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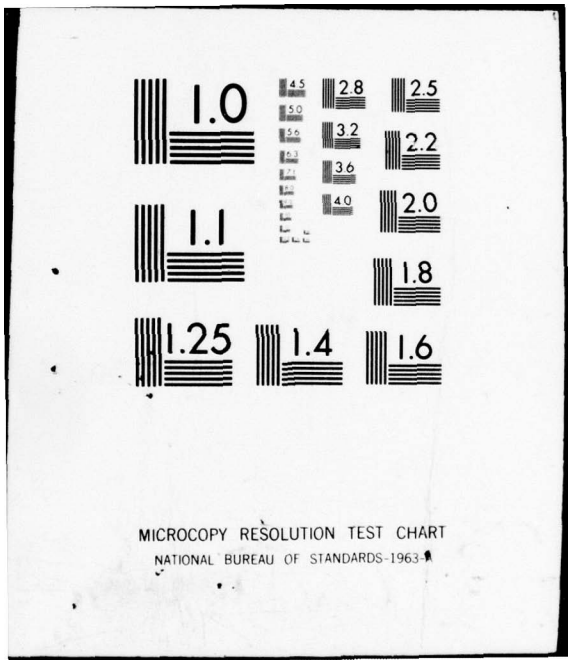
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PRODUCTIVITY IN THE AIR FORCE WEAPONS LABORATORY: MEASUREMENT AND PREDICTION

TECHNICAL REPORT

AFIT/TR 78-1

Michael J. Stahl
Captain USAF

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PRODUCTIVITY IN THE AIR FORCE WEAPONS LABORATORY: MEASUREMENT AND PREDICTION

Air Force Institute of Technology

Technical Report 78-1

by

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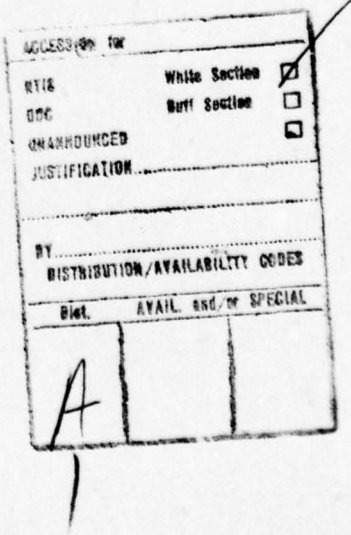
PREFACE

This report is a follow-on analysis of data gathered by Captain Michael Koser for his thesis at the Air Force Institute of Technology. I was advisor to him during his thesis effort. Whereas, Captain Koser does not have the available computer resources in his current job, I performed this follow-on analysis that was requested by the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico.

This report does not repeat the level of detail contained in Captain Koser's thesis. Thus, the reader is referred to the thesis or Stahl and Koser's journal article (see references) if more detail is required.



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ABSTRACT

Productivity in the Air Force Weapons Laboratory was measured with eight separate kinds of output, an unweighted total, and a weighted total measure of output for 135 scientists/engineers. Several individual and organizational variables were also captured. Educational level, communication with other scientists and engineers, attendance at professional society meetings, office membership, and reward contingency perceptions predicted productive vice nonproductive respondents. A discovered lack of consensus between supervisors and nonsupervisors concerning the importance of technical reports was hypothesized to be attributable to differences between the stated and the perceived reward system.

PRODUCTIVITY IN THE AIR FORCE WEAPONS LABORATORY: MEASUREMENT AND PREDICTION

INTRODUCTION

This report addresses the problem of discovering predictor variables (individual and organizational) that discriminate between productive and nonproductive scientists and engineers in the Air Force Weapons Laboratory. Prior to that analysis, the process of measuring productivity and some associated findings are reviewed.

METHODOLOGY

Measures

The survey instrument used in this effort was composed of two separate questionnaires. One was sent to first level supervisors and was designed to provide a weighting scheme to be applied to the various dimensions of scientific/engineering output. The other was sent to working level scientists and engineers and provided a measurement for the organizational variables in question and the output of the individual scientist/engineer.

A major consideration in determining the list of output variables was to ensure that it included items that were readily identifiable to those who were reporting their output and to those who were to apply weights. To determine such a list, meetings were held with laboratory management, and nonsupervisory scientists and engineers. The resultant list of output included (1) technical reports, (2) work unit planning documents (proposals to management), (3) journal articles, (4) procurement packages

(contract monitoring), (5) evaluations of proposals (contract monitoring), (6) computer codes, (7) technical presentations and (8) management presentations.

Using the list of output variables, the first level supervisors were asked to place a weight on each type of output that they felt best represented its relative importance to the laboratory. In order to provide a common point of reference, these weights were to sum to 100 on each questionnaire. The mean of the weights for each type of output obtained was then used as a basis in the determination of the final weighting scheme to be applied to the output reported. The questionnaire sent to working level scientists/engineers asked for a self report on the numbers of each type of output produced over the most recent two years.

Based upon the predictor variables examined by Stahl and Steger (1977a) and the recommendations of laboratory management, a list of predictor variables to be measured was determined (Table I).

The instrument used to measure the predictor variables was a slight modification of Stahl and Steger's (1977a) questionnaire which used nine point rating scales to measure the perceptual variables. For example, a statement which read "What amount of pressure is exerted upon you by your supervisor for quantity of output?" was followed by a nine-point scale. The scale was anchored with the descriptor "No pressure - quantity of output never mentioned" at one end, and "Extensive pressure - quantity of output always stressed" at the other end.

Sample

Table II contains information on the number of working level scientists/engineers, the number of first level supervisors in the lab,

TABLE I

PREDICTOR VARIABLES AND ABBREVIATIONS

Abbreviation	Predictor Variable
AGE	Age
GRADE	Grade/rank
EDL	Educational level
TIMIS	Length of time in current section/group
TIMUS	Length of time under current supervisor
YRSE	Years of scientific/engineering experience since first degree
COMIS[1]	Communication with other colleagues in same section
COMOS[1]	Communication with scientists/engineers outside section
COMWS[1]	Communication with supervisor
QUANP[2]	Pressure for quantity of output
QUALP[2]	Pressure for quality of output
TIMEP[2]	Pressure for meeting schedules/deadlines
MISSP[2]	Pressure for relevancy of work to the Air Force mission
PART[2]	Degree of participation in setting work goals
QUANR[2]	Degree to which quantity of output is rewarded
QUALR[2]	Degree to which quality of output is rewarded
INNOR[2]	Degree to which innovative output is rewarded
EVAL[2]	Extent to which supervisor evaluates work
CONTR[2]	Extent to which supervisor controls work
EMP[2]	Extent to which supervisor understands feelings
NATW	Predominant nature of work
FREQA	Frequency of attendence at professional society meetings
ORGN	Organizational membership in the laboratory

[1]Frequency of communication

[2]Perceptual variables

the numbers surveyed, and the number of returned and usable questionnaires. The sample was randomly chosen. Several questionnaires were not usable due to missing data or the respondents being members of their current sections for less than one year.

TABLE II

THE SAMPLE

	Population	Sampled	Returned	Usable
Working Level Scientist/engineer	390	349	184	135
First Level Supervisors	101	91	65	53

The average age of the scientists/engineers was 33.5 years. Twenty-eight of the scientists/engineers had PhD's, 64 had Master's Degrees and the balance had Bachelor's Degrees. Fifty-five percent were military.

RESULTS

Throughout the results section, variable abbreviations are used for the sake of brevity in the tables. Table III contains the output variables and their abbreviations and Table I contains the other abbreviations.

Weighting

The weight applied to each output variable is listed in Table IV. Using these weights, the Spearman-Brown Reliability formula (Winer, 1971, p. 286) resulted in a reliability of $r = .88$ which demonstrated high interrater agreement.

TABLE III

OUTPUT VARIABLES AND THEIR ABBREVIATIONS

Abbreviation	Output Variables
TR	Technical Report
WUPD	Work Unit Planning Document
JA	Journal Article
PP	Procurement Package
EOP	Evaluation of Proposal
CC	Computer Code
TP	Technical Presentation
MP	Management Presentation
UTO	Unweighted Total Output
WTO	Weighted Total Output

TABLE IV

OUTPUT WEIGHTS AND WEIGHT RANKS

Variable	Weight	Weight Rank
TR	20.97	1
WUPD	9.18	7
JA	8.76	8
PP	13.01	3
EOP	9.92	5
CC	15.62	2
TP	12.77	4
MP	9.75	6

The mean output per category reported by the scientists/engineers is contained in Table V. A comparison of the rank of the output means, as reported by the scientists/engineers, with the rank of the output weights, as reported by the supervisors, is instructive. The ranks are approximately similar except for technical reports (TR). The supervisors ranked it in the number one importance position, whereas it ranked sixth in order of occurrence for scientists/engineers. Several interesting possibilities emerge. Is this reflective of lack of congruence between supervisors and nonsupervisors concerning the importance of technical reports? Is the average number of technical reports produced a measure of the importance attached to them by the supervisors? This issue is further explored after the predictors of productivity are reviewed.

TABLE V

OUTPUT MEANS AND MEAN RANKS

Variable	Mean	Mean Rank
TR	1.80	6
WUPD	1.15	7
JA	0.80	8
PP	2.04	5
EOP	2.30	2
CC	2.16	4
TP	2.97	1
MP	2.27	3

Predicting Productivity

Examination of the distribution of output of the eight separate measures revealed many respondents with zero output in any one category in two years (e.g. one third of the sample had zero technical reports, and two thirds of the sample had zero journal articles). Such distributions were observed in other Air Force Research and Development labs. (Stahl and Stevens, 1977; Stahl, McNichols & Manley, 1977) Thus, those respondents with zero output on a given productivity measure were labeled nonproductive and those with some output were labeled productive. Subsequently, t-tests were performed on each of the predictor variables for each of the productivity variables. For example, the average age of the producers of journal articles was compared with the average age of the nonproducers of journal articles.

The distributions of the two aggregate productivity measures (UTO & WTO) were less skewed than the other distributions and had fewer respondents with zero output. Thus, those above the mean of each of the distributions were labeled the producers and those below were placed in the nonproductive group. Subsequently, t-tests were performed on the predictor variables.

Tables VI, VII, and VIII contain the results of the t-tests for the entire AFWL sample, the respondents from the Advanced Radiation Technology Office (ARTO), and those from the Nuclear Technology Office (NTO) respectively. Only statistically significant differences between the productive and nonproductive groups are highlighted. Group sizes ranged from around 20 to around 80, depending on which productivity measure was tested in which division.

TABLE VI

Means Tests - Productive/Nonproductive for
23 Predictor Variables - AFWL

Predictor Variables	Productivity Variables									
	TR	WUPD	JA	PP	EOP	CC	TP	MP	UTO	WTO
AGE		++				--				
GRADE			+							
EDL	++		++			+	++		+	++
TIMIS		+								
TIMUS										
YRSE		++	+			-				
NATW	-			++		--	--			
COMIS			+		+					+
COMOS	-	++						++		
COMWS					+					
FREQA			++		+	+	++		++	++
ORGN			--	--	-		-		-	--
QUANP			+	+	+					
QUALP										
TIMEP										
MISSP										
PART		+								
QUANR				+	+		+		+	+
QUALR		++								
INNOR		+								
EVAL	-	+		+						
CONTR			-							
EMP				+						

+ Means predictor value significantly higher for producers than nonproducers ($P \leq .05$)

++ Means predictor value significantly higher for producers than nonproducers ($P \leq .01$)

- Means predictor value significantly lower for producers than nonproducers ($P \leq .05$)

-- Means predictor value significantly lower for producers than nonproducers ($P \leq .01$)

TABLE VII

Means Tests - Productive/Nonproductive for
23 Predictor Variabes - ARTO

Predictor Variables	PRODUCTIVITY VARIABLES									
	TR	WUPD	JA	PP	EOP	CC	TP	MP	UTO	WTO
AGE								+	+	+
GRADE			++							
EDL			++				+			
TIMIS								+		
TIMUS		+							-	
YRSE			+							
NATW				++	+					
COMIS										
COMOS								+		
COMWS		+		+	++					
FREQA							+			+
ORGN										
QUANP	+									
QUALP	+					++				
TIMEP			+	+						
MISSP										
PART									+	+
QUANR		+								
QUALR		+								
INNOR		++					+			
EVAL		++								
CONTR			--							
EMP				+						

+Means predictor value significantly higher for producers than nonproducers ($P \leq .05$)
++Means predictor value significantly higher for producers than nonproducers ($P \leq .01$)
-Means predictor value significantly lower for producers than nonproducers ($P \leq .05$)
--Means predictor value significantly lower for producers than nonproducers ($P \leq .01$)

TABLE VIII

Means Tests - Productive/Nonproductive for
23 Predictor Variables - NTO

Predictor Variables	PRODUCTIVITY VARIABLES									
	TR	WUPD	JA	PP	EOP	CC	TP	MP	UTO	WTO
AGE		++				--				
GRADE		++				-			+	
EDL	++		+			+	+		+	
TIMIS		+								
TIMUS										
YRSE		++	+			-				
NATW				++			-			
COMIS	--		+		++				+	+
COMOS		++						+		
COMWS			+							
FREQA	+		++		+		++	+	+	+
ORGN										
QUANP										
QUALP							+			
TIMEP										
MISSP							+			
PART			+							
QUANR	-				+				+	
QUALR	-									
INNOR	-									
EVAL	-									
CONTR										
EMP										

\+ Means predictor value significantly higher for Producers than nonproducers ($P \leq .05$)

++ Means predictor value significantly higher for producers than nonproducers ($P \leq .01$)

\- Means predictor value significantly lower for producers than nonproducers ($P \leq .05$)

-- Means predictor value significantly lower for producers than nonproducers ($P \leq .01$)

Examination of Table VI reveals some predictor variables which discriminate between the productive and nonproductive groups as measured by Weighted Total Output (WTO) and several other productivity measures.

The producers, as measured by Technical Reports (TR), Journal Articles (JA), Computer Codes (CC), Technical Presentations (TP), Unweighted Total Output (UTO), and Weighted Total Output (WTO) had a higher average educational level (EDL) than the nonproducers. Such differences are in accordance with the findings of Stahl and Steger (1977a), Stahl and Stevens (1977), and Vincent and Mirakhor (1972).

The producers, as measured by Journal Articles (JA), Evaluations of Proposals (EOP), and Weighted Total Output (WTO), communicated with other scientists and engineers within their own section (COMIS) more frequently than the nonproducers. This corresponds to positive relationships between performance and communication noted by Stahl and Steger (1977a), Pelz and Andrews (1966), Pelz (1956), Keeler (1966) and Kallick (1964).

Producers identified by Journal Articles (JA), Evaluations of Proposals (EOP), Computer Codes (CC), Technical Presentation (TP), Unweighted Total Output (UTO) and Weighted Total Output (WTO) attneded meetings of professional societies more frequently (FREQA) than the nonproducers. It is difficult to speculate cause and effect with such a finding. However, it may be indicative of the cosmopolitan orientation, i.e. commitment to the professional role of scientist/engineer. This oreintation was found to be related to several productivity measures in four other Air Force R&D Labs (Stahl, McNichols and Manley, 1977).

The respondents in one office within the Lab (ORGN) were more productive than those in the other office on six of the productivity measures.

Producers, measured five different ways, had a stronger perception than the nonproducers of being rewarded for productive output (QUANR). Keeler (1966), Kallick (1964), McCarrey and Edwards (1973), Stahl and Steger (1977a), Stahl and Stevens (1977), and Vollmer (1963) all found similar results. In fact, perceptions of the operative reward system may be one of the most potent predictors of productivity.

Examination of Tables VII and VIII (relationships for ARTO and NTO respectively) yields little additional information except with respect to rewards. In ARTO, the producers of Work Unit Planning Documents (WUPD), had stronger perceptions than the nonproducers of being rewarded for productivity (QUANR), of being rewarded for quality output (QUALR), and of being rewarded for innovative output (INNOR). In NTO, the producers of Technical Reports (TR) had weaker perceptions than the nonproducers of being rewarded for productivity (QUANR), of being rewarded for quality output (QUALR), and of being rewarded for innovative output (INNOR). Interestingly, these weaker perceptions of rewarded behavior surface with regard to Technical Reports, the one measure of productivity for which there was lack of consensus noted concerning its importance.

It is possible that one of the reasons for the lack of consensus noted previously between the relative importance expressed by the supervisors and nonsupervisors concerning Technical Reports is a difference between what the supervisors say is important and what the nonsupervisors perceive is important via the reward system. Such a hypothesis deserves further research.

SUMMARY AND IMPLICATIONS

With regard to the original problem that this research addressed, i.e., discovering discriminators between productive and nonproductive scientists and enginers, several consistent findings are noted. The producers, on the average, are more educated, communicate with other scientists and engineers within their own section more frequently, attend more professional society meetings, are concentrated in greater numbers in one office, and have a stronger perception of being rewarded for productivity than their nonproductive counterparts.

In a somewhat serendipitous fashion through the process of developing weights for the measure of weighted total output, it was also discovered that there is a lack of consensus between the supervisors and nonsupervisors concerning the importance of Technical Reports. This lack of consensus may be due to differences between the stated and perceived reward system. Such a hypothesis requires further research.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Productivity in the Air Force Weapons Laboratory was measured with eight separate kinds of output, an unweighted total, and a weighted total measure of output for 135 scientists/engineers. Several individual and organizational variables were also captured. Educational level, communication with other scientists and engineers, attendance at professional society meetings, office membership, and reward contingency perceptions predicted productive vice non-productive respondents. A discovered lack of consensus between supervisors and nonsupervisors concerning the importance of technical reports was

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hypothesized to be attributable to differences between the stated and the perceived reward system.

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