Title: Impact of Computer-aided Design (CAD) Tools on Product Development Productivity

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Author(s): R. Hammer, T. Hoang, L. Nguyen, E. Oyer, S. Saengsin and S. Runner

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Abstract: Evaluates the impact of a switch from 2-D development system to a 3-D one studying one company. The results suggest that a productivity increase of 150% was achieved. Presents a set of problems and recommendations to improve system level productivity.

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EMP-9656

<u>Term Project</u>

Impact of Computer-aided Design (CAD) Tools on Product Development Productivity

<u>Team #3</u>

RAIK HAMMER, TOM HOANG, LONG NGUYEN,
EDOUARD OYER,
SUPHAKIT SAENGSIN & SCOTT RUNNER

Management of Engineering and Technology (Emgt 520/620)

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on
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1. EXECUTIVE SUMMARY

Rapidly changing competitive, social, economic, and technology climates have exerted great demands on the new product development (NPD) process, particularly with respect to 'High Tech' products. With the significance that new product now carries in a company's performance, and with time-to-market having become a most strategic competitive advantage, NPD greatly influences a company's performance. One of the most significant factors influencing the NPD process is the selection and deployment of Computer-aided Design (CAD) technology.

We hypothesize that the adoption of CAD and new CAD technologies has two fundamental measures of NPD productivity: task-level and process level. Task level productivity is influenced by several factors, but is primarily characterized by the learning curve phenomenon. It is typically task-level productivity that is often the fundamental metric in determining successful deployment of CAD technologies. However, we hypothesize that task-level productivity is an insufficient determinant of the magnitude of effect on NPD, and that factors which effect system-level productivity more greatly influence the development process. We studied the development of a truck family at Freightliner Corporation to assess the task-level and system-level NPD productivity impact of the introduction of a 3-D CAD system (CATIA) which replaced a 2-D system. Our findings suggest that while task-level productivity increased about 30%, Freightliner reduced their time to market to about 40% of the time, implying an aggregate productivity increase of 150%. We conclude with a set of identified problems and associated recommendations which aim at improving system-level productivity. We feel that this area would benefit from further research into specific measures of the impact of CAD/CAM/CAE on NPD processes. It would also be beneficial to study measures of the impact of these technologies on corporate-level business performance.

2. INTRODUCTION

Time-to-market has become perhaps the most significant competitive advantage in high tech business today [8, 26]. For example, the half life of engineering knowledge is dropping below 6 years [28], and semiconductor technology densities are doubling every 18 months [8]. The number of products is waxing, and product development times are waning. Market segmentation is becoming increasingly fragmented to the point where Goldman [8] has defined them as market 'particles'. The product development process is constantly challenged to re-invent itself to at least keep pace.

One of the most significant factors influencing the high tech product development process is the selection and deployment of Computer-aided Design (CAD) technology [7, 18]. Many corporations involved in product development invest significantly in the deployment of CAD technologies aimed at improving product development productivity, often with mixed results [19]. However, the ability to assess the effect that CAD introduction or change will have on

NPD and a company has often eluded CAD management. Given the direct and indirect expenses associated with CAD adoption, this points to a deficiency that demands to be fulfilled. In this paper, we sought to measure the effect of the introduction of new CAD technology on task-level productivity, and to attempt to determine the correlation with NPD performance.

Computer-aided design (CAD) refers to any activity that utilizes a computer to assist in the creation, modification, representation and analysis of a design [15]. It's origins date back to the early 1960's at MIT with the Sage system [7]. This system was motivated by the need for a tool to control numerically controlled machine tools. Thus, CAD in this context was developed to automate what had become the next bottleneck in manufacturing automation, and highlighting that Computer-aided Manufacturing (CAM) was not a descendent of CAD. Early implementations of CAD systems were primarily used as electronic drafting boards, simplifying the process of drawing entry and in particular modification. These early systems were expensive due to their dependence on expensive computers (mostly mainframe computers) and specialized graphics terminals and input devices. Thus while companies such as General Motors could enlist IBM to develop customized drafting automation systems, most companies could not afford these systems.

It was not until the late 70's that CAD emerged from mostly scientific labs into commercial use for economic gains. The advent of the microprocessor-based raster-scan display by Hewlett-Packard in 1978, and the publications by General Motors, Boeing and others that CAD was commercially useful helped move CAD into its commercial market in the 1980's. At this time, CAD was identified as not only useful in improving drawing productivity, but that it was an essential link to CAM through CAD/CAM technology.

Today, the benefits of CAD are characterized as positively improving [7, 15]

- Productivity
- Product Quality
- Product cost.
- Worker Human Factors (reduced stress, better quality of worklife).
- Lead time (time to market)

Of these, productivity is the characteristic that is often associated with CAD. Engelke [7] shows the following conceptual model that illustrates the cost and lead time advantages of CAD/CAM systems over alternate methods.

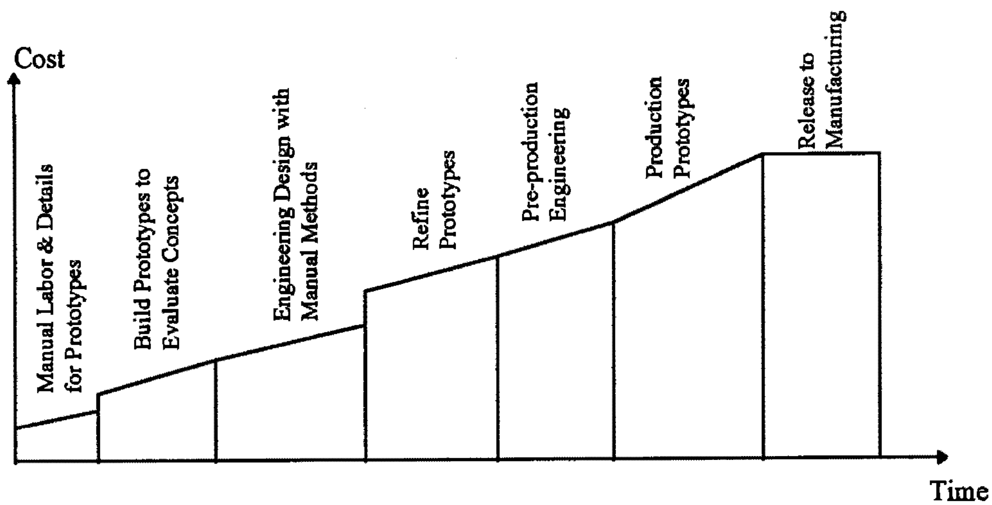

Figure 1 - Cost/Time Profile for Manual Process

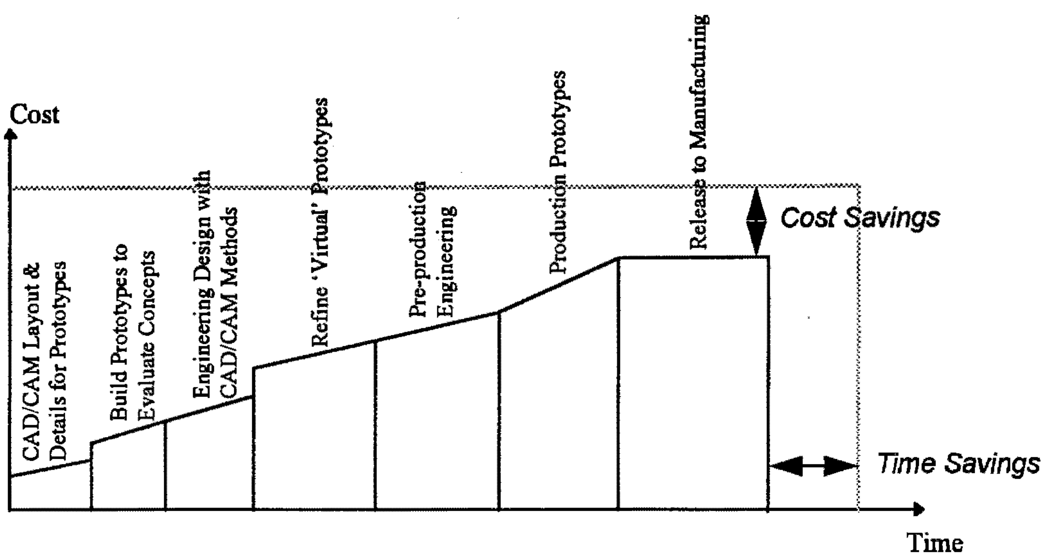

Figure 2 - Cost/Time Profile for Equivalent CAD/CAM Process

However, while the productivity advantages of CAD have been the basis of its existence for about two decades, the cited results not very conclusive, and the adoption is not as great as forecasted. A 1982 survey of manufacturing companies found that only 10% of manufacturing companies surveyed had adopted CAD at all [15]. Orr [19] estimates that of the 15,000 CAD systems installed worldwide by 1985, only 1,000 were being used for design, their original purpose. The remainder are used as electronic 'drawing boards' or drafting tools. The reasons for this may related to lack of models to quantify the impact of CAD on the NPD process and corporation.

3. FACTORS WHICH INFLUENCE NEW PRODUCT DEVELOPMENT PRODUCTIVITY

To determine the effect of CAD tools on the new product development process (NPD), one must have a framework for how NPD productivity is measured. On a simple level, one can say that productivity is the quotient of the output divided by the input. However, these measures can vary widely. Is output measured in number of NPD projects, or revenue generated by the new products? Are inputs measured in terms of total expenses invested? Furthermore, once these measures are defined, how can one accurately correlate the effect of different software productivity tools on these? Perhaps this explains the lack of data available on this topic. Griffin and Page [13] present a framework for measuring NPD productivity, which is shown in Figure 3.

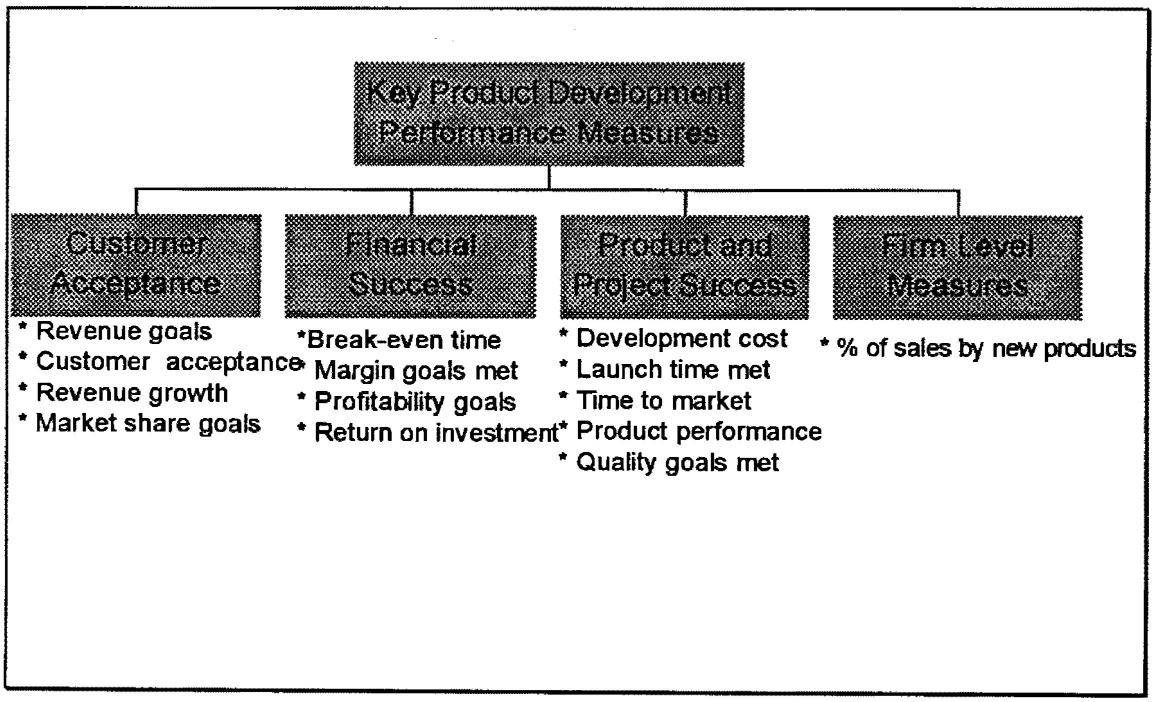

Figure 3 - Performance Measures [Griffin & Page]

These performance measures are business performance measures that are in turn influenced development output performance, by manufacturing performance and by marketing and sales performance. Development output performance, the result of NPD, is of course effected by development process performance. CAD tools are intended to improve development process performance in productivity, time, cost, and quality. How business performance measures are affected by the introduction and evolution of CAD is of great interest in effectively analyzing the cost/benefit relationship of such systems, and of forecasting effects and the effectiveness of CAD in general, and evaluating specific CAD systems.

While [13, 18, 30] all surveyed the effect of various acceleration techniques on NPD, we could find nothing that explicitly establishes a model of the impact of CAD on NPD and corporate level measures. Thus, we recommend this as an area for further work, and sought to define our own model, and to constrain the model to what we could prove given our time constraints. Given these constraints, we choose to determine the effect of CAD on *task-level* productivity, and observe how well this correlated to overall changes in NPD performance in only the time to market dimension. This will be described further in *methodology*.

4. CONCEPTUAL MODEL OF CAD IMPACT ON PRODUCTIVITY

4.1. Task-level Productivity Model

The problem we focused on is the implementation of a new generation of CAD-system to observe the effect of the introduction on NPD performance. At the task level, the transition from manual processes to CAD, or from one CAD system to another implies the transformation of certain functions or operations in various classes as shown in Figure 4.

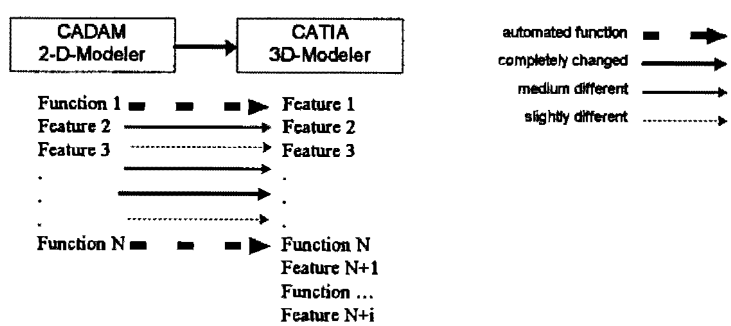

Figure 4 - Changing Features of a CAD system on Different Levels

One can express this transformation by identifying functions that are not changed, are slightly changed, or are completely different. For example, the way you draw is completely different in a 2-D system as compared to a 3-D CAD system. However, the way you specify a title block may not vary much. Some functions performed previously may be automated with the adoption of CAD or a new CAD system. For example, the process of translating the output of the mechanical CAD database into a mechanical form may be molded may be automated in the new CAD system, but have previously been a manual process using a hardcopy drawing. This also applies to simulation and estimation, where CAD models may be automatically evaluated, versus requiring that a model be physically built and evaluated.

A specific example of mapping features into new features that are performed differently lies in the way drawing is performed. With a 2D CAD system, the representation is a view, not an executable model. With a 3D CAD system, you are able to model the body (or part) by using several modeling methods. This drawing then represents the model that can be directly built in a CAM system, or simulated for accuracy.

A key point is that in the introduction of the CAD system, some tasks may be performed more easily, while others might incur a decrease in *task-level* productivity, but lead to "downstream" productivity improvements (*system-level*) such as the direct manufacture of a part from a database in a CAM system, as opposed to manufacturing from hardcopy drawing.

Initially when adopting CAD or greatly changing CAD systems, the operators/engineers are not effective at using the tool, and become more proficient as they are trained and gain practical experience. Adoption results in a loss of productivity, followed by a gain. This follows the profile of the learning process [2, 3, 24]. The time from adoption until effective utilization is a key component of this *task-level* productivity model. The components of CAD integration that affect task-level productivity are shown in Figure 5.

4.1.1. Factors Influencing CAD Productivity

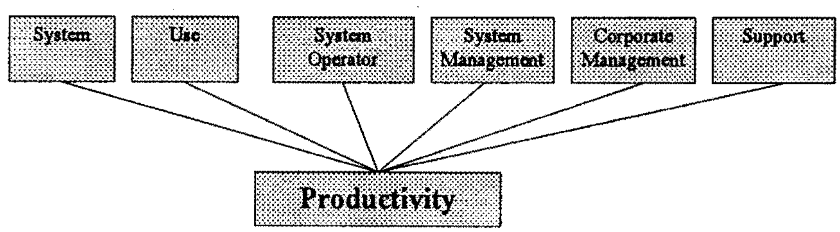

Figure 5 - Productivity components [5]

The first component of the framework is the system itself. The attributes of the system influences the productivity directly. The attributes of the systems are the motivation to implement this new system, because with these attributes, the drafters are able to reach a higher productivity. The system utilization includes number of terminals, number of shifts, type of work, etc.

The system operator has many attributes that include:[21]

- Experience
- Proficiency
- Efficiency
- Personal attributes
- Attitude
- Moral
- Enthusiasm

- Quality of work life
- Money
- Career Path.

The fourth component is the system management. This is a non-measurable component. The attributes of this component include:[21]

- Knowledge of the system
- Proper expectations of the system
- Utilization of the system tools
- System accounting procedures
- File management practices
- Procedures established
- Training of operators
- Scheduling practices
- Data control for security

The next component is the role of the senior management. This includes all managers above the system manager level. The most attribute is the understanding of the system limitations and capabilities. Other parts are:

- The state-of-the-art of CAD technology
- Resources necessary for success
- CAD' s role in the product cycle

The last role is that of support, including training, which is essential to effective CAD utilization.

4.2. Task-level Productivity Model of CAD Adoption

In the literature arise different measures how to cope with CAD-productivity. Basic concepts of productivity are shown in Table 1.

$P = \frac{O}{I}$	O Number of drawings produced I hours of drawing time; or
	O Number of drawings produced I total labor (direct + indirect) + materials + capital + energy
	O Number of wiring diagram drawings produced I Associated labor + materials + capital + energy
	O Number of drawings produced I Cost of support equipment

Table 1 - Basic concepts of productivity[21]

4.3. System-level Productivity Model

4.3.1. The Effect of CAD Adoption on NPD Processes and Corporate Performance

When CAD is adopted, actual productivity gains often do not approach the full spectrum of expected gains. Very frequently, task-level productivity may increase, while the company's overall product development productivity and business measures suffer. Efficiency may increase but at the cost of high CAD operator turnover. Drawings may be more quickly produced, but not more innovative or manufacturable ones. A great percentage of the CAD's users use it as nothing more than electronic drawing boards, barely scratching the surface of CAD's potential. Plonski [20] emphasizes this in his study of introduction of CAD into some of the largest engineering consulting firms (ECF) in Brazil. The result was a misuse and a distortion of CAD concept and implementation.

4.3.2. System-level CAD-Productivity: The Learning Curve

The learning curve portrays the concept, that the cumulative average unit costs decreases systematically by a common percentage each time when the volume of production increases geometrically (that is increases by doubling).[27]

The learning curve is a result of the learning process, respectively represents the relation between output and input variables through equations. The learning curve was first applied in the aircraft industry, where any reduction in the considerable number of direct-labor hours needed for assembly work is quickly recognized and formalized [24]

However, the learning curve was not translated into an empirical theory curve until 1925, when it was observed in a military manufacturing operation. Some eleven years later, T. P. Wright disclosed the results of empirical tests of the learning curve. He observed that on average, when output doubled in aircraft industry, the labor requirements decreased by about 20%, in other words, there was an 80 percent learning factor.[29]

The concept of the learning curve and its several mathematical models referring to cumulative outputs of a production unit or a company, and the identified costs per unit for the first produced unit and several assumptions, which cannot be described further in this paper.

The application of the learning curve for our case is not possible due to the fact, that will be arise measure problems if you want to count results from a drafter, and the time for drafting. We did not deal with units, because the work with a CAD-system is too complex. So instead, we focused on what was more easily measurable, subjective task-level productivity, to determine how closely it correlated to corporate productivity measures (namely time to market). Furthermore you cannot define costs per unit (per draft) by working with a CAD-system. In order to develop a comprehensive set of factors which are part of the CAD productivity to divide a CAD operation into areas or components, which is shown in Figure 6.

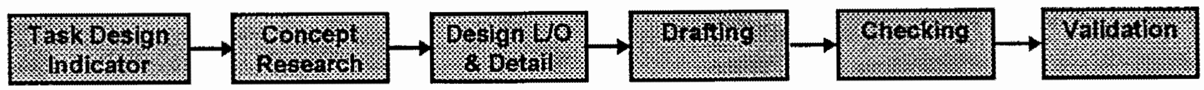

Figure 6 - Major mechanical design activity [21]

4.4. Hypotheses

Our first hypothesis is that from the beginning of the change to new system, the productivity of the engineers decreases by a certain level. This is due to the lack of familiarity, experience, and training on the new tool. Presuming active usage of the system in actual work situations, the model projects that productivity will rise due to the learning process of the people to reach the previous level of productivity.

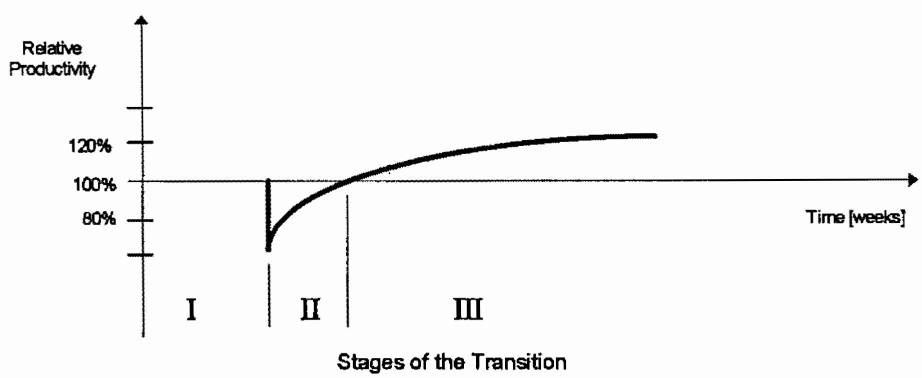

Figure 7 - 3-Phase-Model of Task-level Adoption Productivity (original work)

We propose three stages (or phases) in our hypothesis. Each stage is characterize by influence of factors, which are in charge for the curve in Figure 7. The characteristics of each stage is described in Table 2.

Stage I: Pre-Implementation	♦ decision for Implementing a new system ♦ Strategically reasons for the transition
Stage II: Implementation	♦ Implementing of the new system ♦ Less performance ♦ Training phase ♦ Learning Process
Stage III: High-Performance	♦ Learning Process ♦ Productivity increases to a higher level, caused by a higher performance of the new system and cumulative experience

Table 2 - Stages of the transition process

Hypothesis 1: *CAD task-level productivity will initially decrease, then increase to the level of previous methods. If adoption is successful productivity will increase sufficiently such that the gains will match the productivity lost in adoption at the "productivity break-even point", and will increase beyond that point for gain.*

Hypothesis 2: *Task-level productivity impact measures are insufficient measures of CAD tool impact on new product development and company performance. Such system-level measures should be determined by a different set of measures.*

Hypothesis 3: *The impact of CAD tools on productivity can be greatly improved by addressing problems often associated with CAD tool adoption, such as training, social and organizational factors, and process integration.*

5. METHODOLOGY

The *system-level* impact of CAD tools on corporate product development productivity was based on literature survey of over 20 papers which included case studies and surveys of actual CAD implementations, and various models of product development performance and the effect of various mechanisms, including CAD on them.

In order to determine *task-level* productivity impact, a survey of 72 engineers was conducted at Freightliner Corporation. The sample space was CAD operators implementing a variety of electronic drafting operations and other functions on a variety of components related to those comprising the construction of a variety of models of semi-trailer trucks.

Freightliner Corporation, headquartered in Portland, Oregon, produces and markets commercial vehicles in classes 4-8 and is a member of the Mercedes-Benz AG group, the world's largest commercial vehicle manufacturer. With their expanded product line and strong sense of customer support, U.S. market share grew from 16.3% in 1988 to over 25% in 1995, with a more than 100% increase in unit sales. Freightliner has been the best-selling Class 8 nameplate in North America since 1992. Freightliner has been recognized for over 50 years as a technology innovator in the truck manufacturing business. Evidence of this is in the adoption in 1991 of CATIA (Computer Aided Topographical Interactive Application)

The survey used (included in appendix A) was distributed to 72 CAD operators within the Freightliner corporation in Portland, Oregon. 62 responses were received, of which 40 contained usable data, as illustrated in Figure 8 and Figure 9. The 22 unusable responses included surveys which were incomplete in their data. However, some of these contained useful commentaries which will be discussed under results.

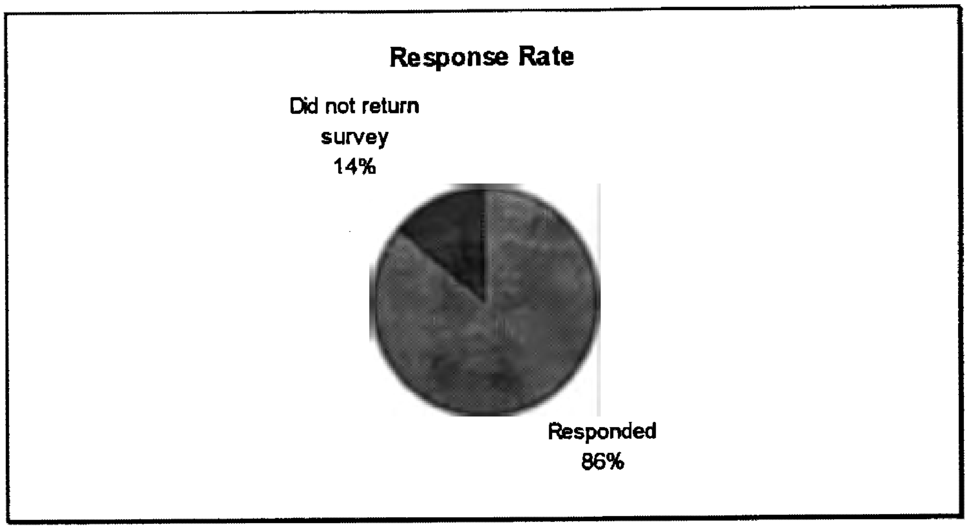

Figure 8 - Survey Response Rate

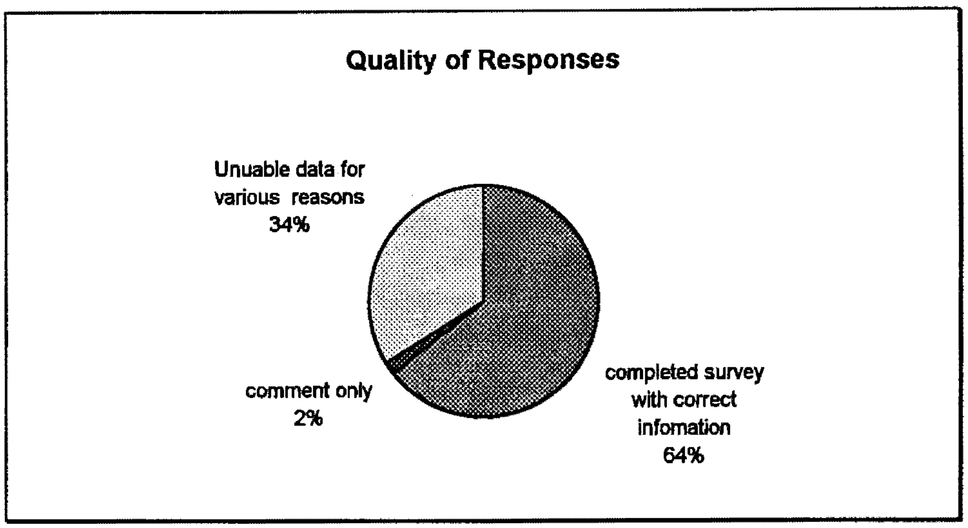

Figure 9 - Validity Rate of Responses

Number of People Surveyed	72
Number of Responses	62
Number of good, qualified responses	40

Table 3 - Summary of Response Statistics

In our survey we did not use measures illustrated in Table 1 of the task-level productivity model, since data could not be accurately measured. Instead, we propose a two variable model. The independent variable is time, and the dependent one is subjective, relative productivity. The subjective relative productivity change is defined as 100% minus the quotient of the time required to perform a given set of tasks conducted by each single CAD engineer using the old system over the time required with the new system to perform an equivalent task. We asked the participants in this survey about their personal (subjective) perceptions about productivity. We using following simple ratio:

$$P = 100\% * \left(1 - \left[\frac{t_{old}}{t_{new}}\right]\right)$$

where P = Productivity (as a percentage increase or decrease), t_{new}, time for a equal draft (part) with the new system, t_{old} equals the time for an equal draft with the previous system, as a function of time over the course of using the new system.

6. RESULTS AND ANALYSIS

6.1. Results

Responses to the survey were screened for accuracy. We summarized the results by mapping responses to a graph of productivity over time. Question #2 corresponded to a relative productivity drop at the initial adoption of CATIA (the vertical axis intercept), while question #3 corresponded to the point in time in which the productivity reached the same level of subjective productivity as the previous CAD system used by the operator (the horizontal intercept). Questions #4 and #5 formed an ordinate pair representing the time and level of productivity reached in steady state, or at the time the survey was conducted (some may have still been in a learning phase). Data were integrated into the model by determining the mean of the valid sample space for all responses and computing the three points to be plotted. Given that the distribution was assumed to be, and fairly closely approximated, Gaussian, a confidence internal with an alpha of .05 was applied (95% confidence). Adding the internal to the mean curve produced a "maximum" curve, while subtracting it produced a "minimum" curve.

The curve, shown in Figure 10, supports hypothesis 1 that task-level productivity drops with initial introduction of a CAD system. This is due to the lack of familiarity with how to use the new system. The loss of working time to integrate the system into the job process and company also affects productivity, those these factors weren't discriminated. The mean of the initial productivity drop was -42.6%, with a standard deviation of 27.3, which was surprisingly narrow given that subjective measures of productivity were used. The time to reach the equivalent task-level productivity as compared with the previous system is represented by the horizontal intercept. The mean was 31weeks with a standard deviation of 43.8. The increased deviation may be due to the fact that learning intervals are dependent on the task performed, variance in individual experience and skill, and variance in training and percentage of job time dedicated to the new system. The last point is the time to reach full proficiency, and the level of productivity at that point. The mean for this point was 39 weeks at 53.4% increased productivity, with a standard deviation of 77.7 and 41.1, respectively. This point, of course, includes both variances in the time and productivity dimension.

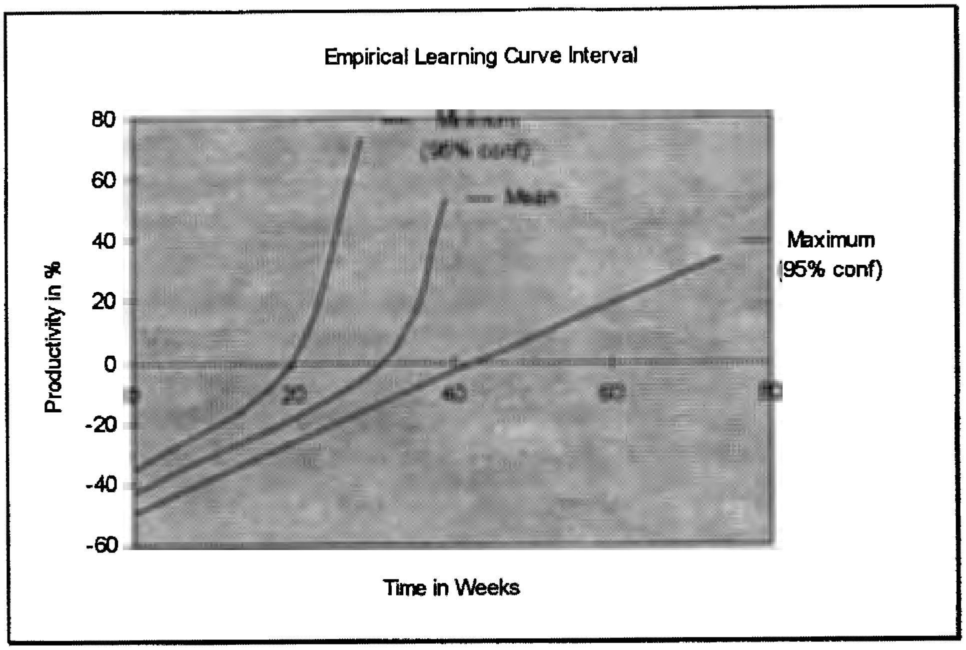

Figure 10 - Subjective Productivity Summary Throughout CATIA Adoption

Other questions qualified the users by experience level. Question #1 determined the period of time users had been utilizing CATIA. The mean of this response was 5.8yrs with a standard deviation of 2.69. All respondents had used some other CAD system(s) prior to CATIA (question #2).

6.2. Analysis

As mentioned, the results support the concept of a learning effect, in the three phases as we have defined them. What is interesting is how long the learning internal required, and the significance of the drop in productivity. Figure 11 illustrates the total deficiency in productivity until reaching proficiency. Until reaching an equivalent level of productivity with the previous generation system, an equivalent of 6.72 person-weeks of effort was lost. Subsequently, 2.12 person-weeks of additional productivity (again normalized compared to what would be expected for the previous CAD system) was gained, still not compensating for the initial loss. Assuming that once proficiency is reached, task-level productivity continues at a rate which is 53% over the level of productivity with the previous system, I requires (6.72-2.12)/1.53 = 3 weeks. Therefore, it is at 39+3 or 42weeks that break-even in productivity is reached. This does not consider non-productivity investments such as monetary cost etc., which would further increase the break-even point. However, this does not reflect the productivity level that would be exhibited on future projects which incur less learning effect, assuming technology and process stability.

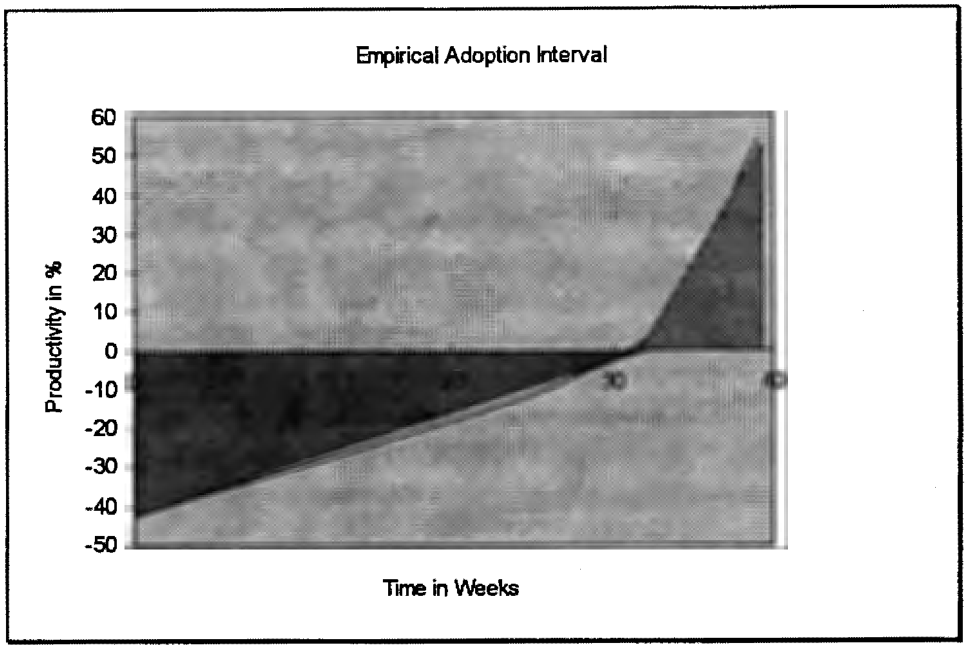

Figure 11 - Analysis of Productivity Deficit/Gain Throughout Adoption

The design cycle of this project was 24 months (2 years), resulting in a cumulative productivity increase of 29.8%. What is interesting however is that with about the same human resource investment performing about the same level of project complexity, the previous project was designed in 5 years, implying a 150% increase in productivity! Differences included that there were additional personnel, but there was a migration of staff to CAD operators at a lower salary level, making the total human resource expense only slightly greater. Is the discrepancy in task-level versus system-level productivity due to the subjective measures? A look at some of the interview responses indicates that task-level productivity measures do no directly correlate with NPD or corporate productivity measures. One engineer summed it up well, saying "I admit that (2-D) CAD programs produce drawings much faster than CATIA, but the benefits you gain by using CATIA are far greater, though it is hard to measure the productivity loss/gain. As example is a 3-D layout for checking form/fit and function of your part or assembly. By checking your parts' form/fit and function prior to release, you eliminate a majority of the rework, redesign and scrapped parts due to interference unseen on a 2-D CAD system."

Another user stated the chief benefit of the system was the reusability of the work "downstream" where databases could be checked for accuracy, and directly translated into manufacturable systems. This allowed the well-integrated CAD system to affect the entire development process, not just drawing, and to reduce the number of errors and amount of re-work.

Another pointed out the difficulties and deficiencies in measuring "proficiency", indicating that many of the more leveraged features were not yet deployed , so there is some latent proficiency. Furthermore, the level of proficiency depends on the intensity of usage.

Someone using the tool 90% of the time may take less time to reach a higher level of capability than another using the tool 30% of the time, or multiplexing often between tasks. However, a fundamental conclusion here supports the hypothesis that task-level productivity is an insufficient measure of impact on NPD, and that better, system-level measures are necessary. These measures, though much more difficult to ascertain, would allow management to access what CAD technologies can best impact their business given certain investments, and how they can best be utilized.

Next we will discuss problems typically encountered in the adoption of CAD in order to determine how to address *system-level* effectiveness. It will be shown that a number of significant issues must be addressed to achieve the types of system-level effects that Freightliner has realized in their time-to-market.

7. PROBLEMS WITH SYSTEM-LEVEL CAD TOOL ADOPTION

Many firms using CAD are under-utilizing it, and there are countless other companies that have tried CAD and failed. Clausen[4]describes an example of a firm discontinuing its installation of a computer-based information system (CBIS) after five years of planning had been undertaken-an investment that could not be recouped. Dickson *et al* [6] describe an MIS(Management Information System) that was so poorly implemented into the Minneapolis Post Office that the system was removed.

In another study on potential reason for CAD failures, Schaffitzel and Kersten[25] examined the experiences of 20 medium-sized German firms. They found that a decisive factor in less successful implementation of CAD systems was the failure to restructure and redesign the existing organization as CAD is first introduced. Rowe[22], who examined a failed implementation of a computerized stock control system, found that while management searched for technical reasons to account for the failure, most technical factors were in practice human and organizational problems. Finally, Health and Gower [9] describe result of numerous pilot studies conduced in the United Kingdom to ascertain the management skills in the implementation of CBISs. The researcher found that management skills were required to overcome several important problems included in implementing new technology. Some of these problems included insufficient personal commitment, unreliable systems, and insufficient technical support.

These finding support the thesis that in the past only technical criteria have been considered to implement a computer aided system. More pointedly for CAD systems, the introducing of such system depends as much or more on human factors, i.e., attitudes, fears, recognition incentives, compatible machine/user interfaces, etc., as it does on the capabilities of the equipment selected.

The problems of effective adoption and utilization of CAD tools in product development will address two main areas. First, social and organizational consequences of CAD will be discussed. Second , managing individuals' resistance to CAD will be presented.

7.1. Social and Organizational Consequences of CAD

When technology changes, Social and organizational factors can be affected. If such social factors are not appropriately managed, expect benefits of the design changed may not be achieved.

1) As a job is resigned or new skills are needed. With CAD, for example, a drafter's job may need to be redesigned to allow the drafter to optimally utilize new information arriving from multiple sources.
2) An employee's willingness and ability to adopt to new technology. With CAD, for example, workers may initially resist training because they fear the effects of CAD on their future jobs.
3) The implementation process, such as when training is appropriately provided and advance planning is undertaken. With CAD, for example, success may be more likely when follow-up training is offered as users adjust to the new system.

Two major categories of social and organizational factors are described that may be changed by implementation of CAD and that may affect whether design process changes brought about by CAD yield CAD's expected benefits. These factors include :a) aspects of the workplace; b) reactions of individuals in the workplace.

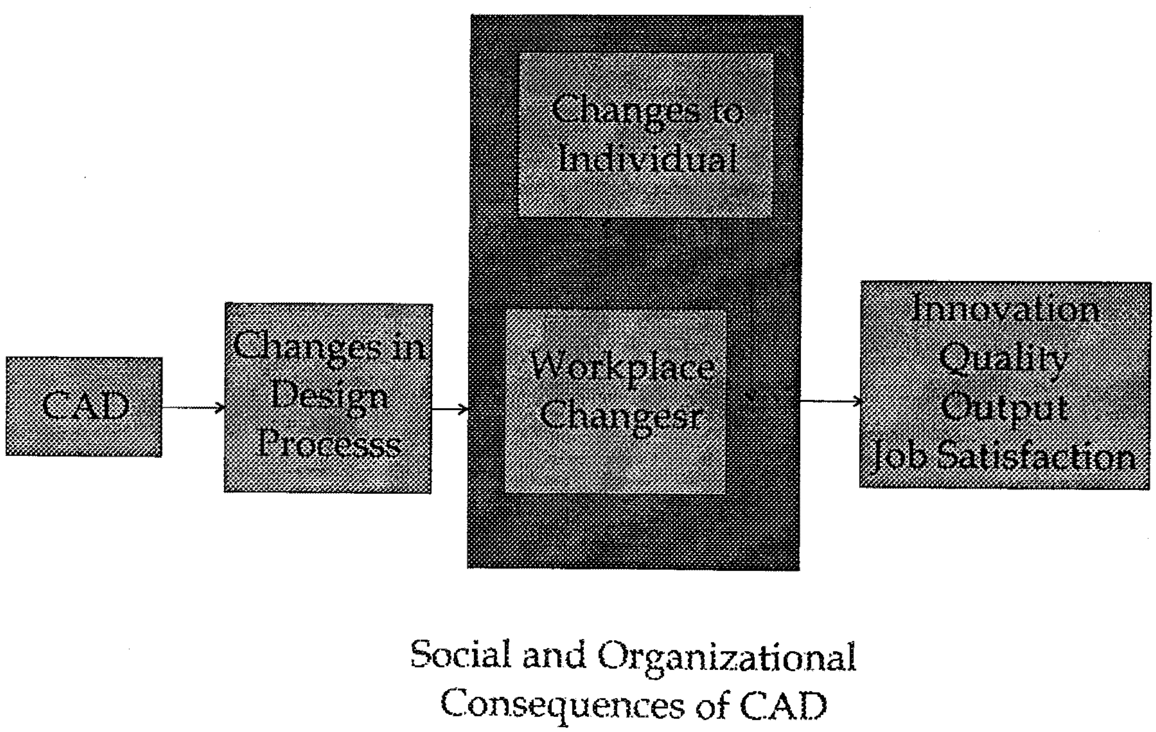

Figure 12 - Social and Organizational Consequences of CAD

7.1.1. Workplace changes resulting from CAD

Workplace consequences of changes in the design process included by CAD can be categorized according to four main descriptors of the workplace :

1. Job tasks.
2. Organizational procedures.
3. organizational structure.
4. Miscellaneous workplace aspects such as workforce size, performance monitoring so on.

7.1.2. Individuals' reactions to jobs with CAD

Individuals can evaluate their jobs in a number of ways : they can assess its challenge to them, the negative effect it has on their non-work life, or their contentment with it. Three such evaluations or reactions have been examined in the research literature as being affected by the implementation of such new technologies as CAD :

1. Perceived stress of the job.
2. Motivating potential of the job.
3. Satisfaction with the job.

7.2. Managing individuals' resistance to CAD

Resistance of individuals to technological change is an issue of much concern to managers. Managers should be concerned about peoples' resistance to change for a variety of reason. For one thing, resistance is a clear and open refusal to respond to managerial directives; When managers define their jobs as controllers and directors of subordinates' work, to resist sends a signal to everyone that the manager cannot do his or her job and the resister cannot adequately cope with authority.

Resistance to change is important for an additional reason: resistance has numerous and serious consequences to an organization. Resistance creates employees who tend to not be highly productive with that new technology. Such employees tend not to be motivated to perform to the prespecified levels of output. Given their low motivation, they are also unlikely to experiment with the new system to attain full benefits from the equipment. This lack of experimentation is particularly troublesome as shown in the findings of Johnson *et al's*[8] that an organization's innovative use of a system is dependent on the willingness of those employees using the system to make suggestion for new uses. Without such willingness, an organization is likely to be constrained to an unsophisticated system not well integrated with the organization. Finally, resistant employee may manifest their lack of motivation in destructive ways such as sabotaging the new technology. The example given by Dickson *et al*[3] describes forms of sabotage to a new MIS that included deliberate errors in transactions, physical sabotage (e.g., paper clips in the machine) and data falsification.

8. MANAGING THE IMPLEMENTATION PROCESS

These finding support the thesis that in the past only technical criteria have been considered to implement a computer aided system. More pointedly for CAD systems, the introducing of such system depends as much or more on human factors, i.e., attitudes, fears, recognition incentives, compatible machine/user interfaces, etc., as it does on the capabilities of the equipment selected.

For these reasons, the management of new technologies, especially management of the organizational issues involved in the installation of a CAD system, is an essential part of how to derive optimal benefits from CAD.

The factor that management can directly control is the implementation process. Implementation process, as the final a potentially important contributor to resistance, concern how the implementation is handled. Training, the manner in which users are involved in the design of the new system, and the degree of preplanning are implementation factors.

In many organizations, the objectives for the new technology are not at all clear. CAD may have been purchase to generally enhance the capabilities of the drafting or design department. While these are general goals for the new technology, they are very specific. Since general capability enhancement is desired rather than the achievement of any one objective, Johnson *et al*[10] have defined success of implementation of as the sophistication of use of the new technology. In the CAD's case, sophistication can be measured as the extent to which the organization adapted and integrated CAD into the ongoing process.

Countless variables that describe the implementation process have been suggested as potentially affecting success of the implementation effort. These variables can be grouped into six categories, which are discussed in the subsequent sections below.

1. Organizational context of the implementation.
2. Top management involvement in the implementation.
3. User participation in implementation decisions.
4. Planning the implementation process.
5. Training.
6. Managing system developers to handle implementation.

8.1. Organization Context of the Implementation

The context is the set of organizational goals and structure within which the implementation of the new technology will take place. Variables that describe the context include the organization's culture or orientation to change, the manner in which the organization is structured, the organization's rigidity, etc. In identifying contextual variables conducive to successful implementation, conclusions about organizational constraint that may prevent success can be derived. As such, a recognition of the limited role of factors in the implementation process may help to explain why some organizations never seem to successfully implement new technology.

Several tentative conclusions about how an organization's context influences the way CAD are implemented were spotlighted. First, because of the penchant of bureaucratic organizations to avoid revolutionary change, such organizations are probably likely to implement CAD as an electronic drafting device only. Second, organizations in particular industries may be more likely to adopt CAD, though not necessary successfully implement it. Third, organizations with more positive attitudes about change are probably more likely to successfully implement CAD. Finally, organizational politics may determine *a priori* the success of an implementation effort.

8.2. Top Management Involvement in the Implementation

The need for top management support and involvement in implementing organizational change is critical. There is specific way in which top management should be involved in the implementation of CAD. First, top management must understand enough of the technology and the organization's business and workflow process to make reasonable judgment on how the technology fits in with the company's needs. Second, top management needs to be involved in the implementation process primarily from a top-down perspective. That is, their focus needs to be on strategic concepts rather than the specific details of either the implementation or the technology. Too much involvement in operational decisions will remove the discretion needed by lower-level system developers as they adjust to the concerns of lower-level users of the system. Third, Top management must recognize a need to become involved not only in specifying objectives and uses, but in resolving the conflict likely to occur as objectives, priorities and uses are defined across department and users. Interest of different department and users are likely to manufacturing tools, how CAD designs are approved, at what point in the design process should CAD designs be finalized and modifications halted. Thus, an important role for top management is to resolve these conflicts as they arise-and preferably to full-scale implementation.

8.3. User Participation in Implementation Decisions

Not only do the organizational context and top management support affect the success of the implementation process, but user involvement in the implementation process itself appears to be important. The first recommendation for enhancing user involvement suggest that design decision can be broken into two types: strategic(which estimated limits and objectives for the system) and technical(which works within the strategic guidelines to develop specific software and hardware options). Given the level of technical knowledge necessary to become involved in technical decisions, and given users' adversity to spending such time, users have to be involved in setting guidelines on issues about which they personally have concerns in a way in which their involvement is productive. A second recommendation for enhancing user involvement is an evolutionary design approach. It's consist in a continuous problem-solving discussion with users on a range of issues from software development to training which would provide a more knowledgeable involvement of users and the sense of continued improvement necessary to maintain a lengthy and changing implementation process. A final recommendation for enhancing user involvement revolves around the management of system developers. Clearly, something is wrong when system developers cannot speak the users' language or leave users with the impression that developers are concerned less with system use than computer hardware. Thus efforts must be made to identify ways to appropriately manage the system developers to help overcome the chasm between developers and users.

8.4. Planning the Implementation Process

Another category of factors that may affect the chances of a successful implementation of CAD is the way in which the implementation process is planned. Common errors in organizational planning are the under estimation of the time, resources and need for organizational adaptation to the new technology, as well as ignorance of the role of organizational issues in the implementation process. Also to be included in the implementation plans is an explicit delineation of specific phases of the implementation process. While installation of new terminal may be the last step of initial implementation, it should certainly not be the final step if an evolutionary approach to implementation and a long-term strategy to adaptation of the organization to the system is adopted. An important step is what is commonly referred in the organizational development literature as the 'refreezing' phase of implementation. Refreezing refers to the set of activities involved in stabilizing the organization at a new equilibrium to maintain and continue the integration of the new technology with the organization. Such activities may take the form of developing new norms of behavior or rules, or providing continued reinforcement for use the new system.

8.5. Training and Learning

Often training is assumed to be necessary for new CAD system adoption, but the broader requirement of learning is ignored. Therefore, initial training classes are given, and management, when told that the new CAD system is not being used effectively due to poor understanding, blame the course material or the CAD engineers, rather than looking at the overall learning process. The learning process as a model is described in [2]. The authors state that the effect of experience on productivity capture in the learning curve model might be due to the influence of identifiable managerial actions. This model begins with the relationship between experience and the generation of data driven that process. This model can be applied to CAD learning to show that the learning process is internally complex. The complexity arises because, in order to respond to problems uncovered in the design process, actions are undertaken, some of which can have sizable, if perhaps temporary, negative effects on performance.

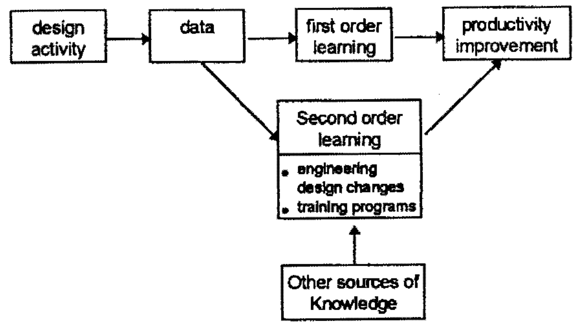

Figure 13 - The Learning Process [3]

First order learning has a direct effect of experience on productivity and second order learning which is captured in all the other path leading from the head to the tail of the cascade as shown in Figure 14.

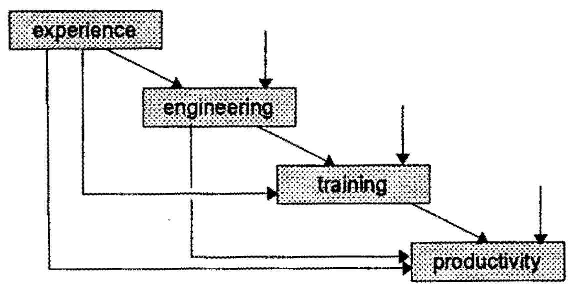

Figure 14 - A recursive Layering Process Model [3]

Training of CAD users is important because it is related to job satisfaction of users, success of new systems, and sophisticated integration of system into the organization's workflow. Training in a learning context is viewed as consisting of two stages: initial training and continued training or follow-up training. Initial training occurs when the individual is selected and may typically consist of sending the individual away to take a vendor training course. Follow-up training may take the form of advanced commands or system problems that arise after installation. Understanding useful characteristic of each stage of training will help to develop a more complete training program. The state of existing initial training therefore seems to be one of a fairly narrow focus on specific terminal functions, little customization of vendor training for specific organizational work processes, and with most training done informally on the job with heavy reliance on peers.

8.6. Management of System Developers

Finally, the management of system developers is also critical. Influence technical design is not just the technology itself, but also the designer's knowledge, skills, values and assumption about people and organizations. Moreover, system developers have been found to be main participants-if not determinants-not only of the system itself but also of the implementation process. Because of their importance in the implementation process, the problem and limitations of system developers are particularly noteworthy. Basically, the critical issue with system developers is their negligible need to work with others-a job characteristic of great importance to optimal implementation. This observation suggests the exceptional need to manage the system designer-user interface. However, not only the management of the user-system designer is important, but when a special technology unit exists, proper management of that unit is essential.

8.7. Conclusion

In summary, failures in implementation are caused by an interaction among multiple factor. Poor training alone will rarely be enough; rather poorly training only those directly involved in the new technology without asking for user involvement may prove much more fatal. Second the organizational context constraint the degree and success of implementation. Third top management must be involved in strategic decision making but kept away from the tactical or operational decisions. Fourth, user participation should be managed for evolutionary problem-solving on setting directions, rather than solving specific technical problems. Fifth, substantial planning prior to equipment installation is call for. Sixth, more emphasis on training is essential. Finally, since system designers tend to have a narrow technical focus that ignores organizational issues involved in new technology implementation, system designers must be managed to enhance that interface.

9. FINAL CONCLUSION

Given the level of investment in CAD technologies, it is surprising that the impact of such tools on new product development and the corporation is not better known. We presented three hypotheses in this paper regarding the relationship between CAD tool adoption and NPD productivity. The first is that task-level productivity follows a learning effect in which the benefit is proportional to the learning interval, the amount of initial productivity loss, and the new proficiency level, and in particular, the ratio of the learning interval to the total product cycle time. The second is, however, that task-level productivity measures are insufficient to determine cycle-level effects, and that system-level effects have greater leverage. This point is supported further by Zirger *et al* [30], who observed that simply increase the rate of new product development can actually reduce NPD productivity if there are not corresponding changes in processes and organization. Our survey demonstrated that task-level productivity was not an insignificant component, but not the exclusive component of system-level productivity. The third is that the impact of CAD tools can be greatly increased by addressing set of commonly encountered adoption problems, as cited in this work. This extends the observation of the second hypothesis to propose solutions to increase the effect on system-level productivity.

Future research in this area, we believe, should focus on measures and empirical studies of what specific aspects of CAD technologies and CAD tool adoption impacts what aspects of system-NPD and corporate level productivity. Other areas of research should include the relationship between learning curve interval and product lifecycle. With product lifecycles shrinking, must learning intervals shrink proportionally? If this is the case, then what training and adoption practices must be instituted? How much singular change in CAD technology will be permissible? Will incremental introduction of incremental modules of new systems be essential?

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