Skill and Organizational Complementarities to CAD/CAM Technology Use in Small and Medium Sized Manufacturing Firms

by Antonio J. Gallardo, January 2004

Summary:

This study was intended to support the future technology implementation efforts of small to medium-sized manufacturing companies by performing a field study of at least 100 firms in the Greater Philadelphia region (Delaware Valley and Lehigh Valley), and by focusing on a given technology, computer-aided design /computer-aided manufacturing (CAD/CAM). In this study we not only confirmed some of the findings of early work, but we also empirically assessed the role of firm-level factors in the successful implementation of technology in small to medium-sized firms, and examine some plausible alternatives to our theory of complementarity among these factors.

Through this study we were able to determine the workforce development practices, the organizational characteristics and the organizational practices that are statistically significant between the highly successful firms and the less successful ones. Additionally, we found that the factors associated with the use of in-house training methods, the level of usage of flexible manufacturing systems, the establishment and frequency of committee meetings, the decision about the pace of work, the training budget, the development of CAD/CAM skills, and the offering of profit sharing incentives to managers are factors related to the perceived degree of accomplishment of typical manufacturing goals associated with CAD/CAM. Moreover, we found that these factors are part of a complementary system.

These findings have implications for the owners, or top managers, of small manufacturing firms, for policymakers, for the manufacturing associations, and for the economic and workforce development organizations.

We believe that this study has offered a great starting point for additional research considering technology implementation in small manufacturing firms.

Conclusions:

The main purpose of this study was to support the future technology implementation efforts of small to medium-sized manufacturing companies by performing a field study of at least 100 firms in the Greater Philadelphia region (Delaware Valley and Lehigh Valley), and by focusing on a given technology, computer-aided design /computer-aided manufacturing (CAD/CAM).

Although there is a vast source of prior research studying the critical factors to successful technology implementation, the most relevant findings from previous research cannot be assumed to be directly applicable to small to medium-sized manufacturing firms. Previous research in technology implementation has mainly focused on large firms, which we cannot assume have the same attributes than the smaller firms. Additionally, previous research using field study as a research method in technology implementation has mainly considered IT as a wide range of applications, from something as simple as electronic calculators to something as complex as a flexible manufacturing system (FMS). This makes it very hard for small to medium-sized manufacturing companies, which do not necessarily have either such a range of technologies or the resources to adopt them, to derive the theories about the factors that could affect the successful implementation of a specific

technology that they are planning to adopt.

Also, previous research in small to medium-sized manufacturing companies, considering a specific information technology, has predominantly used case study research method in a limited number of firms. Again, this makes it hard for us to derive any theories about the factors that could affect the implementation of a given technology due to lack of a better understanding associated with the study of such a limited data set.

As we will be able to see from the main conclusions presented below, this study did not only statistically confirm for small firms some of the findings of early case studies for small firms and/or large firm studies. It has also enabled us to empirically assess the role of firm-level factors, workforce development practices and organizational practices, in the successful implementation of technology in small to medium-sized firms. Additionally, the study helped us examine some plausible alternatives to our theory of complementarity among these factors.

The economic hypothesis was a complementary relationship at a firm level between the degree of success in the implementation of CAD/CAM and (i) workforce development practices; and (ii) organizational practices. While the adoption of CAD/CAM was an important causal force in this story, it was the cluster which was key, since the implementation of CAD/CAM is likely to be more successful in organizations with more organizational practices that previous research has

demonstrated are key in the successful implementation of IT, and with workforce development practices that allow them to have more skilled workers. Those firms that combine these elements were predicted to accomplish more of the expected benefits associated with CAD/CAM than their competitors.

In this section, the research questions guiding this study are restated and are followed by conclusions drawn from the study.

1. Do the current workforce development practices (in terms of the investment, sources of knowledge, training methods, and scope of training) of the small to medium-sized manufacturing firms in the Delaware Valley and the Lehigh Valley support the development of the skills necessary to obtain the full benefit of CAD/CAM? If not, what are the major common challenges facing these firms to prepare their workforce?

   In addressing this question with respect to the firms' readiness, in terms of their workforce development practices, to obtain the full benefit of CAD/CAM we can say than the highly successful ones are more prepared than the less successful ones. We found that six workforce development related factors were statistically significant when assessing the difference between the highly successful firms and the less successful ones: the level of investment in workers training (Training Budget) (the higher the better), whether firms offered training in manufacturing foundation skills, or hired workers with those skills (the more the better), the

percentage of managers and supervisors (the less the better), the percentage of workers with graduate degree education (the more the better), the percentage of workers with uncompleted high school education (the less the better), and the use of in-house training as a method of training (the more the better).

From the results we learned that the less successful firms did not invest as much in workers' training (less than 5% of the total budget), that they paid much less attention to skill areas such as professional skills and fundamental skills and to a much lower extent than the highly successful firms, and that they over-relied on new workers having the skills when hired more than on developing those skills through their workforce development programs. Considering the fact that 85.7% of the firms in this study are in similar conditions, we believe that the matter should be addressed not just by the firms themselves, but also by the manufacturing associations, and the economic and workforce development organizations.

So, what could the less successful firms do to be more prepared to take full advantage of the potential benefits of a technology such as CAD/CAM? In terms of their workforce development practices, they could start by somehow establishing a way to assess the level of skills of their incoming workers in critical areas such as professional skills, manufacturing foundation skills, and fundamental skills. This is especially important if these firms decide to continue relying on the new workers having such skills when hired. They could access the

Manufacturing Resource Centers (MRC's) as a source or support in developing the guidelines to assess the skill level of the new workers. The MRCs offer Human Resources support to small and medium-sized manufacturing firms.

These firms could also have a key role in preparing their future workforce. They could participate more actively in programs established at their local high schools, vocational schools or local community colleges.

Additionally, the less successful firms, considering the fact that they are the ones with the highest proportion of workers with less than high school education (a difference we found to be statistically significant when compared to the highly successful firms), could establish incentive programs to support and encourage their existing workers to complete their high school education or GED. They could extend these programs for workers to even continue their education beyond high school through loans that workers could pay through their tenure with the firms.

Also, small to medium-sized firms should attempt to have a more prevalent role in their local Workforce Investment Boards (WIBs). By participating more actively in the WIBs these firms would be able to promote policy change in the use of public dollars for training purposes that will be more tailored to the economic realities of these firms.

Considering the prevalence of small firms in the USA, we consider that the workforce readiness of the firms is a matter that extends beyond the physical boundaries of these firms. At the policy level, programs could be established to promote small and medium-sized firms investments in the development of their workforce. This could be done either in the form of a tax credit, or for more immediate returns for the firms, through a matching program.

From the researcher's experience in workforce development in the Pennsylvania region, small and medium-sized manufacturing owners have expressed a sense of frustration in accessing the public dollars available to train their workforce. They state that the process is too cumbersome, and the outcomes expected out of the public investment are not tailored for small and medium-sized firms.

In the State of California a program to address the specific needs of the employers on a more individual basis is called the Employers Training Panel (ETP). This panel receives a portion of the taxes the firms pay to the State and distribute it through matching grants that employers could use for training purposes. A similar program could be established in the State of PA either through the Department of Labor and Industry or the Department of Community and Economic Development.

Through our analysis we also found a remarkable pattern in the development of manufacturing foundation skills. This was the skill area where the highly

successful firms invested the highest portion of their training dollars, where they did not expect the new workers to have these skills when hired, where they used formal, as opposed to informal, methods of in-house training, and where they did not rely on the external providers for the development of these skills.

Additionally, we were able to learn that firms invested a higher portion of their training investment in the existing workers than in the new ones, and in the development of manufacturing foundation skills, and that the lack of funds was not the primary reason for firms not to offer additional training.

With respect to the workforce composition we learned that the highest percentage of workers was represented by the skilled blue collar workers. In relation to the training methods we found that firms relied very minimally on the external providers, that none of the highly successful firms or the low successful ones used government-funded agencies for training in any of the skills areas considered, and that in the case of in-house training methods firms relied more on the formal method of delivery.

2. Do small to medium-sized manufacturing firms exhibit a similar behavior in their organizational practices to the one found in previous research for large firms?

When addressing this question we learned that the small firms in this study behaved comparably to the larger ones with respect to the workers' autonomy to

make decisions about the pace of work and the working methods, the limited access to financial information to all the workers, the range of financial incentives they offer, and the establishment of committee meetings to discuss production related issues being the most common practice.

Although with no statistical significance when comparing the highly successful firm with the less successful ones, profit sharing and performance based bonuses were found to be the most common financial incentives offered by the firms under study. These findings are similar to the ones for large firms where gainsharing and performance based bonus programs were the most commonly offered incentives.

Stock ownership plans were the incentive least offered by the firms in this study. We also determined that when financial incentives were offered, the highly successful firms offered it in equal terms to workers and managers.

When analyzing who made the decision about the pace of work, all the firms in the study showed that it was mostly in the hands of the managers. In the case of the decision about how to accomplish the tasks, we observed a tendency to include the workers more. These findings are similar to the ones for large firms.

Another commonly found practice of the firms under study was the establishment of committees made up of blue collar workers and managers to discuss

technology planning and implementation, as well as production related matters. When we performed multiple comparisons, the frequency of meetings for planning new technology was significant when comparing highly successful firms with low successful ones. As it has been found for large firms, committee meetings to discuss production related issues were the most common meetings found for small manufacturing firms.

The practice of sharing information freely was not a common practice of the small firms in this study, especially when the information was of financial nature. The highly successful firms made less accessible the financial information to their employees than the less successful ones.

The sharing of production related information was the most common practice. However, we found that there is not a statistically significant difference between the sharing of this type of information between the highly successful firms and the less successful ones. Although the sharing of production related information is similar to the findings for large firms, the fact that it is not statistically significant when comparing the highly successful firms with the less successful ones differ from the studies for large firm. These studies found that the sharing of production information had a positive and significant relationship with firms' successful implementation of technology.

When assessing the workers' trust in the firms, measured as the proportion of workers who left the company in the twelve months prior to the study to the total number of employees in the firm, we learned that the turnover rate of the low successful firms was almost twice higher than the level of the highly successful firms. This finding is similar to the one for large firms where workers' trust was found to be associated with successful technology implementation.

3. Is there a relationship between the degree of success in the implementation of CAD/CAM, the workforce development practices of the firms that have adopted it, and the organizational practices of these firms?

   By using regression analysis we were able to identify the workforce development practices and the organizational practices that were related with the perceived degree of accomplishment of the typical manufacturing operational goals associated with the successful implementation of CAD/CAM (captured in the variable SUCCESS). These practices are the ones associated with the extent of computer use, the level of usage of flexible manufacturing systems, the level of investment in workers' training, the use of in-house training, how the decision about the pace of work was made, the use and frequency of committee meetings, and the development of CAD/CAM skills.

   Although it was very important to have determined the factors that have a significant relationship in explaining the behavior of SUCCESS, we considered

that it would be relevant for the small and medium sized manufacturing firms to get a more practical perspective about what these results mean to them. In order to do so, we performed a sensitivity analysis. In the process we established a baseline case by considering all the factors related with the perceived degree of accomplishment of the typical manufacturing operational goals associated with the successful implementation of CAD/CAM (SUCCESS) at their mean level. Then we changed the independent variables one at the time in order to determine the significance of these changes on the value of SUCCESS (in terms of the percentile placement for the newly calculated value).

What we learned by performing this sensitivity analysis was that significant changes matter (positively or negatively), when they are considered one at the time, on the perceived degree of success in the accomplishment of the typical manufacturing operational goals. Additionally, when they are added up they also make a difference on the percentile position a firm is placed (with respect to its level of SUCCESS).

For the owners of the small and medium sized firms these findings provide with specific actions they could take in order to move their firm from the current percentile level they are (in terms of SUCCESS) to higher position by performing one or several changes in any of the seven factors we found. This makes it easier for them to assimilate as they would be able to decide on a factor to change

according to their capacity, and before implementing it, realize what kind of change they could expect.

However, we consider that when it comes to factors more associated with organizational practices, such as the decision making process, and the use and frequency of committees made up both blue collar workers and managers, the question is why these firms have not implemented these practices? We consider that it is a matter of culture highly influenced by the firms' owners and their beliefs. Therefore the most plausible way to influence a change when it comes to organizational practices is to start the work with the firms' owners and top managers. This is something that could be started by either the manufacturing associations or the MRCs. Any of these organizations could start organizing seminars for this target group to start promoting a shift in their organizational practices.

With regards to promoting the practices of the use of computers for production related tasks such as part or product design, process planning, quality assurance, and to exchange data with customers, as well as the adoption of advanced manufacturing technologies (such as CAD/CAM and FMS) we consider that the role of the State government is key in promoting the adoption of these technologies.

We can state that in general the behavior in the use of computers and design and manufacturing technologies in the small to medium sized firms in this study is what we expected it to be, i.e. firms typically use computers for common tasks such as product design, process planning, quality assurance and parts planning; many firms are not using computers for automation of the production process; the most commonly adopted design and manufacturing technology is CAD/CAM; few firms are adopting design and manufacturing technologies to increase product variety and process flexibility; and firms do not think that design and manufacturing technologies would work for them.

What is interesting about this answer is that we do not know whether the firms are fully informed about the benefits of these technologies, and still stated that they would not work for them, or they stated that reason by their lack of full understanding and use of the technology. The additional complement for this speculation is the fact that almost none of the firms stated the fact that they were not fully convinced about the benefits of the technology as a reason for not adopting it.

What is clear about these findings is that the small firms, by themselves have not been able to fully appreciate the potential benefits of such technologies. We consider that a policy similar to the one adopted by the Japanese government to promote the adoption of Computer Numerically Controlled (CNC) machines throughout Japan could benefit the small firms in the USA. Through this policy,

the Japanese government required the implementation of CNC as a matter of national benefit to the nation's competitiveness, but also provided the firms with the incentives and support to adopt it. If the State of Pennsylvania government adopts a similar practice, they could rely on the MRCs to implement it due to their objective of supporting firms in the selection, implementation, and optimization of available technologies.

4. Is there a complementary relationship among all of these factors?

The economic hypothesis we studied was that of a complementary relationship at a firm level between the degree of success in the implementation of CAD/CAM and (i) workforce development practices; and (ii) organizational practices. While the adoption of CAD/CAM is an important causal force in this story, it is the cluster which is key, since the implementation of CAD/CAM is likely to be more successful in organizations with more organizational practices that previous research has demonstrated to be key in the successful implementation of IT, and with workforce development practices that allow them to have more skilled workers. Those firms that combine these elements would be predicted to accomplish more of the expected benefits associated with CAD/CAM than their competitors.

After following the strategy we proposed to test several implications of our hypothesis that there is a complementary system among workforce development

practices, organizational practices, and the level of accomplishment of the typical manufacturing operational goals, we concluded that such a complementary system exists for the firms under study.

More specifically, we found the following factors to be complements: extent of use of computers (COMPUSE) and use of in-house training methods (INHTRN), extent of use of computers (COMPUSE) and the establishment/frequency of committee meetings (CMTFREQ), the extent of use of computers (COMPUSE) and the level of usage of FMS (FMSIMP), and the establishment/frequency of committee meetings (CMTFREQ) and the level of usage of FMS (FMSIMP). We can conclude this based upon the results of the first two steps of the strategy we used. First, as we were able to determine that the factors are correlated. Second, as we were able to demonstrate that the increase in one of the factors results in an increase of its complements.

However, when we look at the results of the third step, where we measured the impact of the complementary factors on SUCCESS, we did not find that the marginal contribution of all the interacting factors to SUCCESS was statistically significant. We found that when the interacting factors COMPUSE x INHTRN and COMPUSE x FMSIMP were included in the model their marginal contribution to SUCCESS was statistically significant.

The meaning of these results for small firms could actually be taken as a very

good one: if you change one factor at the time, which could be easier to implement for these firms, you would obtain significant positive effects on the perceived degree of the accomplishment of typical manufacturing operational goals. On the other hand, if the factors are complements, it is even better to change them together.