FOLLOW-UP STUDY -- LEAN 95-06

Lean Aircraft Initiative

Product Development Team Effectiveness

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October 1995

The authors acknowledge the financial support for this research made available by the Lean Aircraft Initiative at MIT sponsored jointly by the US Air Force and a group of aerospace companies. All facts, statements, opinions, and conclusions expressed herein are solely those of the authors and do not in any way reflect those of the Lean Aircraft Initiative, the US Air Force, the sponsoring companies (individually or as a group), or MIT. The latter are absolved from any remaining errors or shortcomings for which the authors take full responsibility.

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I. Introduction

The current study explores the relative influence of function managers and team leaders in managing integrated product development teams (IPTs). This study was prompted by the results of an earlier study, completed in Spring 1995, which suggested that the most successful high risk projects had a 50/50 balance of influence in decision-malting between function managers and team leaders. This study also suggested that in the most successful low risk projects, the balance of influence shifted heavily toward team leaders.

The current study addresses the relationships between project success and the following:

1. The relative balance between the function goals and project goals in day-today decision-making;
2. The relative influence between function managers and team leaders in evaluating team member performance and determining the nature and size of team member rewards;
3. The effect of project risk on the above two relationships;
4. The quality of the team leader's relationship with function managers;
5. The manner in which team leaders resolve issues with function managers; and
6. The effect of team-leader strength (measured in earlier studies), and the relationship between this variable and the variables measured in the current study.

II. Sample Description

A. Data Collection

Thirty-one projects were included in the original sample to be surveyed. Data were collected through telephone interviews with team leaders of projects in LAI-participating companies. Both high risk and low risk projects (as identified in the first study) were included. Respondents were team leaders. A total of 28 interviews were conducted, each lasting approximately 60-90 minutes. Three team leaders were not able to be contacted. The three that were eliminated were teams that were not doing new project development or were terminated without activities to describe.

Survey questions addressed team composition; goals; balance of goals in daily decision-making; relative influence of team leader and function managers in evaluating performance and determining rewards; nature of relationship between team leader and function managers; Project risk; critical issues and resolution methods; and project success. Twenty-five questions formed the basis for the interviews. Questions included open-ended, 7-point scale, and multiple choice. Respondents were encouraged to describe in their own words the operation of their team.

Functions included in this analysis are: Design, Manufacturing, Test, Quality, Engineering, Administration, Logistics and Project Engineering & Management.

B. Phases of New Product Development

Teams included in this study fell into the following project phases:

Phase 2: Demonstration and Validation - 7 projects

Phase 3: Engineering & Manufacturing Development - 9 projects

Phase 4: Pilot Production - 3 projects

Phase 5: Production - 3 projects

Phase 6: Deployment - 3 projects.

It is useful for analysis purposes, however, to group these phases into three rather than five groups because of the small number of cases in several of the groups. The logical three-phase grouping includes (1) Demonstration and Validation; (2) Engineering & Manufacturing Development AND Pilot Production; and (3) Production AND Deployment. These groupings place similar project activities and/or priorities into the same category. The new phase categories include:

Phase 1: Demonstration and Validation - 7 projects

Phase 2: Engineering & Manufacturing Development and Pilot Production - 12 projects

Phase 3: Production and Deployment - 6 projects.

C. Project Risk

The original measure used in the first study assessed project risk by assessing the “newness” of the product and process technology being employed by the team as well as assessing the newness of the product being developed. New in the context of technology or process can be new to the world or simply new to the team. Either way, the presence of a new product or process technology was perceived as increasing complexity of the team's mission. New in the context of the product is based on whether the team was working on an entirely new development or on a substantial upgrade to an existing product. Complexity was believed to be a good proxy for project risk in the first study. Using the original measure, 22 of the teams included in this analysis are high risk and 3 are low risk projects. The current study expanded the analysis of project risk to include team leader perceptions of present and past risk. Team leaders were asked to identify both elements of "new" product or process technology and to describe their perception of the project's risk. To determine past risk, the elements of risk were combined with the team leader's perceptions of past risk. Current risk was determined based on team leader perceptions. Using the new measure of past risk, the sample is nearly identical in risk categorization: 21 high risk projects; 4 low risk projects. Based on this, results in the current study can be generalizable only to high risk projects.

The team leader perception of present risk compared to past risk is that risk is declining over time. Often, however, the team leader assessments included a breakdown of risk into components, for example, risk for schedule and risk for performance. Although anecdotal, since this information was not systematically collected of all team leaders, it does imply that there is a continuing evolution of the elements of risk over the life of a project. The data do not allow for any conclusive statements to be made about the evolution of individual risk elements in high risk projects.

Only one team leader indicated that overall risk was increasing over time. He explained this by noting that the timetable of the project had been changed due to customer financial difficulties. This increased the time lag between Phase 1 and Phase 2 activities. The team leader believes that this lag increased his technical risk.

D. Measurement of Project Success

This study seeks to relate team management practices to team success. Success is estimated by asking the respondent to distribute 100 points among several measures of project success and then to determine how close to the target the team has come. Seven measures of success were provided, including: development cost, unit cost, life cycle cost, process quality, product quality, product performance, and meeting schedule. Respondents were asked to select any measure from the list which applied to their project, with an option to add other measures. A team which achieved 100 % of all of its targets (as of the date of the interview) would have a success score of 100 points. Teams which exceeded any of their targets could have a score greater than 100. Figure 1 shows the distribution of project success scores for the 25 teams included in this sample. The average success score is 91.8, with a low of 52 and a high of 129.

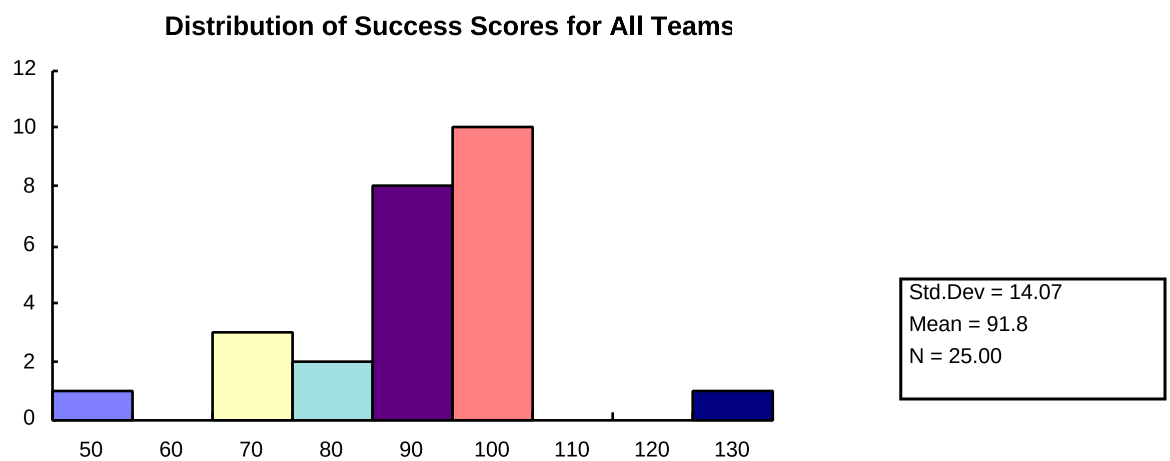

Figure 1: Distribution of Project Success Scores. The average success score for all 25 teams is 91.8, with a low of 52 and a high of 129.

III. Team versus Function Goals

Two different sets of goals are relevant to this discussion: team goals and function goals. Two questions regarding these goals are (1) what are the team's goals for the project? and (2) how did these goals compare to the goals of the functions represented by the core members of the team? Core members are those who spent 40% or more of their time doing team-related tasks. Core functions are performed by core team members.

The mean rank of goals during the various phases of the product development cycle is presented in Figure 2 for the 25 teams. In the earlier phases such as Demonstration/Validation (Dem/Val), performance is the highest ranked goal, with quality second and cost and schedule rated below these top two goals. As new product development progresses into later phases such as Engineering and Manufacturing Development (EMD) or Pilot Production (Pilot), performance and quality both become less important and cost and schedule become more important. In the production and deployment phases, the most important goal is schedule. Cost loses some of its importance from the previous phase.

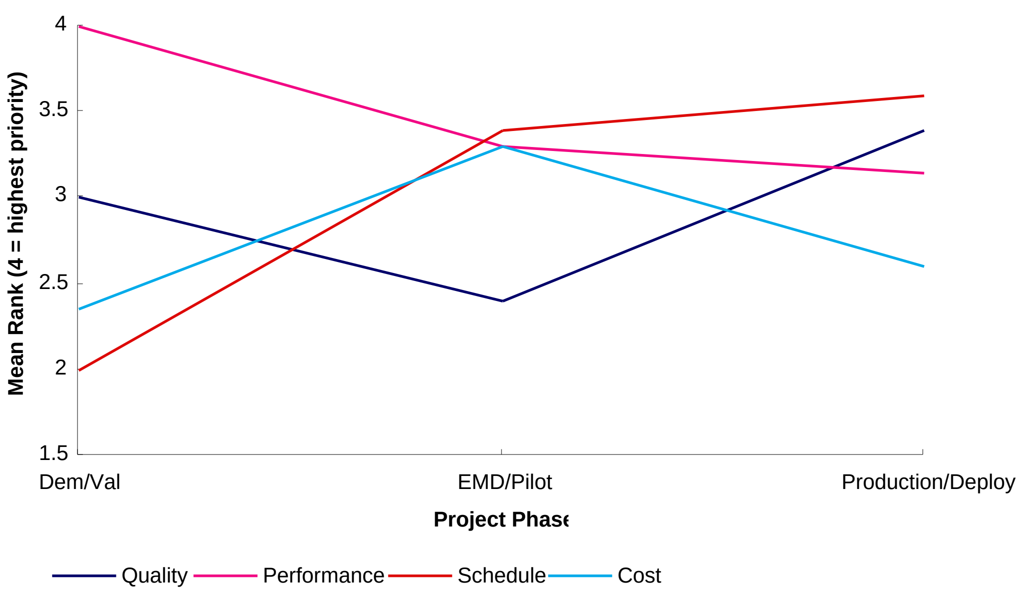

Figure 2: Changing Goals over Project Phases

The changing emphasis in performance over the life of a new product development project follows what might be expected. Early phases emphasize performance, while later phases take this aspect as set and, therefore, is not an option for consideration. The declining emphasis on quality in the middle phases may reflect the team’s concentration on engineering and prototype development issues, rather than on quality, specifically. As the product gets into production, quality assurance becomes an issue to consider once again. The changing importance of schedule as the project progresses would be expected also. The only surprising result in this sample is related to cost. The importance of cost rises during the middle phases of new product development and then declines in the later phases. This might reflect the fact that by the time the product reaches production, many of the costs are established by activities in previous phases. The increased emphasis on cost in the middle phases may occur as the team addresses the engineering and manufacturing development issues which impact cost directly.

The interpretation of goal ranks requires further comment. Team leaders were asked to rank team goals if they had more than one. This approach forced team leaders to choose among goals. Although they were able to do this, many often stressed that two goals were of almost equal importance. Thus, the ranking of two goals as second and third does not necessarily reflect the distance or closeness of the two goals. This point is particularly important as the ranking of goals within different phases is considered.

Comparing the goals of the team with those of the various core functions is a first cut at determining the divergence of team and function goals. The underlying hypothesis is that the greater the similarity between team goals and function goals, the better the project will progress and the higher the success score. Conversely, projects where the team’s goals and the function goals diverge will be less successful. Although the overall sample does not present a consistent trend, evaluating the top two teams and the bottom two teams is illustrative of this issue. The bottom two teams in terms of project success have 3 and 6 functions, respectively, which did not share at least one of the team’s three top ranked goals. In fact, the team with 6 unshared functions had the lowest project score (52). On the other hand, all of the functions on the top two teams shared at least one of the team’s top three goals.

The synergy between team and function goals is influenced by the culture of the company or division in which the team resides. For example, one team leader of a team that met all of its targets (success score = 100) noted that "...the entire [company] subculture is aimed at team goals. Team leaders make most decisions with input from the function managers." Another successful team leader (success score = 94) described the corporate culture's contribution to his team's success with the following: "[Our project] works well because the [division] started with the project management style. It has been difficult for those that were matrixed first and then forced to switch."

IV. Issues Between Team Leaders and Function Managers

The current discussion focuses on the issues that arose between the team leader and the function managers. The issues which arise most frequently between function managers and team leaders are summarized in Table 1. By far, priority and resource issues outweigh all others, accounting for 59% of all issues described by team leaders.

Table 1: Issues Between Function Managers and Team Leaders

Issue	**Number**	**% of Total**
Technical Issues	10	12%
Priority/Resource Issues	51	59%
Procedures/Requirements	8	9.3%
Administrative Issues	10	12%
Production Issues	7	8%
Total	**86**	**100%**

Table 2 gives a breakdown of the primary issues by function. Reporting of issues between team leaders and function managers was relatively consistent across functions, ranging from a low of 7 issues to a high of 16 issues. All functions are represented. Across all functions, priority/resource issues make up the bulk of issues which arise between team leaders and function managers.

Table 2: Breakdown of Critical Issues by Function

Issue	**Design**	**Mnfg.**	**Admin**	**Test**	**Quality**	**Proj.**	**Engr.**	**Logist**	**Total**

						Engr			
Technical Issues	5	-	-	1	-	1	3	-	10
Priority/ Resource Issues	10	9	5	6	5	6	5	5	51
Procedures/ Requirements		1	1	3	2	-	1	-	8
Admin. Issues	1	I	4	-	1	-	1	2	10
Production Issues	-	2	-	-	3	1	1	-	7
Total	16	13	10	10	11	8	11	7	86

Further exploration of individual functions shows that there is a relationship between the issues raised in one function and those raised in another. The crosstabular association (lambda) between the issues that arise between the team leader and the function managers for a given team is high only for a few functions. In general, issues that arise between the team leader and the Engineering function manager paralleled the issues that arise between the team leader and function managers in Quality and Manufacturing. Likewise issues arising between the team leader and the Quality function manager were related to those which arise between the team leader and the Test and Manufacturing function managers. Team leader problems with Administration were often related to those with the Test and Design functions. Table 3 summarizes the crosstabular associations of issues between functions that are significant at $p < .10$ or less.

Table 3: Association of Issues Between Functions

Function	Related Function	Association Probability	Number of Observations
Engineering	Manufacturing	$p < .083$	6
	Quality	$p < .093$	5
Quality	Test	$p < .067$	5
	Manufacturing	$p < .108$	6
Administration	Test	$p < .093$	5
	Design	$p < .093$	5

The top performing teams appear to have a different combination of goals than do the bottom performing teams. Although not statistically significant, the bottom team, for example, had function goals which focused on details rather than on the broader function responsibilities. This resulted in issues between function and team which stressed compliance with procedures and requirements. In the top performing teams, the functions shared the team's goals or focused on the broad responsibilities of the function. For example, the Quality function had quality-related goals; the Manufacturing function had assembly or producibility goals. In these top teams, the issues which arose between team leader and function managers were technical or design questions, not priority and resource issues for the most part.

V. Balance in Daily Decision-Making

Team leaders were asked to assess the daily balance between the team's goals and the function's goals in decision-making. The seven point scale ranged from 100% of decisions influenced by function goals (score = 1) to 100% of decisions influenced by team goals (score = 7). This assessment was made for managers of each core function.

In the previous study, a 50/50 balance between the function and team goals appeared associated with projects with higher success scores. The current data do not conclusively support the 50/50 balance hypothesis, although several different measures suggest that there is a "best" combination of function and team balance of goals and that the combination of team/function balance on either side of that “best” point results in projects with lower success scores.

Only the Project Engineering & Management function showed a significant relationship between the daily balance and success (regression with quadratic curve estimation, $p < .028$). For all other functions - Design, Logistics, Manufacturing, Test, Quality, Administration, and Engineering -- no clear relationship is significant. This finding, in itself, suggests that there is a relationship between the daily balance between function and team goals and project success, and that this relationship is curvilinear. There is a ‘best’ point somewhere near the midpoint of the scale. The further away from this “best” point the balance is, the less successful the team. This works in both directions. Although this is not borne out statistically with other functions within the sample, data plots do suggest the presence of a curvilinear relationship. Figure 3 which shows the relationship between the balance of Engineering and team goals with project success is a good representation of the type of curvilinear relationship which is present in Engineering, Manufacturing, Project Engineering, Test, and Design functions. The relationship between balance and project success is not clearly curvilinear for functions of Quality, Logistics, and Administration. In Figure 3, the highest team success appears related to a balance which is in the range of 80% team-based and 20% engineering-function based. Beyond this point in either direction, the success score declines.

Table 4 summarizes the range and mean for balance in daily decision-making. When the ‘best’ point can be determined (though not statistically) from the data plots, its approximate value is also included. This table demonstrates the relative influence that team goals have over function goals in daily decision making in new product development teams. In no cases did the function goals assert 100% influence over daily decisions being made by the team. In several cases, the team exerted 100% influence over decisions. The raw data suggest that a balance is, indeed, maintained between function goals and team

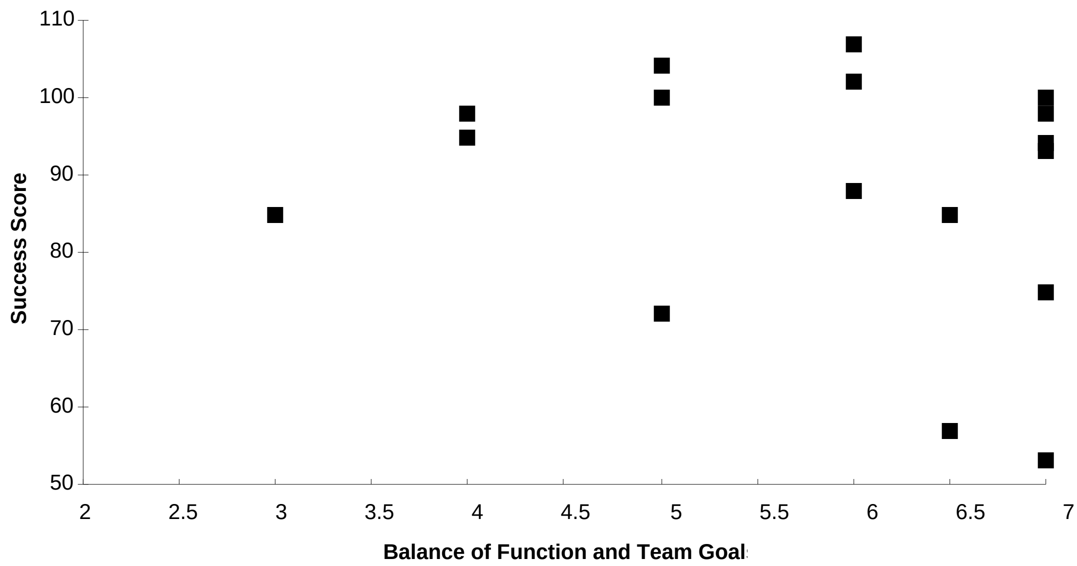

Figure 3: Balance Between Engineering Function and Team Goals. Range is 3 (75% function/25% team) to 7 (100% team)

Table 4: Balance in Daily Decision-making Between Function and Team Goals

Function	**Mean (% Team)**	**Range (Min Team% - Max Team%)**	**"Best" (%Team)**
Engineering	77%	33% - 100%	80%
Manufacturing	72%	50%- 100%	80%
Project Engineering	45%	20% - 100%	50%
Test	75%	40% -100%	80%
Design	71%	28% - 100%	80%
Quality	67%	20 - 100%	--
Logistics	71%	50% - 100%	--
Administration	48%	20% -100%	--

goals on the most successful teams. Further, that balance tends to lean toward the team influence. Kruskall-Wallace (K-W) rank means suggest the notion of a “best” point, although not in a statistically significant way. The lowest K-W rank means (low ranks are best for success) are associated with balance measures ranging from 50-50% balance between function and team goals in daily decision-making to a 20-80% balance between function and team, respectively.

Figure 4 suggests that the changing balance between function and team goals is related to the phase of the project. Here, the mean of the balance among all functions and the team leader is 4.8 indicating an approximate balance of function to team of 37% - 63%, respectively. Team goals rise in both Phases 2 and 3, with the team balance in decision-making nearing 75% team goals by the Production/Deployment phase.

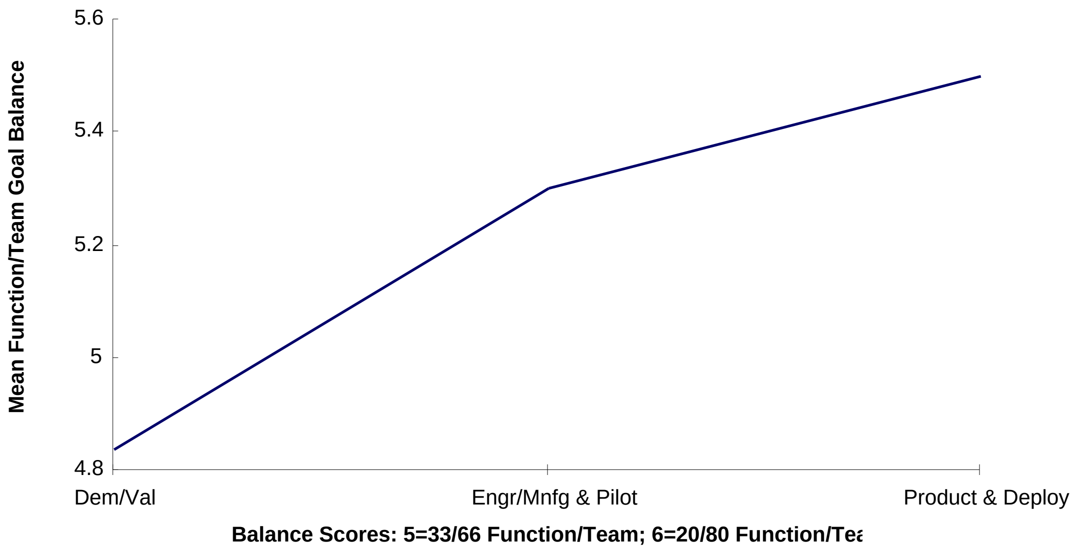

Figure 4: Changing Balance Between Function and Team Goals over Project Phases

Several team leaders noted that as the new product became a “sure thing” that was going to be produced, the team worked well with others and that all tended to share the same goals, regardless of function or team association. In an uncertain environment, team leaders indicated that every employee wanted to contribute to the company’s financial stability, thus function-based issues which might have been hurdles in early, more uncertain phases of the new product’s development, become less important stumbling-blocks as everyone worked toward a common goal: getting the product out the door.

VI. Relationships Between Team Leader and Function Managers

As would be expected, the better the relationship between the team leader and the function manager, the more successful the team. Team leaders were asked to rate the quality of their relationship with various function managers on a scale from 1 = Poor to 7 = Excellent. Relationships between team leaders and four function managers showed significant correlations with project success: Quality ($p<.059$;14 observations), Test ($p<.027$; 16 observations), Design ($p<.016$; 17 observations) and Administration ($p<.053$; 12 observations). Interviews with the team leaders indicate that most of them come from engineering backgrounds, either by training or experience.

The four good relationships that are related to project success represent non-traditional product-development disciplines. The team leader who can bridge to these other groups increases the project’s likelihood of success. It is the ability to reach out beyond the engineer’s perspective that appears to be most important. This reasoning would also explain why there is no significant relationship between the team leader and Engineering function manager. The relationship between team leaders and Engineering would be expected to be good already or would not have as great an impact on project success as a good relationship between team leaders and other function managers.

One team leader (project success score of 104) summarized the importance of relating well to non-traditional product development functions. He noted that Test, Manufacturing and Quality function-based core team members stuck to their roots and were less receptive than others to new ideas. In his company, this was the first time that staff from these functions had been included on the team “so far up in the design process.” His relationship with the managers of these functions, although good, was evolving over the course of the project as they learned to speak the same language.

VII. Team Leader Influence over Evaluation and Rewards

The relative influence between function managers and team leaders in evaluating performance and determining the nature and size of rewards is explored in this section. Both of these variables were measured using 7-point scales (1 = 100 % function-based to 7 = 100 % team-based). Although the two variables (EVALUATE and REWARDS in Table 5) were significantly correlated ($p < .028$), their scale reliability was not sufficiently high (Chronbach's α =.55) to warrant combining them into a single scale. Both evaluating performance ($p<.079$) and determining rewards ($p<.101$) were correlated with project success. This means that the more influence the team leaders had relative to function managers in evaluating performance and determining rewards, the higher the project success.

Table 5: Correlation of Success with REWARDS and EVALUATION

	Success	REWARDS	EVALUATE
EXPECT	.009	n.s.	.012
REWARDS	.079	---	.028
EVALUATE	.101	.028	---

The earlier study measured the percentage of team members who expected to receive a reward if the project were successful. Applying this measure (EXPECT in Table 5) to the current study indicates that it is significantly related to project success ($p<.012$). The correlation between EXPECT and the relative influence of team leaders in determining rewards was not significant. However, the correlation between EXPECT and evaluating performance was significant ($p<.028$).

Anecdotal evidence provides some insight as to why EXPECT and REWARDS are correlated with success, but not with each other. When team members were asked in the earlier study about their expectations for rewards, they were not asked to indicate who was responsible for providing these rewards. Team leader influence in determining the nature and size of rewards is different from actually providing these rewards, even if the most successful projects had team leaders who had more influence in determining the nature and size of rewards. These data suggest that team members' expectations of rewards may be based more on team leader's influence in evaluating their performance than on team leader's influence in determining the nature and size of the rewards.

Analyzing data by functions indicates that Design and Manufacturing may contribute the most to the correlations between REWARDS and EVALUATE and between them and project success (See Table 6). Also function managers of the lowest four projects (success scores < 75) had more influence in evaluating team member performance than the highest three projects (success scores >

100). The difference between low and high projects in mean influence across all functions was 4.96 and 5.40, respectively. It appears that even in the low success projects that the balance between functions and teams is slanted towards teams.

Table 6: Correlation of Design and Manufacturing Functions

	Design Evaluation	**Design Reward**	**Mnfg. Evaluation**	**Mnfg. Reward**
Success	$p < .065$ (n= 19)	$p < .022$ (n= 19)	$p < .082$ (n= 16)	$p < .029$ (n= 16)
Design Evaluation	---	$p < .064$ (n= 19)	$p < .000$ (n= 14)	n.s.
Design wards	$p < .064$ (n= 19)	---	n.s.	$p < .000$ (n= 14)
Mnfg. Evaluation	$p < .000$ (n= 14)	n.s.	---	n.s.

Team leaders also were asked if their team members would be rewarded if the project were successful as well as what the nature of the rewards would be. This measure was not significantly related to project success. This might appear inconsistent with the EXPECT measure. However, EXPECT was a measure of the percentage of team members who answered “Yes” to this same question. Apparently, team members perception of expectation of rewards is more important to project success than the team leader’s report that team members would receive such rewards. As indicated earlier, the issue as to who provided the rewards and when was not clear for the EXPECT measure. Also, team members may judge as insignificant some of the rewards that team leaders said that team members would get, such as dinners and pizza parties.

The criteria on which rewards are based is significantly related to project success ($p < .042$). Teams that base rewards on criteria such as critical milestones (objective) or team peer review (broad-based review) are more successful than teams in which the team leader or the project manager (or higher level manager) determines these criteria. It appears that more formal, impersonal methods for determining rewards leads to greater project success than reliance on the judgment of superiors. See Figure 5.

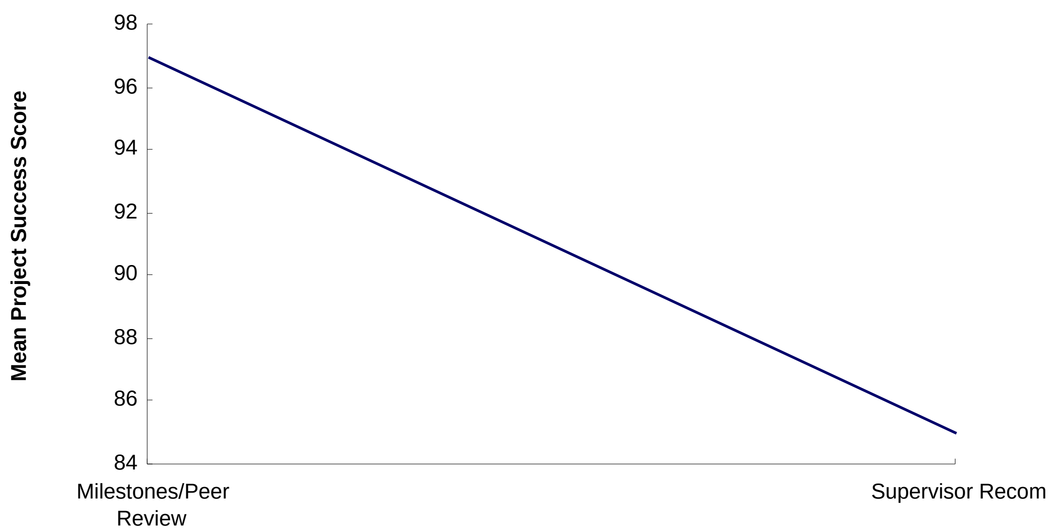

Figure 5: Relationship of Reward Criteria to Project Success

VIII. Team Leader Strength

The first study assessed the impact of team leader strength on overall project success. Team leader strength was an index consisting of team leader influence over budget, team leader “clout” relative to other team leaders, and final say by the team leader over project goals (compared to function managers). The correlation between project success and team leader strength was significant in that study. The current data set also shows a strong correlation between project success one year later and the team leader strength ($p<.004$). The data collected in this follow-up study expand our understanding of what makes a strong team leader and offer some examples of the way in which a strong team leader can impact project success.

One variable used to determine what helps to make a strong team leader was RESOLUTION. This variable summarizes the issue resolution style of the team leader when dealing with function managers. The team leader was asked to identify the way in which he or she resolved issues which arise between themselves and each function manager. Four categories were offered as choices: compromise, problem-solving (team based activities), common supervisor resolves issues, or don't resolve issues. The RESOLUTION score for each team is a percentage of core functions where compromise and/or problem solving were used exclusively to resolve issues. RESOLUTION scores range from a low of 28 to a high of 100. RESOLUTION is significantly correlated to project success ($p<.013$ with 24 observations). Team leaders who were able to resolve issues between themselves and the function managers internally (without the help of a common supervisor) were more successful than those who either did not resolve issues or who had to rely on a common supervisor to resolve a particular issue.

The strength of the team leader alone, accounts for nearly one third of the variance observed in the project success scores (R^2 of .34 measured with regression methods; 19 observations). However, in cases where team leaders needed to work out resource or priority issues with the Manufacturing function, the team leader's strength accounts for nearly 70% of the observed project success score (R^2 of .68 measured with regression methods; 19 observations).

The importance of a strong team leader is clearly evident in Figure 6 which shows the relationship of the Team Leader Strength variable to project success for those projects when team leaders "don't resolve" issues or have them "resolved by a common supervisor." For such projects, the stronger the team leader, the higher the success score.

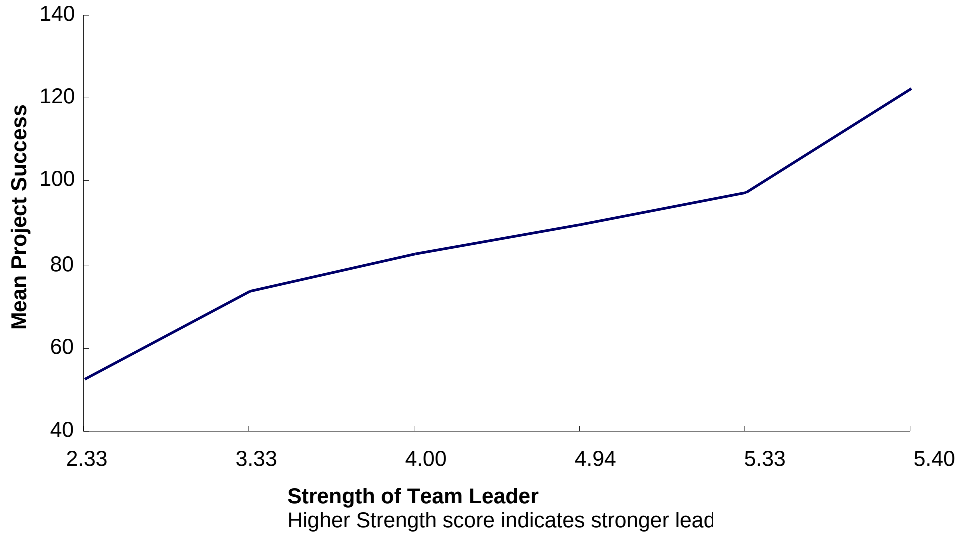

Figure 6: Relationship of Team Leader Strength and Project Success for Projects where Don't Resolve or Common Supervisor was the Issue Resolution Method.

The full range of team leader strength is not reflected in Figure 6. By contrast, the range of team leader strength for those projects which use compromise and problem solving to resolve issues is 4.33 to 6.67. This indicates that stronger team leaders are more likely to use problem solving and compromise to resolve issues.

Manufacturing, Design, and Test showed correlations between team leader strength and evaluating performance and determining rewards. As was noted earlier, Manufacturing and Design were the only functions that showed correlations between evaluating performance and project success and determining rewards and project success. Thus, a strong team leader might influence project success indirectly by influencing the evaluations and rewards for team members in Manufacturing and Design.

IX. Team Influence and Project Success

This follow-up study began by asking what influence the balance between team and function had on-project success. The measures discussed in the previous sections, when combined, offer some insight into this issue. A composite score for team leader influence in rewards and evaluation, and balance of goals in daily decision-making was created by comparing individual team scores on each of these aspects of team management to the median of that score for the sample. Teams with a score above the median received a 1 and those below the median received a score of 0. These three measures were then summed to create the index of team influence, COMPOSITE, which ranged from 0 to 3.

Figure 7 shows the mean COMPOSITE scores for projects in different project phases. The COMPOSITE score is lowest in the early phase, Demonstration and Validation, indicating high influence among upstream functions, e.g., Engineering, Design, Test. The COMPOSITE score peaks in the middle phases, Engineering and Manufacturing Development and Pilot Production, indicating high team influence. The COMPOSITE score declines in the late phase, Production and Deployment, which may reflect increased influence among downstream functions, e.g., Manufacturing, Logistics.

COMPOSITE is correlated with project success ($p<.085$). This implies that the greater the influence of the team in rewards, evaluation and daily decision-making, the greater will be the project's success.

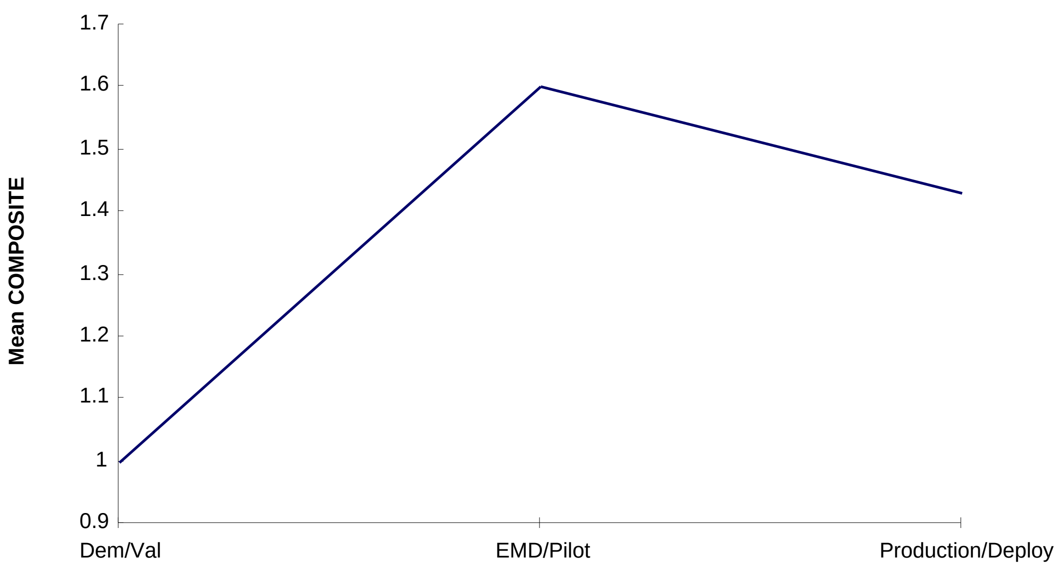

Figure 7: Composite Team Influence by Phase

X. Conclusion

This study explored in detail the meaning of a finding from an earlier study concerning the merits of a 50/50 balance in daily decision-making between function and team goals. The data from the current study suggest that too much influence toward team goals in daily decision-making may be counter-productive; however, the optimal point appears higher than 50/50 in the direction of team influence. More conclusive is the relationship between project success and team leader influence on evaluating performance and determining rewards. Strong team leadership was shown to be important to project success in the earlier study. One of the ways in which strong team leadership may manifest itself is through influence over evaluating performance and determining rewards.

Team leaders of successful projects also appear to form good working relationships with function managers who have different backgrounds and responsibilities than they do. Team leaders of successful projects focus more on resolving technical and production issues with function managers than on resolving priority and resource issues. They resolve such issues through compromise and problem-solving rather than relying on common superiors to resolve them or not resolving them at all. Finally, the optimal balance between goals, and influence over evaluation and rewards may vary over project phase. This matter could be explored in greater depth by tracking projects over their entire product development cycle to see if a transition in influence occurs between phases and how the transition is managed.