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September 1989
NSRP 0310

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1989 Ship Production Symposium

Paper No. 15: A Study of the Causes of Man-Hour Variance of Naval Shipyard Work Standards

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

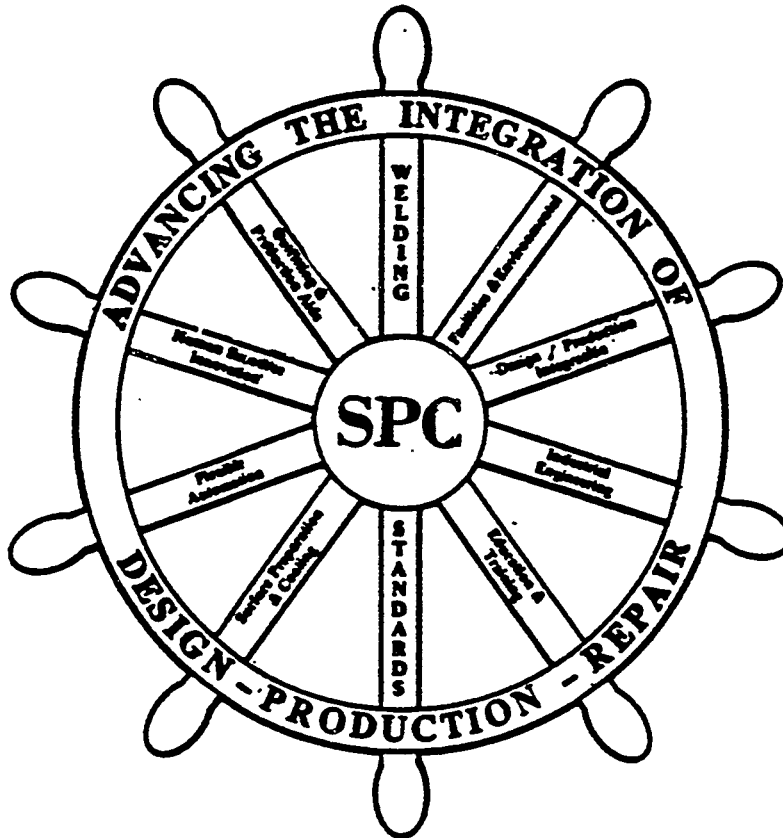
Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE SEP 1989		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE The National Shipbuilding Research Program 1989 Ship Production Symposium Paper No. 15: A Study of the Causes of Man-Hour Variance of Naval Shipyard Work Standards				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Bldg 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 12	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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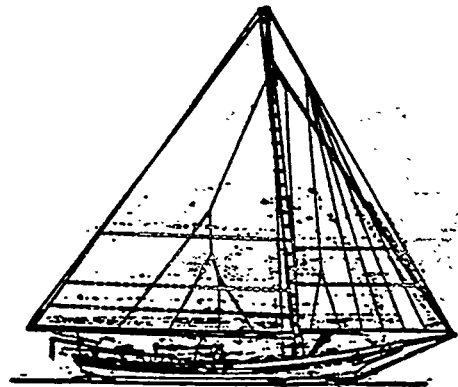
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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM 1989 SHIP PRODUCTION SYMPOSIUM

NSRP
0310



SEPTEMBER 13-15, 1989
SHERATON NATIONAL
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A Study of the Causes of Man-Hour Variance of Naval Shipyard Work Standards

Howard M. Bunch, Member, UMTRI, University of Michigan, Ann Arbor, MI

Abstract:

This paper is a presentation of the results of a study conducted at a U.S. Navy shipyard during 1987 concerning the relationship between engineering standards and the variances that were occurring in production budget and charged manhours. The 10 engineering standards having the greatest manhour variances were examined. These standards, as a group, accounted for about 62 percent of the manhour variance that was reported during the first nine months of 1987. The study indicated that, with one exception, all of the standards were "generic" in their application, i.e., they can be applied over a wide range of job orders. The study also concluded that engineered standards are only partially responsible for the production variance.

Introduction

In 1985-86 there was an intensive management analysis of U.S. Navy shipyard operations with the objective of making specific recommendations that would strengthen the operations of these activities. The report indicated that inflated return costs lead to misuse of shipyard resources and increased costs. A sample of 38 key operations showed an average variance² of 41 percent over the standards. One of the specific elements identified as a contributor to this problem was "estimates derivation".⁴

In 1987 the author, while on temporary assignment at Philadelphia Naval Shipyard, was asked to investigate the role of engineered (or pre-determined) time standards as a contributor to the workload variances that were occurring at that yard. The request was partially the result of the criticisms levied by the Navy shipyard operations evaluation, cited above; however, Philadelphia Naval Shipyard's management had independently arrived at a desire to investigate the link-up between cost variance and engineered standards, especially as it might affect their planned implementation of zone-logic construction concepts.⁶

This paper is a summary presentation of the investigation that occurred, and includes the conclusions and recommendations that were a part of the report. Finally, there is an update of what has actually occurred relative to the recommendations in the 18 months since the investigation was completed.

Engineered standards

At Philadelphia Naval Shipyard the engineered standards are developed from the "Allowed" or "Standard time (T), which is the combination of "Work-Factor" time (W), plus an allowance factor for personal, unavoidable delay, and fatigue (A):

$$T = W.A \quad (1)$$

"'Work-Factor' time represents the output attainment capability of averaged experienced operators, working with good skill and good effort and without interruptions or delays; it is the common denominator and index of output capability (expected attainment) for the world population of average experience operators." ⁷

"Personal, fatigue and delay allowances is the time allowed a worker to compensate for attending to personal needs, for fatigue, and for delay occurring due to conditions beyond his control. This time is additive to the normal time required to accomplish a job. The inclusion of this allowance is common practice in the development of a labor standard. . . ."⁸ The allowance factor will typically have a range of 1.02 to 1.30.

The standard time (T) is further adjusted to allow for non-productive or standby time. This final calculation is performed by the planner and estimator, and results in the "Standard Manhour Allowance" (SMH), or sometimes called the "Planning Standard" (PS). At Philadelphia Naval Shipyard the term is called "Engineered Standard"; this expression was the one used in this paper. Thus the Engineered Standard (ES) is the time actually assigned to a particular task, and includes the standard time (T), plus allowances for non-process (or non-productive) time (NT):

$$ES = T.NT \quad (2)$$

The Study Approach

The study plan was comprised of three phases:

1. analysis of the yard's use of engineered standards during 1987, isolating those that had the largest occurrence of manhour variance (both overall and by production group);

2. development of a cause-effect diagram that described the factors that can cause production variance to occur; and evaluating the effect of engineered standards on the over-all work variance, and

3. suggestion of an action plan for reducing production variance attributed to engineered standards.

Analysis of Engineered Standards

As shown in Table 1, a total of 2,173,988 manhours was budgeted for assigned work on 22,334 key operations during the study period; there was, however, a total of 2,846,717 manhours expended to accomplish the assigned tasks. The difference (or variance) between the two amounts is 672,729 manhours, or a performance factor of 1.31.9

The key operations were then linked to the engineered standards used to develop the budgets for each key operation; the standards were next arrayed on the basis of the amount of variance occurring on key operations associated with each standard. The Top 10 standards, in terms of amount of variance, are shown in descending order in Table 1. Six standards accounted for over 50 percent of the variance; yet they were involved in only 26 percent of the key operations (5,882 versus 22,334). The average key operation was budgeted at 153 manhours, but required 210 manhours to complete. The resulting performance factor was 1.38.

Table 1 continues the listing through the "Top 10"; the group accounted for nearly 62 percent of the total reported variance, even though it accounted for only 38 percent of the total key operations (8437 versus 22334). The average key operation for the group was budgeted at 129 manhours, but required 178 manhours: the performance factor was 1.38. It should be noted, also, that the "Top 10" standards were with one exception, generic in nature, i.e., they were designed to provide guidance for a broad functional work activity. e.g., structural welding.

---ENGINEERED STANDARD---		# of Line Items	-----MANHOURS-----			Percent of Total Variance		Performance Factor	Manhours Budget/#Items	Manhours Actual/#Items
Number	Name		Allowed	Expended	Variance	Line	Cumulative			
056-801	Piping--Remover, Fabricate, Class P1, P2, P3	1,868	426,794	536,765	109,971	16.35%	16.35%	1.26	228.48	287.35
100-303	Structural Field Installation Aluminum and Steel	671	79,836	163,737	83,901	12.47%	28.82%	2.05	118.98	244.02
026-903	Welding, Structural/Production	894	100,263	155,217	54,954	8.17%	36.99%	1.55	112.15	173.62
304-301	Electrical Electronic & Fire Control Cable & Equipment Installation	1,943	188,043	221,616	33,573	4.99%	41.98%	1.18	96.78	114.06
505-349	Welding, Pipe Class P1 & P2 (Field)	492	68,648	98,174	29,526	4.39%	46.37%	1.43	139.53	199.54
587-914	Catapult Launching Engine Components, Shipboard RPR	14	35,657	61,192	25,535	3.80%	50.16%	1.72	2546.93	4370.86
0038-306	Valves, GTV, LD&H1, Press & Welded-In, Insp Rpr & Test	147	22,612	46,701	24,089	3.58%	53.74%	2.07	153.82	317.69
0100-305	Structural Foundation, Al & Steel Assemble & Install	678	39,050	61,590	22,540	3.35%	57.09%	1.58	57.60	90.84
0100-306	Access Opening, Remove and Install	688	46,596	62,325	15,729	2.34%	59.43%	1.34	67.73	90.59
0804-352	Rigger Service Surface Craft	1,042	77,131	91,206	14,075	2.09%	61.52%	1.18	74.02	87.53
---Total, "Top 6"---		5,882	899,241	1,236,701	337,460	50.16%	50.16%	1.38	152.88	210.25
---Total, "Top 10"---		8,437	1,084,630	1,498,523	413,893	61.52%	61.52%	1.38	128.56	177.61
---All Standards Beyond "Top 10"---		13,897	1,089,358	1,348,194	258,836	38.48%	100.00%	1.24	78.39	97.01
---GRAND TOTALS---		22,334	2,173,988	2,846,717	672,729	100.00%		1.31	97.34	127.46

TABLE 1. THE "TOP 10" ENGINEERED STANDARDS HAVING THE GREATEST MANHOUR VARIANCE AT PHILADELPHIA NAVAL SHIPYARD-NINE MONTHS OF 1977.

The exception was standard #587-914, dealing with catapult launching equipment repair. But, even in this case the key operation budgets were so large (approximately 2500 manhours) that it too could be considered as a generic standard.

The rest of the engineered standards beyond the "Top 10" accounted for about 38 percent of the total reported variance. The performance factor for this group was 1.24, and the average work order was budgeted at 76 manhours, but required 97 manhours.

The relationships between key operation size and the performance factors for the engineered standards are shown in Figures 1 and 2. A least-squares fit of the data for nine of the top ten standards¹⁰ indicates a slight upward movement in the performance factor for those engineered standards with larger budgeted manhours per work order, depicted in Figure 1. The wide scatter in the data (confirmed by $R = .12$) suggests, however, that budgeted manhours is not the major variable affecting the performance factor. Or, at least, there is a weak linear relationship between the two variables.

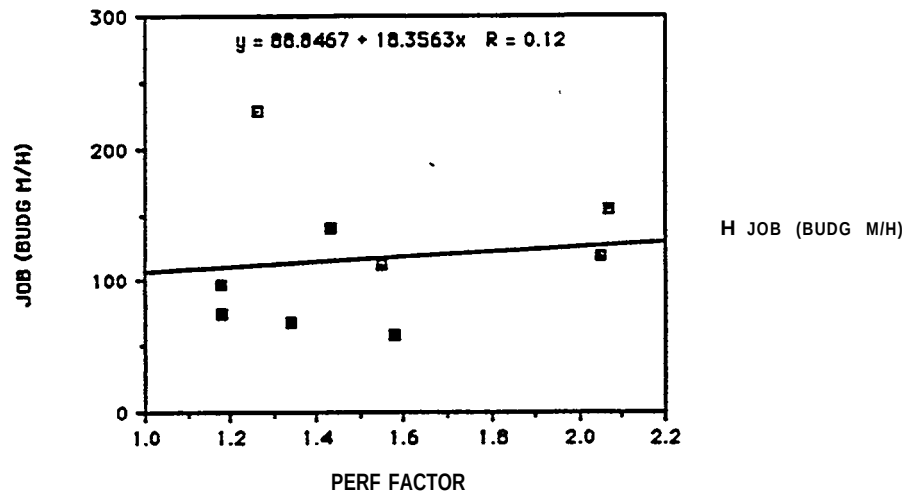


FIGURE 1 KEY OPERATIONS AVERAGE JOB BUDGET MANHOURS FOR VARIOUS ENGINEERED STANDARDS. PHILADELPHIA NAVAL SHIPYARD-NINE MONTHS OF 1977.

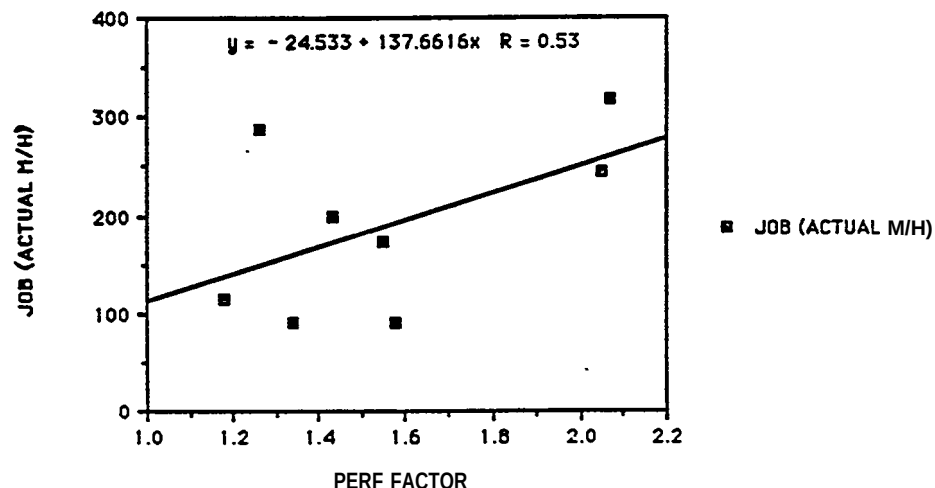


FIGURE II. KEY OPERATIONS AVERAGE APPLIED MANHOURS FOR VARIOUS ENGINEERED STANDARDS. PHILADELPHIA NAVAL SHIPYARD-NINE MONTHS OF 1977.

Figure 2 plots the relationship between the performance factor and the actual manhours required to complete the key operation. In this case, there is a significant increase in the performance factor as the amount of manhours required to complete the job increases. Too, the strength of the relationship increases, as evidenced by the higher "R" statistic.

There were three conclusions from this portion of the analysis:

1. Engineered Standards that produce larger manhour allocations for a work assignment tend to result in larger performance factors.
2. A common characteristic of those standard producing the greatest manhour variance (i.e., the "Top 10") was that they were generic in scope, i.e., the standards consisted of general descriptions of tasks and associated manhours, and the planner was required to construct the specific work assignment budget: by referring to the general data tables in the standard; and
3. Consistent with the situation in many cause-effect analyses, a significant amount of the total production manhour variance could be linked to a few engineered standards. (This was an example of the "significant few versus the the trivial many" phenomena.)

The study was expanded to examine the relationship between the performance factors of specific production unit key operations and their link-up with engineered standards.

Figure III presents the key operations performance factors during the study period for each of the production units; the range was from a low of 1.10 (for the production services group) to a high of 1.58 (for the mechanical machinery group). The figure shows that the production groups can be divided into two classifications: those groups whose performance factor is below the average (the Production Services Group, Pipe Boiler Group, and the Electrical Group), and the groups whose performance is above the average (Mechanical Machinery Group and the Structural Group).

An attempt was then made to see if there was any clear link-up between the below- and above-average clusters, and their involvement in the "top-10" standards. To do this, an examination was made of standards most associated with high variances in each of the production shops of each group. The "Top 5" standards in each shop were examined. Table 2 shows the results of this analysis, with the groups with above-average performance factor (as shown in Table 1) being displayed above the dashed line. The analysis gave mixed results. The data indicated that the

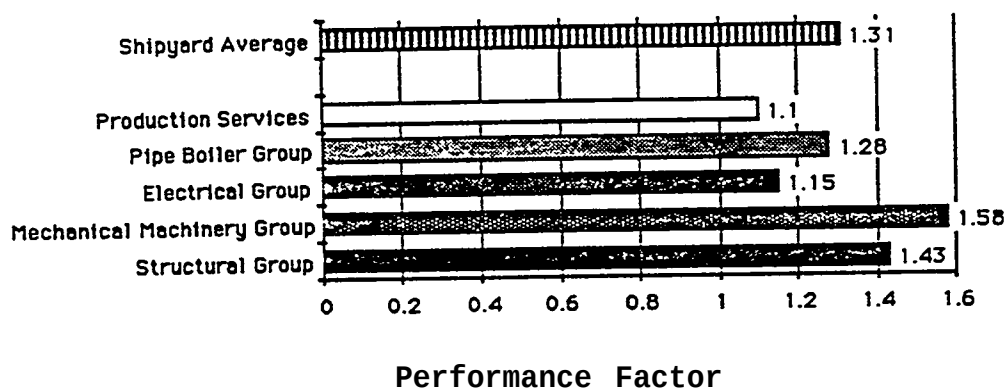


FIGURE III. PRODUCTION PERFORMANCE FACTOR FOR PRODUCTION GROUPS.

---Production Shop---	-----Top 10 Standards-----				-----Total, All Standards-----				Part Factor w/o Top 10
	Budget	Actual	Variance	Performance Factor	Budget	Actual	Variance	Performance Factor	
	-----Manhours-----				-----Manhours-----				
Structural Group	325983	532952	206969	1.63	698349	996557	298208	1.43	1.25
Mechanical/Machinery Group	57902	107422	49520	1.86	248355	392753	144398	1.58	1.50
Electrical Group	164611	189155	24544	1.15	243168	278695	35527	1.15	1.14
Pipe/Boiler Group	414168	534134	119966	1.29	521510	671466	149956	1.29	1.28
Production Services Group	82826	97535	14709	1.18	462604	507238	44634	1.10	1.08
Totals, All Groups	1045490	1461198	415708	1.40	2173986	2846709	672723	1.31	1.23

Source: PHSY

TABLE 2. RELATIONSHIP OF 'TOP 10 STANDARDS UPON PRODUCTION GROUP PERFORMANCE.

Structural Group's greatest amount of variance was associated with those standards in the shipyard's "Top 10". The other above-average production group, Mechanical and Machinery Group, did not have the same association. Only about 23 percent of its variance was associated with the "Top 10".

The same inconsistency occurred in the below-average groups. The Pipe and Boiler Group had an extremely strong link-up with the "Top 10"; the Electrical Group had moderate link-up, and the Production Service Group had about 18 percent link-up.

Table 2 does reveal, however, how much the performance factor for the groups, and for the entire shipyard, would be reduced if the variance for the Top 10 standards were eliminated. For the entire shipyard the improvement factor would be reduced from 1.31 (indicated in Table 1) to 1.23 an improvement of eight points, or about a 415 thousand manhour reduction.

This portion of the analysis resulted in the following conclusions:

1. Eliminating the variance in the "Top 10" standards would result in significant reductions in manhour overruns;
2. While there are major differences in the performance factors for the production groups, the variances associated with the "Top 10" standards affect all of the production groups. However, the Structural Group would show the greatest improvement if the variance for the "Top 10" were eliminated.

Analysis of Cause-Effect Relationship for Production Variance

Cause-and-effect diagrams are drawn to illustrate the various causes affecting a result by sorting out and relating the causes. The cause-and-effect diagram, sometimes called an "Ishikawa diagram" after the Japanese professor that first used the concept, can be applied to any problem. It was applied to this problem because of the need to better understand all of the factors that can affect production variance.

Figure IV is a cause-and-effect diagram that shows some of the causes that can effect production variance. During preparation of the chart several interviews were held with production, planning, and industrial engineering personnel at Philadelphia Naval Shipyard¹¹ The figure includes the comments of those interviewed as to the more significant reasons for production variance.

In making the chart the following steps were followed:

- Step 1: Decided upon the effect characteristic to be evaluated. In this case, the effect statement was: "the difference in allowed versus expended manhour budgets."
- Step 2: Wrote the effect characteristic on the right side of the chart. Then drew a broad arrow from the left side to the right side.
- Step 3: Wrote the main factors causing the effect, directing a branch effort for each factor to the main arrow. The causal factors were grouped into four main categories: equipment (machines and tools), procedures (processing actions), policies (management or organizational guidelines), and people (training, attitude, behavior).

step 4: Wrote in the detailed factors relating to the main factors. The subdivisions of the detailed "factors" are shown as connecting twigs.

Step 5: Indicated with an asterisk the detailed factors that are in some way related to engineered standards.

Figure IV dramatically illustrates the variety of factors affecting production variance in the shipyard. Importantly, any one of the Factors could, in any specific situation, be the major cause for a project overrun (or production variance).

An asterisk (*) is attached to those causes that are related to engineered standards. Importantly, standards-related causes for production variance account for only a few of the total possibilities. On the Policies branch of the diagram, for example, "unclear instructions" can lead to an engineered standard that is incorrect, or might be improperly applied.

The other instances where cause-linkup occurs with an engineered standard are in the Procedures

branch of the diagram. The causes are "wrong assumptions," "not clear," "calculations incorrect," and "antiquated procedures." With respect to the last item, it was estimated in one interview that at least 40 percent of the standards are antiquated at any moment in time.¹² Additionally a percentage of the procedures are not covered by engineered standards: one estimate was that about 70-80 percent of the production manhour budgets are developed from engineered or estimated standards.^{13 14}

At the beginning of the interviews most interviewees expressed the opinion that engineered standards were major causes of production variance. When the interviewees were shown a cause-effect diagram, similar to that displayed in Figure IV, they then acknowledged that other causes were probably more significant, and that the standards-variance link-up was not as strong as originally surmised. One especially knowledgeable interviewee, a person who has been involved in several shipyard reviews of production variance, felt that "poor communication" among people was the greatest single contributor to production variance.

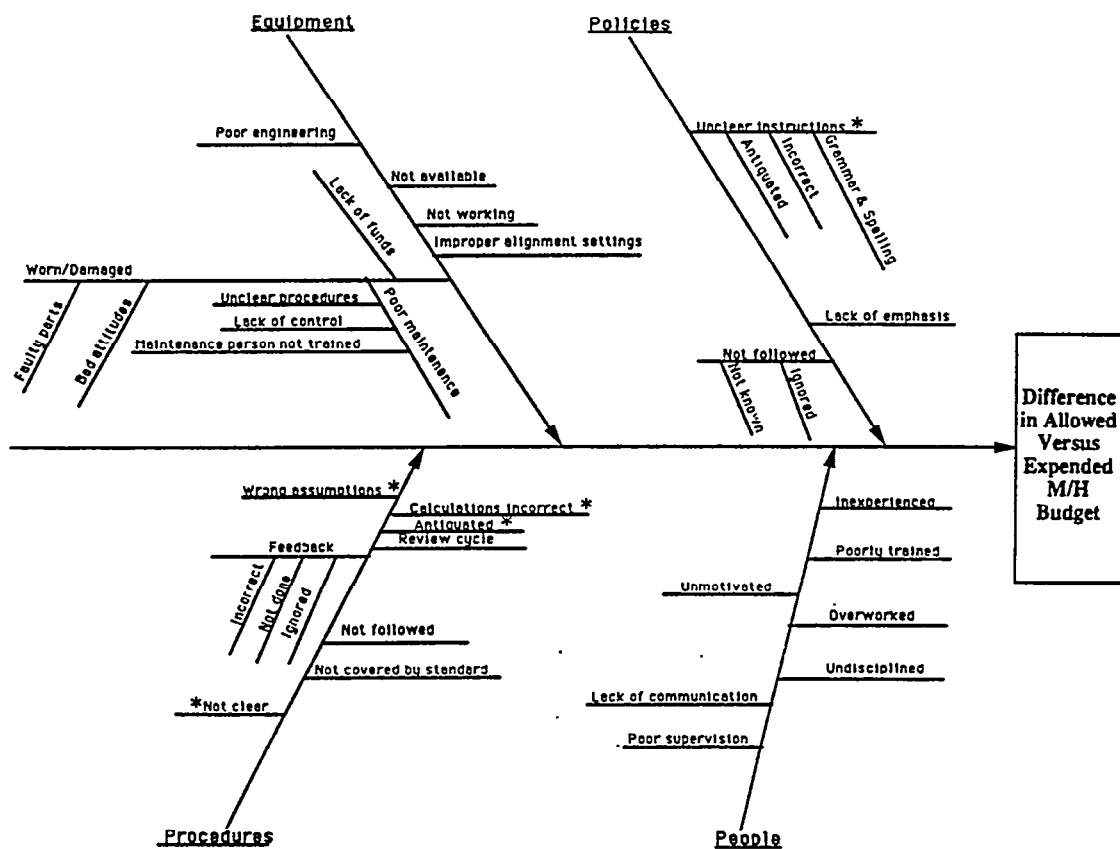


FIGURE IV. CAUSE-EFFECT DIAGRAM OF DIFFERENCES IN ALLOWED VERSUS EXPENDED PRODUCTION MANHOURS AT PHILADELPHIA NAVAL SHIPYARD.

The conclusions of this phase of the analysis were:

1. The causes for production manhour variance are numerous, and those related to engineered standards are in the minority.
2. Antiquation is the major deficiency of engineered standards relative to production variance. About 40 percent of the standards are antiquated relative to current practice, at any specific point in time.
3. Causes linked to engineered standards are not as significant a factor in production variance as is generally surmised by some shipyard management.

Action Plan for Reducing Production Variance Attributed to Engineered Standards

It was decided to focus attention on reducing the variance associated with the "Top 10" standards, listed in Table 1, shown earlier.

The decision was made by Philadelphia Shipyard management to adjust their priorities of updating specific engineered standards; the standards listed in the "Top 10" were moved up in the time schedule for reconsideration. Table 3 describes the changes in priority that were made. The table also shows the status of those commitments for change as of June 1, 1989--some 22 months after the decision to proceed.

As a result of the investigation, and recommendations, the shipyard did take action to effect improvements in the relationship of engineered standards to production variance. While the study also highlighted the fact that engineered standards are not the major cause of production variance, the significance of the standards-variance relationship was sufficiently strong to warrant proceeding with an improvement effort. Importantly, the investigation gave guidance as to those standards which should be given the greatest priority in being reevaluated. 15

--ENGINEERED STANDARD--		PRIORITY ADJUSTMENTS MADE IN 1987	STATUS A/O JUNE, 1989
Number	Name		
056-801	Piping--Remover, Fabricate, Class P1, P2, P3	Was being reevaluated at time of study. Release was set for 12/87.	Superseded by #0056-349. New standard issued in 1/89
100-303	Structural Field Installation Aluminum and Steel	Moved up to #25 on priority list. Not on list previously. Scheduled to start work before 12/87	Superseded by 0100-349. New standard issued in 11/88.
026-903	Welding, Structural/Production	Was being reevaluated at time of study. Release was set for 9/87	Superseded by 0026-348. New standard issued in 12/88
304-301	Electrical Electronic & Fire Control Cable & Equipment Installation	Was being reevaluated at time of study. Release was set for 8/87	Revised and updated Change issued in 9/88
0505-349	Welding, Pipe Class P1 & P2 (Field)	Moved up to #6 on priority list. Previously had been #34 on list.	Revised and updated to 0505=349A Change issued in 1/88
587-914	Catapult Launching Engine Components, Shipboard RPR	Release projected for 10/87. Moved up in priority.	no change
0038-306	Valves, GTV, LC*H1, Press & Welded-In, Insp Rpr & Test	Moved up to #9 on priority list. Previously had been #13 on list.	Revised and updated to 0038-306A Change issued in 8/88
0100-305	Structural Foundation, AI & Steel Assemble & Install	Listed as #29 on priority list. No change in status.	Superseded by 0100-349 New standard issued in 2/89
0100-306	Access Opening, Remove and Install	Moved up to #12 on priority list. Previously had been #30 on list.	no change
0904-352	Rigger Service Surface Craft	Moved up to #10 on priority list. Previously had been #28 on list.	Superseded by 0904-349 New standard issued 2/89

TABLE 3. CHANGES MADE IN THE SCHEDULE FOR REEVALUATION OF THE "TOP 10" ENGINEERED STANDARDS AFTER BEING IDENTIFIED TO SHIPYARD MANAGEMENT.

As can be seen in examination of Table 3, several of the "Top 10" standards were evaluated and put into the shipyard's system in 1988. It is expected that it will be at least two years before sufficient data is available to determine whether production variance reductions have occurred as a result of these reevaluations. Current management is of the opinion, however, that reductions will occur. Additionally, the management is now consistently giving high priority for reevaluation to any standard that is shown to have links to those key operations that have high production variance.¹⁷

Acknowledgements

The author is grateful to the Philadelphia Naval Shipyard organization for its willingness to cooperate in the project, and for its continuing openness in responding to questions during the research effort. Without such cooperation the effort would have been impossible to accomplish.

It is important to note that the views and analyses expressed are the opinions of the author, and are not necessarily those of Philadelphia Naval Shipyard, or any of its personnel.

References

Captain Donald A. Stouffer; Kehoe, Joseph; and Purdy, William, "Management Analysis of the Navy Industrial Fund Program: Shipyard Review Report," Contract N00600-84-C-4259, June, 1986.

² "Variance" was defined as the difference between allocated (or budget) manhours and applied (or charged) manhours. The same definition applies in this paper.

³ *Ibid* pg. OPS-5

⁴ *Ibid* pg. OPS-5

⁵ "Engineered time standards" describes the time assigned to a particular task, which represents how long it will actually take to perform the work. It involves the use of time measurement procedure for determining a standard. The steps taken are (1) a systematic analysis of the actions for performing a given job, (2) measurements are made of the actions, and (3) computations are made to determine the total effect (or cost) of the actions upon the system.

⁶ Personal conversations during July and August, 1987, with Captain H. P. Willimon, Jr., USN, Planning Officer, Philadelphia Naval Shipyard...

⁷ Joseph H. Quick, "A Universal Standard for Work Measurement", Science Management Corporation, 1977.

⁸ Personal, Fatigue, and Delay Allowances Philadelphia Naval Shipyard Document, Undated.

⁹ The performance factor is the quotient of actual manhours divided by budgeted manhours.

¹⁰ Engineered Standard #587-914, "Catapult Launching Engine Components, Shipboard RPR," was omitted from this analysis because of its unique statistical profile. The sizes of work orders performed under this standard were approximately 15-30 times greater than for the remainder of the standards.

¹¹ Interviews were held during the period August 1-12, 1987. Interviewed persons included W. Hemphill, Owen Moran, W. Stepler, J. Miller, and A. Cates, Code 380; N. Battista and D. Helker, Code 2030. All interviewed personnel were civilian employees of Philadelphia Naval Shipyard.

¹² *Ibid*

¹³ *Ibid*

¹⁴ With the introduction of zone technology at Philadelphia Naval Shipyard, the percentage of manhours budgets derived from standards has diminished, and as of June, 1989 was running about 60 percent (Source: telephone conversation with Mr. T. O'Donnell, PNSY, July, 1989.)

¹⁵ Telephone interview with Mr. T. O'Donnell, Head, Methods and Standards Branch, Production Engineering Division, PNSY, July, 1989.

¹⁶ Ironically, reports were already being issued on a quarterly basis in the Philadelphia Naval Shipyard reporting system (PNSY Report #PCL05-A) that showed the relationships of production variance and engineered standards. For some reason, the reports were being overlooked by the shipyard's management as they made priority decisions concerning reevaluation of specific standards.

¹⁷ *Op.Cit.* O'Donnell.

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