Evaluation of Adaptation Alternatives During The Implementation of Amt In Small- to Medium-Sized Firms.

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Implementation is represented in the capital budgeting process as a solitary stage that begins after the decision to adopt and ends with the post-audit. For investments in advanced manufacturing technology, this belies the complexity of implementation and the financial risk. Many unexpected problems arise. The alternative solutions, with their costs and benefits, warrant rational evaluation. This study explores the process of implementation to identify what cost-benefit evaluation is done and the implications for project feasibility.

Introduction

Investment in advanced manufacturing technology (AMT)[1] can be a difficult and risky venture for companies. Much of this risk manifests itself during the implementation phase of the investment when problems arise that demand resolution. Even when planning has been thoughtful and extensive, in this stage, things go wrong. Unplanned and often considerable expenditures are needed to get the investment back on course. In the end, the financial performance of the new technology can be quite different from that planned.

Much research has been done on pre-adoption stages of capital budgeting and the post-audit. However, little has been written in the capital budgeting literature on the very critical process of implementation. The research described in this paper deals with the implementation of advanced manufacturing technology, financial decision-making in this stage and the measurement of project success.

Capital Budgeting Evaluation of AMT

Empirical studies, such as Pike (1996), have identified the techniques used to evaluate the risk and net benefits of capital investments. ‘Sophisticated’ techniques for the latter have been identified as net present value and internal rate of return and the less sophisticated, although well represented, pay back period. These are well entrenched in business practice.

In the case of investments in AMT, however, various researchers have noted a departure from the traditional evaluation techniques. In his case study of five American manufacturing companies, Dean (1987) found that while clearly acceptable projects were argued on the basis of the economics, marginal projects were “bolstered by a story about strategic and intangible benefits (p.132)” Dean found the tendency to emphasize the strategic and intangible benefits increased as

[1] Most commonly, AMT is computer-controlled equipment used for such things as manufacturing, design, engineering, raw material and inventory handling and control and decision support. AMT ranges from a solitary stage in the manufacturing process that is numerically controlled (NC) to computer integration of all stages of operations including cost accounting and purchasing.

the cost or risk of the project increased, as financial returns decreased or as the returns became harder to calculate. Nixon and Lonie (1992) also noted a shifting emphasis on financial versus qualitative factors, which depended on the project's technological and commercial risk as well as its strategic significance.

Carr, Tompkins and Bayliss (1995) studied strategic investment decisions (SIDs)[2] in German and UK automotive companies to observe the use and influence of financial and strategic analytical techniques in the investment decision process. Although they found many differences cross-nationally, Carr et al (1995) found a good deal of commonality. For example, they found accounting/finance, used mostly for "devil's advocate" purposes, took place late in the decision process and had little influence in strategic investment decisions; contrary financial results would be overridden if there were compelling strategic reasons; pay back method predominated as an evaluation technique; and beyond crude sensitivity analysis, little risk analysis was employed.

In contrast with the UK companies, many of the German companies studied were small to mid-sized, privately held and in many cases, owner operated. Carr et al found the German SID-making was less financially oriented, more informal, strategic and longer-term in perspective. The German companies, in general, used longer pay back hurdles and these were less rigidly adhered to. Overall, Carr et al (1995) found SIDs were "ultimately determined more by strategic considerations emerging from informal decision-making processes, than by application of more formal capital budgeting techniques (p. xiii)."

Similarly, Collier and Gregory (1995) noted companies with "dominant leadership exercised by one individual" used simpler, more informal appraisal methods (p. 52). They also found the simpler, informal evaluation system tended to be used by companies that were concentrated in a single, well-defined industry (p. 52).

In making these observations, Collier and Gregory (1995) and Carr et al (1995) recognized capital budgeting activities, although unconventional or less 'sophisticated,' were indeed taking place in the organizations studied. Together with Dean (1987) and Nixon and Lonie (1992), these studies serve to expand the definition of capital budgeting evaluation of AMT, particularly in small, focused, owner-managed organizations.

The studies described above deal with the phases of capital budgeting preceding and including the decision to adopt. Like most other studies of capital budgeting, they disregard the significance of AMT implementation. The following section, drawing from the innovation literature, describes more fully the process of implementation.

The Process of Implementation

Voss (1988) defines implementation as "the user process that leads to the successful adoption of an innovation of new technology."[3] He argues the success of an innovation in a user organization

[2] A major investment in AMT, made to replace conventional technology, typically qualifies as a SID.

[3] Voss (1988) describes implementation as beginning at the time of planning and design, arguing that many of the actions at this stage, such as strategic and technical planning and workforce participation are important determinants of implementation success (p. 59). He describes the implementation process as consisting of at least three stages: pre-installation, installation and commissioning, and post-commissioning (consolidation). Pre-installation begins with planning and design and ends with the decision to invest. Installation and commissioning begins once the decision to adopt is made and ends when the technology is operational and achieving target technical measures consistently. Post-

can depend greatly on implementation. Marsh et al (1988 p.61) likewise stress its importance: “implementation is not the end of the process, but the key overall issue.”

Studies of AMT implementation have revealed the process is fraught with setbacks, at times threatening the entire project. Leonard-Barton (1988) terms these setbacks *misalignments*, which often result from mismatches between the technology and the user environment in terms of the project’s technical requirements, the system delivering the technology to users or user organization performance.

Leonard-Barton studied the implementation of new process technologies and found misalignments between the technology and the user environment in her case studies. She described the process undertaken by the organizations as *cycles of adaptation*: "the process of circling back to revisit a decision point - re-opening issues of technical design that the developers assumed were resolved, redesigning delivery systems in the user environment or 'unfreezing' organizational routine to re-examine the goals implied by current performance criteria" (p. 260). She found these cycles varied in magnitude depending on how fundamental the misalignment (p. 261) and they could be either beneficial or detrimental.

The adaptation cycles observed by Leonard-Barton fell into two groups: a) technology adaptation and b) organizational adaptation. The former encompassed the resolution of technology misalignments and the latter dealt with organizational performance criteria and delivery system misalignments. [4] She also observed adaptation alternatives -- a given misalignment could often be resolved with either an organizational or technological adaptation or a combination of the two. This has particular relevance to the study of capital budgeting as *each action would have its own benefits and costs.*

Measures of Project Success

When evaluating implementation, it is important to consider project success and its measurement. Willcocks and Lester (1993) surveyed forty companies to determine what level of project evaluation was carried out at various stages of an investment in information technology. Eighty percent of the companies evaluated the project in the post-commissioning stage, but many used additional criteria to those used in the feasibility stage. Willcocks and Lester suggest the acceptance of a project using one set of criteria and measurement of its success using another may be problematic (p. 32). They did not suggest what the problems might be, nor did they establish why such changes to success measures arise.

In reviewing various studies, Voss (1985) found success of implementation measured in technical terms such as percent of up-time, use in actual production and whether the new technology had been in use for a full year (p. 58). Often overlooked were expected benefits and the original objectives of the investment such as flexibility and improved quality. "Full success," Voss argues, "can only be considered to have been realised if the benefits being looked for are realised, and ideally realised in the marketplace through increased competitiveness" (p. 58).

Method

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commissioning activities include technical improvements and any changes (adaptations) necessary to achieve business success (p. 59).

[4] Lindberg (1992) added ‘strategic adaptation’ to this classification, which occurs when the goals of the implementation or the project’s “strategic tasks (p. 61)” are changed in response to performance misalignments.

The aim of this study was to explore what capital budgeting evaluation goes on in the post-adoption stages of AMT investments and the implications. Project success and its measures were also explored.

Data was collected using the case study method as described by Yin (1989). This qualitative, field-based technique is particularly well suited to the study of processes in general (Leonard-Barton, 1992) and the field of capital budgeting in particular (Bower, 1970; Carr et al, 1991) because of its ability to observe subtleties and changes not collectable with survey instruments.

The case study method requires in-depth data collection by interview, document review and/or participant observation following a pre-set protocol. The sites are not randomly selected and are not expected to be representative of a greater population. Rather, they are specifically selected on the basis of their similarity on various variables so other variables can be compared. From the data, propositions are derived, ready for further study either with more cases or empirical methods. This grounded theory approach (Glaser and Strauss, 1967) is particularly appropriate for exploration of uncharted processes and concepts.

Private and closely-held, preferably owner-managed companies were desired. Of five companies studied, three had invested in AMT in the previous two years and were in post-adoption stages of implementation.[5] To qualify as a case study site, companies had to have had at least one misalignment of sufficient magnitude to yield relevant data.

Companies to which advanced technology was important for competitiveness were sought. The companies selected were either serving small local markets or were disadvantaged by distance from large markets. For the former, economies of scope and flexible technology were particularly important. For the latter, economies of scale and low unit costs were important.

The studies took place between March and December 1995. The managers involved with the project were interviewed. Included were those people integral to the adoption decision and those involved in the implementation. Open-ended interviews guided respondents to discuss the project goals, misalignments, how these misalignments were resolved, analysis of adaptation alternatives and success as per project goals. All companies described misalignments and adaptations in the implementation of their investment. There were various degrees of success and satisfaction with the projects. A summary of the cases is provided in Appendix 1.

The procedure for data analysis was adapted from Carr, Tompkins and Bayliss (1995). Themes on which to compare and contrast the cases were selected. These included owner background, profitability, market share, in-house expertise, newness of the technology to the company, customization, reason for the investment (economic, strategic), stage of implementation, misalignment attributes, how resolved, rationale, extent to which goals were met, necessity/urgency of technology's operation and ad hoc adaptations. Data were compared by theme, company, project and misalignment. Companies were also grouped by their standing on various themes and compared with other themes. For instance, companies making the investment for economic reasons were compared against those making a strategic investment. As patterns emerged, propositions were developed, which form the basis for further research.

[5] The fourth company was implementing new product technology (rather than process) and the fifth company was still in the pre-adoption stage of the investment process.

Data and Analysis
Case Descriptions

CP, an owner-managed manufacturer of pre-cast concrete products, invested in a comprehensive batch plant with programmable logic control (plc) as part of a major strategic initiative. To save money, the system was designed in-house by the resident engineer/plant manager. This investment was a top-management initiative, which was long into the post-installation stage. Although operating, it was still not achieving business success. The designing engineer left the company shortly after installation.

CP experienced several significant misalignments, the essence of which was poor quality output necessitating regular manual override of the plc. Continued operation of the batch plant was critical, as it had completely replaced the old mixer. High raw material variances, particularly of stabilizing chemical additives, red-flagged the misalignments.

FP, run by a general manager reporting directly to the two owners, manufactured fiberglass reinforced plastic pipe using conventional machinery almost entirely. In order to increase output and meet a huge surge in demand, FP retrofitted a mechanical filament winder with computer control. The change in capability of the winder was to be accompanied by a change in the manufacturing process to take advantage of winder's new flexibility. The investment was evaluated using payback period. The benchmark used was 1.5 – 2 years, as this was the rate of payback on most FP's investments in equipment. The project was part of a larger investment, on which payback would be longer than usual. To shorten the payback period, only one part of the project was initiated, with FP taking a wait-and-see attitude for later stages.

After many technical glitches were resolved, the FP winder still performed erratically, even dangerously. Operators noted its problems occurred on certain diameters of pipe and thus avoided its use on these diameters. Ironically, these particular diameters were the ones specifically intended for the automated winder to maximize savings. For two years, engineering and management were not aware of the operators' adjustments to the process. At the time of the study, the winder investment was in the consolidation stage and achieving most technical and some business measures.

AP, an owner-managed manufacturer of aftermarket automobile parts, invested in CNC laser cutting technology to diversify its product line and markets. Although somewhat familiar with advanced manufacturing technology, this was the first experience with a laser. The owner and top managers initiated the investment. The investment was evaluated using the ROI technique, but managers where emphatic in saying this had little influence on the decision. The most conservative comments were those of the Vice President: Administration/Comptroller:

> We do (estimate) our rate of return, but we don't pay that much attention to it initially because [the new technology] is more of a developmental tool. We are very fortunate, we're in a business where the margins on our core products are very nice. We can afford to take risks sometimes, we can afford to do something on a whim, by the seat of our pants and we do that because the gentleman that owns the company somehow has a tremendous vision and he is very insightful into where our industry is going. As with anybody, sometimes you are wrong but more than not, he gets into technology that is very helpful down the road, if not today. We find a way to use it that will ultimately help our bottom line. Maybe not this year, but eventually it will.

Due partly to lack of manufacturer support, the laser had a very long installation. Once operational, AP discovered it could not cut plastic, latex and rubber, which was fifty percent of its intended application. They quickly responded by acquiring a water-jet cutter to supplement the laser. For other materials, the laser was achieving technical and some business measures at the time of study. The water-jet was still being installed and tested.

Analysis

During the post-adoption stages of implementation, nine misalignments arose amongst the three companies. They were a mix of technical, organizational and strategic misalignments. Adaptations ranged from recalibrating weigh scales to the $350,000 purchase of an alternative technology (water jet cutter).

In the adoption stage of the investment the companies compared the incremental costs and benefits using accepted, although unsophisticated techniques. However, as misalignments arose and were resolved, the companies did very little *traditional* analysis of the economic costs and benefits. Their focus was very much on getting the equipment to work as best they could, in the most expedient manner. This is not to imply costs and benefits were ignored, however. Informal cost-benefit evaluations using atypical measures were described by respondents. The forecast costs of adaptation were compared against either:

I. the cost to date of the total investment,
II. original benefits of the project yet to be realized,
III. adaptation costs compared to ongoing misalignment costs to be saved, or
IV. the total investment cost of the alternative technologies (in addition to the initial capital outlay).

In the *cost to date* evaluation, the managers used the justification that the value of the overall investment could be recovered with the expenditure under consideration. The relative size of the adaptation expenditure, as compared to these other costs, guided the decision. This was evident at CP and FP.

Using an *original benefits* evaluation, decision-makers compared the adaptation cost to the original benefits to be recovered from fixing the technology. The benefit to be gained may have been part or all of the original benefits depending on the extent of the misalignment and how much of the misalignment the particular adaptation was expected resolve. For instance, at AP, the adaptation cost of a new water jet cutter was compared to the rubber cutting cash flows the original cutting technology had been expected to generate.

Adaptation cost evaluation was evident, such as at CP, where the cost of the adaptation was weighed against the savings of extra chemicals otherwise needed to compensate for the performance problems of the equipment. CP's general manager/controller described the evaluation as follows:

> The raw-material variances were $30,000. That's about what we will pay the electrician/ automation specialist to work on it for a year. It was a tradeoff. Any other benefits are gravy. It was a no-brainer.

This evaluation involved a sunk cost rationale; however, net economic benefit of the original project was compromised.

The final evaluation type, *alternative technology investment cost* involved comparing the total cost, including quantifiable adaptation costs, with the projected costs of the original project alternatives. After explaining that the investment cost was nearly triple the forecast amount of $55,000, one manager justified the added investment as follows: "I offset that amount with the fact that the $150,000 actual investment is still inexpensive compared to [the commercially available technology], even $400,000."

These four types of evaluation were used almost unconsciously for relatively minor expenditures and more deliberately for larger adaptation expenditures. While some may have been sunk cost rationale in action, some were simply an act of desperation with little regard for overall project feasibility.

Of the companies studied, only AP used a traditional capital budgeting evaluation of its adaptation. When the installation and operation of the new technology was fraught with problems and delays, a second technology was purchased. This major adaptation had its own ROI calculation, done as a matter of procedure. Far more influential, however, was its operational and strategic relationship to the original investment. The second investment, made to replace the first acquisition until it was working, was also expected to help recover the strategic benefit lost to its unanticipated, permanent limitations. Such attendance to the project's non-financial goals was a common element in adaptation evaluation among the companies that had made the investment for strategic reasons. Similar to the observations made by Carr et al (1995) that economic analysis was overridden by strategic considerations, the goals of the AMT project often overrode the economics of adaptation selection.

The economic techniques observed for evaluating adaptation expenditures can allow an investment to become infeasible. While the comparison of the adaptation expenditure with the project benefits to be recouped or with ongoing misalignment costs to be saved is consistent with sunk cost rationale, the comparisons did not include the value of abandonment. The net benefit of the adaptation should not be less than the value of abandonment.

The two other justifications of adaptation expenditure observed, the comparison of the adaptation expenditure with the to-date capital investment and the comparison of the adaptation expenditure plus the initial capital outlay with the total investment cost of the alternative technologies, are in violation of sunk cost principles. In these cases, some of the behavioral finance phenomena described by Kahneman and Tversky (1979) and Statman and Caldwell (1987) may have been at play. These behavioral influences may help explain the decision-making observed. Certainly, the investments described in the case studies were major investments for the companies. The owner/managers were, understandably, very emotionally committed to the investment. In the words of one owner/manager, "this investment cost too much, I'm going to get it to work or die trying."

The use of a TINA (There Is No Alternative, Carr et al 1995) rationale was also observed. It occurred only with economic investments, for technical misalignments and when there was a sense of urgency or production was highly dependent on the new equipment. TINA was also prevalent among adaptation decisions made by equipment operators who were unfamiliar with the greater purpose and goals of the investment. Naturally, the occurrence of TINA is problematic since limiting alternatives bounds rational decision-making and can result in inferior project performance.

Project Success Measures

Implied in every discretionary investment is the goal of economic feasibility: the project should yield a net economic benefit. This seemed to be the goal that suffered the most. Often companies did not really have a grasp of whether the project was still a net benefit or not. In AP, feasibility became increasingly dependent on the project's real options.

Generally, managers made compromises throughout the process of implementation. Occasionally, some measures of success increased, however, expectations were mostly lowered as described by the comptroller of AP: "The laser is now working. It is doing everything we wanted it to do … now that we have accepted that it can't cut certain materials." At CP and FP, managers simply felt relieved the technology was functioning, if only minimally.

As a result of learning and compromises made, companies adopted a longer view of project success -- they accepted that success would be realized much later than originally anticipated. This was articulated by CP's President: "This investment is reasonably successful. It will be very successful. It could have been successful sooner." In some cases, this acceptance was difficult since delay was expensive.

These results shed some light on Willcocks and Lester's (1993) survey results that criteria for post-completion evaluation were different from those of the design and feasibility phase. The current study revealed an evolution of goals and measures of success as misalignments and adaptations occurred, as compromises were necessitated and as learning was gained. [6] Indeed, Butler et al (1993) consider the learning gained as part of a project's success.

Conclusions

Observations of three companies in the post-adoption stage of capital budgeting revealed activities similar to those described in the case studies of capital budgeting and SID-making for AMT by Bower (1970), Butler et al (1993), Carr et al (1995), Collier and Gregory (1995), Dean (1987), Lumijarvi (1991) and Nixon and Lonie (1992). These activities included cost-benefit and strategic analysis and the unfolding of measures of success.

This suggests the presence of capital budgeting decision-making throughout implementation.[7] Indeed, the complexity and financial impact of some of the misalignments observed suggest *rational evaluation of adaptation alternatives throughout implementation is needed to help achieve project and corporate objectives*.[8]

This study, however, noted economic evaluation of adaptations significantly different from the pre-purchase capital budgeting techniques considered customary. This suggests we question the rationality of these adaptation expenditure evaluations as well as consider the applicability of pre-purchase techniques to post-purchase decisions.

In no case did the companies appear to revisit the overall project evaluation to question whether

[6] In fact, the changed criteria are likely more realistic than the originals, which would be an improvement.
[7] Since multiple misalignments can occur, organizations may engage in iterative capital budgeting evaluations.
[8] It may also improve decision efficiency if, as suggested by Bowler, Primrose and Leonard (1995), "varying opinions on the relative merits of particular implementation techniques are able to be resolved as the enforced discipline of estimating costs and quantifying benefits helps clarify implementation decisions"(p. 10).

the project was still feasible with the added costs of adaptations and foregone benefits. Given the observed absence of post-audit activities, economic feasibility may never be known.

The cases bring to light the importance of "feasibility checks" of the overall project. It is important to be diligent in reviewing the investment periodically as it progresses through the stages of implementation. The review should be comprehensive and objective. The exercise alone can bring to light areas where things have gone wrong. Unlike the typical post-audit, however, the performance of the investment has to be measured against its goals, technical measures of success and impact in the marketplace (business success). Its use on the plant floor needs to be studied and the insights of all involved in the implementation should be gathered.

Implementation misalignments pose a threat to project feasibility and uneconomic adaptations exacerbate this. Rather than leaving post-purchase activities to the discretion of engineers, technicians and operators, those concerned with the project's overall economic value should remain involved throughout post-purchase stages as misalignments threaten the value of the project and further choices need to be made that impinge on the net benefit of the investment.

Appendix 1: Case Data

	CP Company	FP Company
Private, locally owned	*	*
Owner operated	*	
Primarily custom manuf.		*(70%)
Local vs. Export market	local	majority local
Employees	27	280
Annual Sales	$2,600,000	22,000,000
Profit Margin	5%	n/a
Total Assets (TA)	$2,400,000	8,000,000
Ann. Capital Budget	$225,000	2,700,000 (normally $500,000)
Usual proportion of capital budget for advanced technology	irregular, automation necessary but not prevalent	very little new technology
Projected invest (PI)	$150,000	$65,000
PI/TA	6.25%	13% (2.4%)
Technology	Automated batch plant	Automate filament winder
Investment made from strength/ weakness	from weakness economically, reactive; modest strength strategically	from weakness/ reactive
Reason	economic, to support strategic investment	economic
Use of TINA	yes	yes
Accountant and training	one, MBA degree	yes, Chartered Accountant
Necessity/ urgency	critical	necessary
No. of Misalignments	5	2
Essence of misalingments	poor quality output required regular manual override	winder erratic, ruined product and was potentially dangerous
Predominant rationale	TINA, some economic and non-economic on long- term solution	TINA
Financial consideration	short-term - disregard costs to maintain production; long-term - research and spend as needed to make it work. Costs compared to overall cost of project and size of losses	not concerned with optimal use, for modest expenditures, spend as needed. Major expenditures not encountered, but delay incurred high opportunity cost.
Success/ goal achievement	not achieving technical measures	achieving technical and some business measures
Stage	Installation and commissioning	consolidation

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