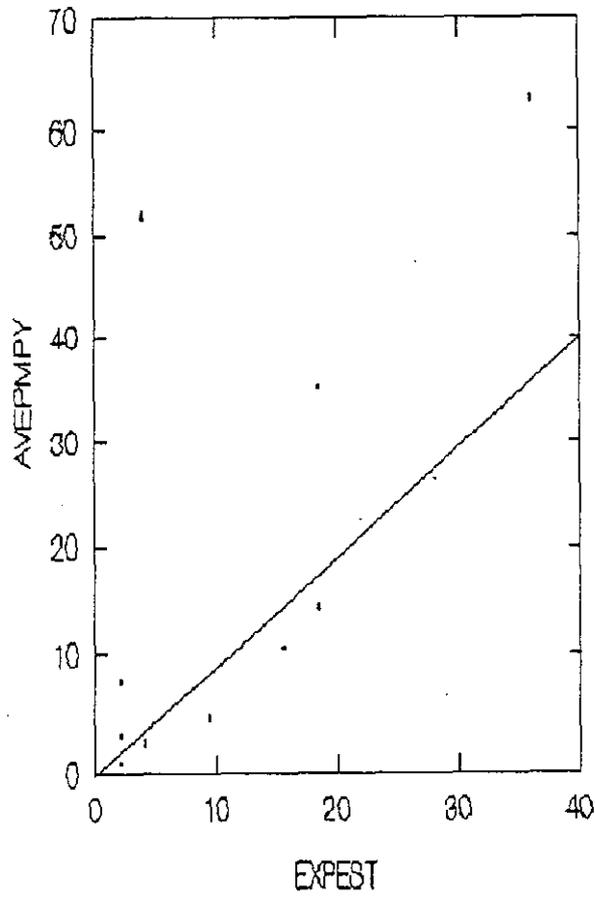
EXEST

Figure 6 - ACTUAL SIZE VS PREDICTION (Implementation)

Figure 5 - ACTUAL SIZE VS PREDICTION (Definition)

13. **ABSTRACT** (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), or (U). It is not necessary to include here abstracts in both official languages unless the test is bilingual).

In times of tight budgets, an ability to forecast personnel requirements for new DND commitments is critically needed. This research note illustrates a battery of analytical techniques that were used to determine parametric equations for the size of Program Management Offices (PMOs). These equations, once thoroughly developed, can provide Senior Management with timely manpower planning guidance in this departmentally significant area.

14. **KEYWORDS, DESCRIPTORS or IDENTIFIERS** (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Parametric Model
Personnel Requirements
Staistical Analysis Techniques
Program Management Office Sizing