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Investment in Advanced Manufacturing Technology: A Study of Practice in Large UK Companies

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Abstract

This paper reports the results of a survey investigation into the investment decision making practices of large UK manufacturing companies, especially in relation to investments in advanced manufacturing technologies. A 24% response rate was received in a survey of the finance directors of 466 large UK manufacturing companies. Responses were classified into three groups ranging from non-users of AMT to sophisticated users and analysis revealed that more sophisticated users do emphasise certain intangible benefits in combination with measures relating to the traditional dimensions of return and risk.

Key words: Advanced Manufacturing Technology (AMT); capital investment decision; survey; intangible factors.

1. Introduction

This paper reports the results of a survey investigation into the investment decision making practices of large UK manufacturing companies. The interest of the researchers was in the manner in which companies justify investment in advanced manufacturing technologies (AMT) and whether the methods used are significantly different from those used in justifying non-AMT investments.

Slagmulder et al. (1995) highlighted strong interest in the topic, perhaps because investment in Computer-integrated Manufacturing (CIM) technologies such as Computer-aided Manufacturing (CAM), Flexible Manufacturing Systems (FMS) and Automated Storage and Retrieval Systems (AS/RS) can develop manufacturing capabilities that create or sustain competitive advantage.

The literature can be divided into three strands. First there are a large number of *surveys of practice* such as those of Klammer et al (1991) in the USA, Pike and Wolfe (1988) in the UK, Van Cauwenberg et al. (1996) in Belgium, and Kalyebara (1996) in Australia. These have concentrated particularly on the measures of financial performance and project risk used in

practice. Most survey studies deal with capital budgeting decisions in general and relatively few with AMT decisions in particular. However, the surveys of Pike et al. (1989) and Slagmulder et al. (1995) were exceptions and these studies highlighted the importance of non-financial or 'intangible' factors in AMT decision making.

A second strand of research can be traced back to Haynes and Solomon (1962), Hastie (1974) and King (1975). These researchers have gained insights through *field studies of practice*. They point out that much of the capital budgeting literature places great emphasis on the appraisal of investments. However, in practice, investment decisions involve many steps, of which appraisal is only one, and possibly not the most important. These researchers emphasise other steps such as the creation of investment proposals, their progress through the organisation, the interplay of financial and 'strategic' information in the process etc. More recent field studies by Slagmulder and Bruggeman (1992) and Nixon (1995) concentrated on AMT investment decision making. Their conclusions echo those of the earlier field studies, emphasising *all* the stages in the capital budgeting process and the importance of "strategic" (as opposed to purely financial) considerations in AMT decision making.

A third strand of research can be described as 'normative', developing *prescriptions for practice*. Whereas the first two strands are broadly descriptive: identifying practice either through questionnaire surveys or field studies, this strand emphasises the development of theoretical models. This work has a long history, from the development of the return on investment (ROI) measure to the discounted cash flow measures of net present value (NPV) and internal rate of return (IRR). Subsequently, the rapid development of finance theory has seen the relationship between return and risk theorised and empirically tested (see for example: Lumby, 1995; Davis and Pointon, 1994; and Pike and Dobbins, 1986).

During the 1980s a number of researchers focused on the alleged difficulties of justifying AMT investment proposals against the, by then traditional, return-risk theoretical framework. Kaplan and Atkinson (1989) provided a powerful analysis in which they identified excessively high hurdle rates, incorrect base-case forecasts and failure to recognise all the benefits of AMT as deficiencies in traditional appraisal methods when applied to AMT investments. Perhaps in response to Kaplan's (1986) question: 'Must AMT be justified by faith alone?' Several researchers have developed theoretical models which combine both financial and non-financial variables and Slagmulder et al. (1995) note: 'More and more authors are convinced that good investment appraisal requires that strategic and financial considerations be reconciled and integrated'.

The increasingly rich literature supplies many possible theoretical models and suggestions as to how AMT investment decisions 'should' be taken. The particular aim of this research was to test a number of hypotheses and assumptions which are endemic, either implicitly or explicitly, in the existing literature. These are developed in the next section.

2. Development of Hypotheses

In this section a number of hypotheses will be developed that postulate relationships between several investment variables (the dependent variables) and level of AMT investment (the independent variable). Table 1 provides a summary of the dependent variables.

While some authors, (e.g. Primrose and Leonard, 1987 and Park and Son, 1988) suggest that all the costs and benefits of AMT investments should be quantified financially and others (e.g. Medearis et al., 1990 and Elango and Meinhardt, 1994) suggest that strategic considerations might totally over-ride financial ones, the majority (e.g. Meredith and Suresh, 1986; Srinivasan and Millen, 1986; Parsaei and Wilhelm, 1989; O'Brien and Smith, 1993; Accola, 1994; Angelis and Lee, 1996) opt for a combination of financial and strategic considerations in AMT appraisal. Meredith and Hill (1987) suggest a relationship between the appropriateness of traditional financial analysis and strategic analysis in evaluating an investment. They suggest that traditional

financial analysis is most appropriate when evaluating stand-alone systems while strategic analysis becomes most appropriate in evaluating fully integrated systems (see also: Meredith and Suresh, 1986 and Slagmulder et al., 1995).

These considerations lead to the following two hypotheses:

H1: Companies rely more on strategic decision criteria for AMT investments than for non-AMT investments.

H2: Less reliance is placed on financial analysis for AMT investments than for non-AMT investments.

Many authors (e.g. Putrus, 1990; Datta et al., 1992; O'Brien and Smith, 1993; and Accola, 1994) have made various assumptions about the 'intangible' or 'strategic' benefits that are associated with AMT investments. The 'normative literature', especially, is replete with theoretical analyses that include throughput, market share/growth, flexibility, quality, organisational learning, company image, human factors, workforce morale, technology position and other benefits of AMT.

H3: A wide range of intangible benefits become important in the justification of AMT (as opposed to non-AMT) investment.

The use of capital budgeting techniques such as payback (PB), return on investment (ROI), and discounted cash flow (DCF) methods has been a major subject in almost every previous survey. DCF methods have been classified as 'sophisticated' while PB and ROI have been seen as 'unsophisticated' or 'naive' (e.g. Klammer et al., 1991; Pike, 1988; Chen, 1995). Generally, surveys have reported increasingly widespread use of sophisticated, DCF, methods with a preference for internal rate of return (IRR) over net present value (NPV) (Klammer et al., 1991; Pike, 1988 and 1996). However, the payback period method is still the most widely used evaluation technique with virtually all companies using it either as a primary or secondary technique (Lefley, 1994). Previous surveys found a significant relationship between company size and the use of sophisticated investment appraisal methods such as NPV and IRR with the largest companies usually using the most sophisticated method(s) (e.g., Schall et al., 1987; Drury et al., 1993; and Chen, 1995). In the survey reported here, large companies were sampled, so:

H4 : Sophisticated, DCF, methods of investment appraisal are now more important than unsophisticated methods in large companies.

Just as large companies tend to use more sophisticated techniques it might be expected that companies investing in more advanced forms of AMT might employ more sophisticated investment appraisal techniques. Indeed, Woods et al. (1985, p. 42) had expected that '... users (of new technology), by definition, are more advanced in their thinking and therefore more likely to use more modern investment appraisal techniques with their greater sophistication ...'

H5: The sophistication of the financial evaluation technique used increases with the sophistication of the investment project being evaluated: from non-AMT to fully integrated AMT.

In addition to 'financial' and 'strategic' considerations, evaluation of AMT projects, like other investment opportunities, needs to take account of project risk. Two approaches are usually considered: the moment-oriented approach and the dimension-oriented approach (see, for example, Accola et al., 1995; Accola, 1994; Aschenbrenner, 1984; and Schoemaker, 1979). The moment-oriented approach assumes that data are available to identify the multiple possible project outcomes and their related probabilities. In this approach, the riskiness of an investment project may be measured by its standard deviation or variance. The dimension-oriented approach presumes that project risk can be analysed in different dimensions. For example, Accola (1994) suggested: impact on company liquidity; variability of project outcomes; and possibility of massive (ruinous) loss. In recommending a dimension based approach, Accola (1994) argued that risk adjustment of the hurdle rate or payback period to take account of risk was suspect

because this confounded two intrinsically different project characteristics: return and risk. The following hypothesis is set to test the applicability of Accola's suggestion:

H6: Practitioners consider three risk 'dimensions' to be important: impact of the project on company liquidity, variability of project outcomes, and possibility of massive loss.

Moment-oriented approaches to risk measurement are usually classified into two categories (Ho and Pike, 1991; 1992; and Walker and Klammer, 1984). Simple (naive) techniques involve intuitive adjustments to either the cash flows or a parameter in the evaluation model. For example, increasing the discount rate, reducing the required payback, or using conservative cash flow forecasts. Sophisticated techniques, on the other hand, are based on comprehensive evaluation of uncertainties and include probability analysis, simulation, and the capital asset pricing model (CAPM). Where researchers (e.g. Meredith and Suresh, 1986 and Hundy and Hamblin, 1988) have commented on the risk associated with AMT investments, they have assumed that such investments, because of their large outlays, long lives, delayed benefits and possibly unfamiliar technology are more risky than other investments.

H7: More sophisticated treatments of risk are employed in the evaluation of AMT as opposed to non-AMT investments.

Underpinning much of the existing literature is a presumption that traditional, economic/financial investment appraisal measures systematically penalise AMT investment proposals (see, for example, Kaplan, 1986; Kaplan and Atkinson, 1989, ch. 12; Dugdale and Jones, 1995; and Abdel-Kader, 1997). First, traditional, financial, analysis, it is argued, fails to capture many of the 'intangible' benefits which should flow from AMT investment. Second, traditional approaches militate against AMT because of high discount rates and short payback targets which systematically penalise long-term investments.

H8: The same financial criteria are applied to AMT investments as other (non-AMT) investments.

H9: AMT investments are difficult to justify because of failure to recognise all their "strategic" or "intangible" benefits.

The development of hypotheses is summarised in table 2.

3. Research design and data collection

The survey instrument was designed to identify differences between the evaluation of AMT and other types of investment and to investigate any relationship between the sophistication of investments themselves and the sophistication of the technique(s) used to evaluate them. Of particular interest was the impact of qualitative factors on AMT decisions and how practitioners incorporate such intangible factors into their analysis. An attempt was therefore made to identify and investigate all the qualitative factors previously reported in the literature.

Respondents were asked to rate the importance of each technique or criterion on a five-point rating scale. Previous surveys indicate that most companies use more than one technique, so it was logical to gather information about the importance of each technique rather than to categorise or rank them. However, to provide information comparable with previous surveys, respondents were also asked to identify the financial appraisal technique they regarded as most important if the firm used several techniques.

While previous studies have compared practices relating to different project types (replacement, expansion, etc.), no attention has been paid to distinguishing between AMT investments and other types of investment. A particular feature of this survey is the division of responding companies into three groups: those not employing AMT; those using less integrated forms of AMT and those using fully integrated AMT systems. This division facilitated relatively sophisticated statistical analysis. As noted by Chen (1995), most previous surveys have been analysed using only simple descriptive statistics but here, Kruskal-Wallis one-way ANOVA was

used to compare the importance of various techniques and criteria across each group of companies. The Kruskal-Wallis one-way ANOVA is a non-parametric statistical test for repeated measures and three or more mutually independent samples (see, for example, Gibbons, 1993 and Siegel and Castellan, 1988).

The survey was structured so as to identify the extent of AMT investment in the responding firm, the techniques employed to measure financial return and risk when evaluating investment opportunities and the “intangible” variables considered. The grouping of companies according to their commitment to AMT allowed comparative analysis of the return, risk and intangibles dimensions. The survey also sought the opinions of practitioners on the expected benefits of AMT investments and the difficulties they experienced in obtaining approval for AMT investments.

A postal questionnaire was used to collect primary data. This method was chosen in order to access a sufficiently large number of respondents without incurring undue costs. The questionnaire was developed during September 1995 - January 1996 and involved study of the literature and pilot interviews with finance directors of three UK manufacturing companies in order to ensure that the final version was not easily misunderstood and of manageable length.

A sample of 466 UK manufacturing companies were chosen from the ‘FAME’ database (Financial Analysis Made Easy). These companies satisfied two criteria: (1) the first digit of their primary SIC UK industry codes are either ‘3’ or ‘4’¹ so that they operate in the manufacturing sector, and (2) they are large companies so that they are more likely to have invested in AMT. The size of companies was measured by three variables: turnover (a minimum of £30 million for the year ended 1994), fixed assets (a minimum of £30 million for the year ended 1994) and number of employees (a minimum of 100 employees for the year ended 1994). Based on these criteria, questionnaires were mailed to the financial directors of 466 large UK manufacturing companies during the last week of January, 1996 and follow-up telephone calls were made to non-respondents in the last week of February, 1996. By the end of March 138 responses were received, a response rate of 29.6%. Of those received, 36 were returned unanswered because the company policy was not to respond to surveys (20 Companies), the questionnaire was not relevant to the company (8 companies), lack of time (5 companies), or the company was in the middle of a merger (3 companies). So, the net response rate was 23.7% (102 completed questionnaires / 430 potential respondents). Further, three completed questionnaires were judged as not valid to the analysis because the respondents had not participated in investment evaluation processes. Hence, 99 usable completed questionnaires were used in the analysis giving a net usable response rate of 23% (99 / 430). This response rate is comparable with other similar surveys such as those of Lefley (1994) and of Chen (1995) which had response rates of 28.8% and 20% respectively.

Follow-up interviews were carried out during April-June 1996 with nine of the respondents who had experience in AMT decisions making. These interviews enabled the reliability of questionnaire responses to be checked and allowed further investigation of some issues raised by the questionnaire results.

In order to assess the possibility of any sample bias the 99 responding companies were compared with the sample frame of 466 companies. The comparison was based on the two criteria for choosing the original sample, the industry distribution (according to the first digit of

¹ The first digit of ‘3’ includes metal goods, engineering and vehicles industries while the first digit of ‘4’ includes other manufacturing industries

SIC UK primary industry) and the size of the company measured by turnover, fixed assets, and number of employees for the year ending 1994.

The chi-square test of homogeneity indicated a significant difference between the industry distribution of the responding companies and the sample frame ($p = .005$) and a crosstabulation for the industry distribution of both samples suggested that responding companies might be biased towards SIC UK industry code '3'. Two-sample t-tests were conducted on company size measured by turnover, fixed assets and number of employees for the year ended 1994. The results indicated that responding companies were significantly larger than the sample frame in terms of turnover ($p = .007$), but not significantly different in terms of fixed assets ($p = .943$) or number of employees ($p = .981$).

To further investigate the effect of non-response bias, the answers to the main questions in the questionnaire from respondents who replied without the follow-up telephone calls (72 respondents) were compared with the answers from respondents who replied only after the follow-up telephone calls (27 respondents). There was no significant difference between the two groups of answers². Thus, it might be concluded that more respondents would not change the results of the study.

It can be concluded that non-response bias is not likely to be a threat to the conclusions of the study. However, the analysis indicates that the findings are more generalisable to larger rather than smaller companies and to companies with SIC UK primary code '3' rather than '4'.

4. Survey Results and Hypotheses testing

4.1. Classification of responding companies

In order to test the research hypotheses, responding companies were categorised according to their level of AMT investment. Seven types of AMT system are frequently referred to in the literature: CNC, robotics, AMH, FMS, CAD, CAM and CIM and, following Meredith and Suresh (1986), these systems were categorised into three groups according to level of integration. The first level comprised stand-alone systems such as CNC and robotics, the second level comprised linked systems such as CAD, CAM, and AMH, and the third level comprised integrated systems such as FMS and CIM.

Seventy-six companies (77%) had invested in AMT and table 3 shows that most of these had invested in several different AMT applications. The table shows that CAD systems were most prevalent while the relatively lowest percentages were for FMS and CIM. This categorisation permitted the operationalisation of the independent variable in the study, defined as 'degree of AMT investment' and ranging from none through stand-alone to fully integrated systems.

There were no companies in the "stand-alone" AMT group, so the companies were classified into three groups: non-AMT companies, less-integrated companies (those adopting CAD and/or CAM and/or AMH) and fully-integrated companies which have invested in FMS and/or CIM. Table 4 summarises the number and percentage in each group.

4.2. The importance of financial return, intangibles and risk in AMT investment

Most of the hypotheses developed postulate differences between the evaluation of non-AMT and AMT investments. (The exceptions are H4 and H6 that deal with practitioner attitudes to investment appraisal methods and risk measurement in general). In order to test the hypotheses responding companies were asked to rate the importance of 27 different factors/techniques in investment decision making. Responses are summarised in table 5 under four broad headings:

² For example, means differences in the importance of 'payback', 'quality and reliability of outputs' and 'sensitivity analysis' were 0.12 ($p = .883$), 0.10 ($p = .834$) and 0.20 ($p = .318$).

financial appraisal techniques, non-financial criteria, risk analysis techniques and Accola's risk aspects.

In table 5 the mean "score" for each factor/technique is shown separately for each category of respondents: non-AMT, less integrated and fully integrated. This analysis facilitated the use of a non-parametric analysis of variance (the Kruskal-Wallis test) in order to determine whether there were statistically significant differences in the AMT investment behaviour of the three groups of companies. The results of this test are summarised in table 6.

Table 6 shows that there are no significant differences (at the 5% level) among the three groups of companies as regards financial appraisal and risk analysis techniques. However, this is not the case for non-financial criteria. Here there are four criteria: 'quality and reliability of outputs' (p -value = .0006), 'reduced lead-times' (p = .0045), 'obtaining greater manufacturing flexibility' (p = .0140), and 'reduced inventory levels' (p = .0398) which are significant. It can be concluded that the importance of these four non-financial criteria are affected by the level of AMT. All four criteria have higher degrees of importance in fully integrated companies than in less integrated companies while their importance in less integrated companies is greater than in non-AMT companies. There is thus evidence that these four 'strategic' criteria may be major reasons for investing in AMT and hypothesis 1, that companies rely more on strategic decision criteria in evaluating AMT, can be supported³.

The results do not support hypothesis 2: less reliance is placed on financial analysis for AMT investments than for non-AMT investments. While strategic analysis becomes more important for AMT companies this is *not* at the expense of financial analysis. Casual inspection of table 2 suggests that AMT companies see financial analysis as *more* important than do non-AMT companies. However, the Kruskal-Wallis test failed to reveal any significant differences in the behaviour of the three groups of companies and the null hypothesis (no difference between AMT and non-AMT companies) cannot be rejected.

Analysis of non-financial investment criteria (tables 5 and 6) does suggest that these factors become more important in AMT investment and significantly so in four cases: quality and reliability of outputs; greater manufacturing flexibility; reduced lead-times and reduced inventory levels. Additionally two factors: requirements of customers and consistency with corporate strategy were seen as important by all respondents with no significant differences between companies. The remaining factors were not so important, being relatively lowly rated by all respondents with no significant differences between companies. Hypothesis 3 is supported but the number of significant intangible benefits is restricted. Four such benefits were identified in this survey.

Hypothesis 4 relates to investment decision making in general and states: sophisticated, DCF, methods of investment appraisal are now more important than unsophisticated methods in large companies. However, on the basis of the sample of large companies surveyed, this hypothesis cannot be supported. With the exception of discounted payback, all the measures of financial performance were seen as important, with the unsophisticated methods (payback and ROI) rating marginally more important than the sophisticated, DCF, methods.

³ Strictly, a hypothesis cannot be 'proved', it can only be rejected or supported. Here, the hypothesis is that there is a difference in reliance on strategic decision criteria across non-AMT, less integrated and fully integrated AMT companies. The test relates to the null hypothesis- that there is no difference across companies- and this null hypothesis is rejected. By inference the alternate hypothesis is supported.

The results do not support hypothesis 5: the sophistication of the financial evaluation technique used increases with the sophistication of the investment project being evaluated. All the methods of appraisal, with the exception of discounted payback, were considered to be important and there were no significant differences in the behaviour of the three groups of companies. The null hypothesis cannot be rejected and it can be concluded that a “package” of financial return indicators is employed by most companies in appraising investment opportunities - whether investing in AMT or in more conventional projects.

The results are somewhat inconclusive in testing hypothesis 6: that practitioners consider the three risk ‘dimensions’: impact on company liquidity, variability of project outcomes, and possibility of massive loss to be important. Almost as many respondents regarded these issues to be relatively unimportant as thought them important or very important. Analysis of the results by type of company was also uninformative with the less- integrated group of companies rating these issues less important than either the fully integrated or the non-AMT groups of companies.

The results do not support hypothesis 7: that more sophisticated treatments of risk are employed in the evaluation of AMT investments. Only the relatively unsophisticated technique of sensitivity analysis was considered to be really important by any of the respondents and the “AMT companies” were just as reluctant to use sophisticated methods (such as simulation and the capital asset pricing model) as the non-AMT companies. The Kruskal-Wallis test did not reveal any significant differences (at 5% level of significance) in the behaviour of the three groups of companies.

4.3. Further analysis of financial return measures

Respondents who use the payback method as a financial appraisal technique for evaluating investment projects were asked to indicate the required payback period which is most frequently used in their firms. Table 7 shows the percentages of respondents for each group of companies. A period of 3 years or less is most frequently used: 70% of the non-AMT companies, 76% of the less integrated companies, and 83% of the fully integrated companies require payback in 3 years or less.

Respondents who use discounting methods were asked to indicate the range of minimum rates of return or discount rate required by their firms, see table 8. The modal band for non-AMT companies and less integrated companies was in the range 10 - 15% while it was in the range 16 - 20% for fully integrated companies. The results indicate increasing discount rates from non-AMT companies to less integrated companies to fully integrated companies. In non-AMT companies 41% of respondents use a discount rate higher than 15% but the corresponding figures for less integrated and fully integrated companies are 53% and 60% respectively.

The results suggest that the more integrated AMT companies specify more stringent payback periods and hurdle rates. However, chi-square tests failed to reveal any significant difference in the behaviour of the three groups of companies and the null hypothesis (no difference between non-AMT and AMT companies) cannot be rejected.

The survey results appear to support hypothesis 8: the same financial criteria are applied to AMT as to other investments. (In fact visual inspection of tables 7 and 8 even suggests that financial criteria may become *more* stringent from non-AMT to less-integrated to fully-integrated companies.) The typical payback periods in the range 1 - 3 years and discount hurdle rates of 10-16% or even more might be expected to penalise AMT investment proposals.

This evidence therefore appears to support those who argue that AMT investment proposals, with long lives and delayed benefits are penalised by the financial criteria used in their evaluation. However, caution must be exercised in drawing conclusions about hypothesis 8 because respondents were also asked whether they agreed with the following proposition: “It is difficult to get AMT investment proposals approved because of stringent financial criteria”. Only

15% of respondents agreed or strongly agreed with this statement, the vast majority were either neutral or disagreed, see table 9.

The conflicting results mean that hypothesis 8 is neither supported nor rejected.

4.4. Further analysis of the benefits of AMT investment

The practices of companies which invest in AMT were further investigated through a question which aimed to identify which factors they evaluated financially and which non-financially. A list of 21 benefits was provided and respondents were asked to identify whether each benefit was considered financially, non-financially or not at all in the evaluation process. The results are shown in table 10.

These results indicate that eight benefits are almost always considered, either financially or non-financially, in evaluating AMT investments: reduced material costs (100%), reduced scrap and rework costs (100%), improved product quality (100%), reduced labour costs (98%), reduced inventories level (98%), faster response to market needs (97%), improved competitive position (97%), and reduced lead times (96%). Conversely, a significant minority did not consider the following four benefits in the evaluation process at all: obtaining experience of new technology (45%), effects on employee morale (40%), floor space reduction (34%), and reduced after sale costs (32%).

Most firms were willing to quantify seven benefits in financial terms: reduced labour costs (97%), reduced material costs (96%), reduced inventories (92%), reduced scrap and rework costs (89%), increased sales volume (79%), savings from less frequent set-ups (69%), and increased manufacturing capacity (52%).

The benefits which were considered on a non-financial basis by the majority of respondents were: improved product quality (86%), faster response to market needs (86%), consistency with corporate strategy (78%), improved competitive position (77%), greater manufacturing flexibility (75%), reduced lead times (74%), improved company image (71%), easier production scheduling (65%), retention of market share (58%), and increased market share (54%)

The results appear to support hypothesis 9: AMT investments are difficult to justify because of failure to recognise all their strategic or intangible benefits. The responses do indicate that some benefits might be ignored altogether. However, caution should be exercised in drawing conclusions, because these benefits (experience of new technology, employee morale, reduced floor space, reduced after sale costs) are not considered to be particularly important by practitioners (see table 5).

Two further questions were asked in relation to recognition of the benefits of AMT and the possibility of implementing AMT investment on “strategic” grounds only (see table 9).

These results again offer broad support for hypothesis 9. Practitioners confirm that some potential benefits are not taken into account because they are difficult to express in financial terms and they disagree with the proposition that AMT investment might be approved on non-financial grounds alone. Again, however, caution should be exercised in assessing the strength of these views. If some benefits are unimportant it hardly matters that they are ignored, and, just because AMT investment cannot normally be justified on non-financial grounds alone, it does not necessarily follow that AMT is especially difficult to justify.

5. Discussion

The survey indicates that investment projects are affected by three groups of factors: financial return measures, non-financial criteria, and risk measures. This conclusion is based on the perceived importance of at least some of the measures or criteria within each group of factors. For example, the payback period, a financial measure, was judged important or extremely important by 75% of respondents. Eighty seven percent of respondents considered the ‘quality and reliability of outputs’, a non-financial criteria, important or extremely important. ‘Sensitivity

analysis', a risk measure, was considered as important or extremely important by 77% of respondents. The following discussion is structured around these three groups of factors.

5.1. Financial return measures

The evaluation of projected financial return (Hypotheses 2, 4, 5, and 8) remains important. All the measures of financial return are important, with the 'naive' techniques, ROI and payback period, being seen as marginally more important than the sophisticated discounting techniques. This finding is consistent across all three groups of companies (non-AMT, less-integrated, and fully-integrated AMT) so hypothesis 5 that: the sophistication of the project affects the choice of financial technique, is rejected. This finding is consistent with those of Woods et al (1985), Lefley (1994) and Chen (1995).

It would be tempting to conclude that investment evaluation is still undertaken in a relatively naive manner in many companies. However, the continuing importance of payback (see also, Klammer, 1970; Woods et al., 1985; Schall et al., 1987; Pike, 1982, 1988 and 1996; Drury et al., 1993; and Lefley, 1994) and ROI should not be taken out of context. The survey results lead to the rejection of hypothesis 2- that less reliance is placed on economic/financial analysis in justification of AMT investments than for non-AMT investments. In fact, the results indicate that all the measures of financial performance are seen as important, whether evaluating AMT or non-AMT investments. In addition, most respondents disagreed with the proposition that: 'it is possible to implement an AMT investment proposal based only on potential non-financial benefits.' It is clear that financial analysis is important, a range of financial indicators is usually employed and most of these indicators are seen as important (discounted payback period being a possible exception).

While hypothesis 5 concentrated on the choice of *technique* in relation to AMT, hypothesis 8 concentrated on *criteria*. Hypothesis 8, that the same criteria are applied to AMT as to other investments, was supported. A picture of practice emerges where the same financial techniques and financial criteria are applied to all investments whether AMT or not. As other researchers have found, stringent criteria are often applied in practice and this survey supports previous findings with short payback periods and relatively high discount rates being the norm.

It would be logical to conclude that AMT investment proposals are penalised by these practices, supporting Kaplan's (1986) question 'Must AMT be justified by faith alone?' and Lefley's (1994, p. 2758) assertion that: '... the use of [the] PB method of investment appraisal practically guarantees rejection of AMT projects ...'. Lefley continued: '... the payback method, with its 'short' payback period, is inappropriate for projects such as AMT where the capital expenditure is spread over a number of years, and the returns do not fully materialise until well into the life or [of] the project.'

However, care must be exercised in reaching such conclusions because respondents did not generally agree with the proposition: 'It is difficult to get AMT investment proposals approved because of stringent financial criteria.' Traditional techniques are used and stringent financial criteria applied but this does not necessarily mean that AMT proposals are more difficult to approve than other investment proposals. One could speculate about the reasons for this finding. Perhaps, contrary to expectations, AMT investments actually meet the criteria laid down; or financial analysis is seen as a post hoc exercise to confirm an investment decision made on other grounds; or the apparently high return demanded is offset when non-financial factors are taken into account. This issue is considered next.

5.2. Non-financial criteria

Hypotheses 1, 3, and 9 relate to the evaluation of non-financial criteria in AMT investments. Hypothesis 1 postulates increasing use of 'strategic' analysis and hypothesis 3 suggested that a wide range of intangible benefits would be incorporated in such analysis. The first hypothesis was supported and there was restricted support for hypothesis 3.

There was some evidence in support of hypothesis 9: that AMT investment is difficult to justify because of failure to recognise all their intangible or non-financial benefits. Respondents tended to agree that ‘some of the potential benefits of AMT are not taken into account because they are difficult to express in financial terms.’ However, this is not conclusive, because the omission of criteria such as ‘improved company image’, ‘employee morale’ and ‘experience with new technology’ is not significant if such issues are judged unimportant- and many respondents did not consider these ‘benefits’ to be important. It was surprising that ‘employee morale’ was judged unimportant because other researchers (for example, Accola, 1994 and Mensah and Miranti, 1989) have seen this as an important motivation for investing in AMT.

Table 6 suggests that at least eight non-financial criteria (or intangible factors) are considered important in the evaluation process. Further analysis of the importance of intangible factors across the three groups of companies indicated that these factors were seen as more important by fully-integrated companies than by the other two groups (non-AMT and less-integrated companies). The mean scores for almost all the intangible factors were higher for fully-integrated companies than for the other two groups of companies (see table 6) and this supports the view of Meredith and Hill (1987) who argued that the justification of higher levels of automation usually needs more attention to intangible factors relative to economic justification. For four non-financial factors the Kruskal-Wallis one-way ANOVA indicated *significant* differences among the three groups of companies and these factors may be the key ‘drivers’ behind many AMT investments. Additionally, the intangible factor ‘requirements of customers’, is very important in all groups of companies and indicates that firms should pay considerable attention to market research during investment appraisal.

The importance of intangible factors in investment appraisal is confirmed by this survey and specific factors are identified as important by the majority of respondents.

5.3. Risk measures (hypotheses 6 and 7)

The survey results indicate that sensitivity analysis is the most important technique for dealing with investment project risk. This finding is consistent with the findings of Klammer et al. (1991), Pike (1988) and Ho and Pike (1991).

A significant difference⁴ was found in the importance of sensitivity analysis among the three groups of companies. It was less important in both less-integrated and fully-integrated companies than non-AMT companies. This finding is consistent with that of Lefley (1994) who found a reduction in the use of sensitivity analysis in assessing AMT investment project risk.

The widespread use of sensitivity analysis as evidenced by the current survey might be attributed to its simplicity and the availability of computer packages which can help in applying it in practice. Strictly, sensitivity analysis is not a technique of risk analysis at all, it merely describes the sensitivity of key factors through their effect on the profitability of a project. It gives an indication of the most sensitive variables but not their probability of occurrence. A further limitation is the consideration of only one variable at once. (This could be overcome by use of computer based simulation but this technique was considered important by only 11% of respondents). This does not mean the technique is irrelevant but it does mean that it should only be a first step in evaluating risk. Knowing the key sensitive factors, decision makers can then estimate their variability and more sophisticated methods of risk analysis can then be undertaken.

Adjusting the required PB period according to the riskiness of a project was judged either important or extremely important technique by only 40% of the respondents. This may appear

⁴At 8% level of significance

inconsistent with the earlier findings of Lefley (1994) who found 71.5% of respondents used this method. However, Lefley's respondents may use the technique without considering it especially important and, when this is taken into account, the results of the two surveys can easily be reconciled. The low percentage of respondents who consider adjusting the required payback period as an important way of reflecting project risk may seem inconsistent with the high importance given to payback as a financial appraisal technique but this provides evidence that decision makers separate the two issues of financial evaluation and risk assessment.

In this survey, 70% of respondents in the non-AMT companies required payback in 3 years or less while 76% and 83% of respondents in less-integrated and fully-integrated companies respectively required this payback period. If shorter payback is required for higher risk investments, it might be inferred that AMT investments are perceived to be riskier than other investments. A similar inference could be drawn from the finding that higher discount or hurdle rates are employed in both less-integrated and fully-integrated companies than in non-AMT companies. While only 41% of respondents used 16% or more as a hurdle rate in non-AMT companies, 53% and 60% of respondents used the same range in less-integrated and fully-integrated companies respectively.

In general, the survey findings relating to risk analysis did not give a clear idea about how practitioners deal with investment risks. Only sensitivity analysis and the use of conservative cash flow estimates were considered important in dealing with risk by the majority of respondents. The most preferred theoretical methods in evaluating investment risk: probability analysis, CAPM and computer simulation, were judged to be important by very few respondents. Furthermore, when respondents were asked to indicate the importance of the three possible dimensions of risk suggested by Accola (1994) (the impact on company liquidity, the variability of the project outcome, and the possibility of massive loss) only the impact on company liquidity was rated important by over 50% of respondents.

6. Conclusion

A recurrent theme in the AMT literature is the strategic importance of such investments and hence the need for a wider analysis when appraising them. Many researchers have developed theoretical models designed to meet this perceived need by combining both financial and strategic analyses. Such models range from simple combination of multiple attribute scores (e.g. Parsaei and Wilhelm, 1989; Meredith and Suresh, 1986; Nelson, 1986) to the relatively sophisticated analytic hierarchy process (e.g. Wabalickis, 1988; Ghosh and Wabalickis, 1991; Putrus, 1990; Datta et al., 1992; O'Brien and Smith, 1993; Angelis and Lee, 1996) and the use of 'strategic cost management' analysis (e.g., Shank, 1996 and Carr and Tomkins, 1996).

The models in the literature usually either illustrate a particular algorithm (such as the analytic hierarchy process) or a particular theoretical perspective (such as Porter's strategic analysis). Whilst many models do not have clear justifications, there are now a number of themes in the AMT literature and these themes provided a basis for framing the hypotheses tested in this research.

The results suggest that AMT investment decisions in practice do involve increasingly 'strategic' analysis but not at the expense of economic or financial analysis. 'Intangible', 'strategic', benefits such as customer requirements and consistency with corporate strategy are important in investment decision making and four specific intangible benefits: 'quality and reliability of outputs', 'reduced lead-times', 'obtaining greater manufacturing flexibility', and 'reduced inventory levels' are of particular significance in justifying AMT.

Several measures of financial return are considered to be important in practice and most companies employ a 'package' of such measures (typically, payback, return on investment and discounted cash flow measures) when evaluating investment projects. Practitioners appear to make no distinction between AMT and other investments either in the techniques employed or in

the criteria used in decision making. The financial criteria employed seem quite stringent with payback period of less than 3 years and discount/hurdle rate in excess of 10% per annum being common.

It might seem logical to conclude that the difficulties of incorporating intangible benefits and omission of some benefits together with stringent financial criteria would penalise AMT investment proposals. There is evidence that this may be so but caution should be exercised in drawing conclusions because practitioners do not appear to regard, some benefits (such as 'improved company image', 'employee morale' and 'experience with new technology') as important - so their omission may not matter. And practitioners do not perceive gaining approval for AMT investments to be more difficult than other investment proposals.

The findings provide practitioner support for a number of normative proposals in the literature. Models which attempt to combine 'financial' and 'strategic' analyses would be favoured as would the inclusion of several financial measures and certain, specific, 'intangible' benefits. Conversely, models which concentrate solely on financial or strategic analysis would not be favoured and some 'intangible' benefits routinely incorporated in examples in the literature would not normally be regarded as important by practitioners.

The survey suggests that the treatment of risk in practice is relatively naive. Sophisticated techniques of risk analysis are not employed for AMT (or any other) investment project and the only really popular technique is sensitivity analysis. Here a significant difference between companies was found with the technique being rated most important by non-AMT companies!

In general the survey results provide confirmation of work by field researchers such as Nixon (1995) and Slagmulder and Bruggeman (1992). Typically, practitioners adopt holistic approaches incorporating both financial and strategic analyses in the evaluation of AMT investment proposals. There is also support for Shank's 'strategic cost management' (SCM) analysis. Shank (1996) identified three SCM themes which 'should' be considered in AMT appraisal: value chain analysis, cost driver analysis and competitive advantage analysis. These three themes can readily be discerned in practitioners concern with: quality and reliability of outputs and requirements of customers (value chain analysis); greater manufacturing flexibility, reduced lead-times and reduced inventory levels (value chain analysis and cost driver analysis); and keeping up with competition (competitive advantage analysis).

While this survey highlights practitioner concern with financial and strategic analyses it does not necessarily indicate that such analyses are undertaken in a systematic manner. This provides motivation for further research into the development of normative models which practitioners would find acceptable. Multiple attribute, analytic hierarchy process and strategic cost management models hold promise for this line of research.

The survey also suggests that the treatment of risk in practice would be a suitable topic for further research. A series of interviews with nine of the survey respondents was undertaken in order to both confirm the survey findings and to further investigate this topic. These interviews did support the survey findings and, additionally, revealed that practitioners were not so concerned with measuring project risk as with minimising it. The normative recommendations in the literature appear to find little favour with practitioners and the development of models which would be acceptable to practitioners and the (empirical) identification of 'best practice' would also appear to be fruitful area for further research.

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Table 1

Summary of the dependent variables

Importance of financial analysis	Where financial analysis implies the use of techniques such as payback, return on investment and discounted cash flow methods.
Importance of intangible benefits	Typical intangible benefits being: flexibility, delivery performance, improved quality/ reliability, etc.
Sophistication of financial analysis	Where discounted cash flow techniques are seen as more sophisticated than payback and simple return on investment calculations.
Importance of risk analysis	Where risk analysis implies the use of techniques such as sensitivity analysis, discrete probability analysis, simulation, the capital asset pricing model (CAPM) etc.
Sophistication of risk analysis	Where simulation and CAPM are seen as more sophisticated than sensitivity analysis and simple adjustments to payback periods and/or hurdle rates.
Financial criteria	Related to stipulated parameters such as required payback period and/ or hurdle rate.

Table 2

Summary of the hypotheses development

Underlying theme	Relevant literature	Hypotheses
As an investment becomes more integrated and strategic' the balance of analysis 'should' change away from traditional methods towards more 'strategic' evaluation.	Meredith and Suresh (1986), Srinivasan and Millen (1986), Parsaei and Wilhelm (1989), O'Brien and Smith (1993), Accola (1994), Angelis and Lee (1994).	<p>H1: Companies rely more on strategic decision criteria for AMT investments than for non-AMT investments.</p> <p>H2: Less reliance is placed on financial analysis for AMT investments than for non-AMT investments.</p>
AMT investments, typically, generate a range of 'intangible' benefits which are difficult to evaluate using traditional economic/financial analyses.	Putrus (1990), Datta et al. (1992), O'Brien and Smith (1993), Accola (1994).	<p>H3: A wide range of intangible benefits become important in the justification of AMT (as opposed to non-AMT) investment.</p>
'Sophisticated' methods of investment appraisal have become increasingly widespread, especially in large companies.	Klammer et al. (1991), Pike (1988a and 1988b), Chen (1995), Schall et al. (1987), Drury et al. (1993).	<p>H4: Sophisticated, DCF, methods of investment appraisal are now more important than unsophisticated methods in large companies.</p>
More sophisticated users of new technology are likely to employ more sophisticated techniques of evaluation.	Woods et al. (1985).	<p>H5: The sophistication of the financial evaluation technique used increases with the sophistication of the investment project being evaluated: from non-AMT to fully integrated AMT.</p>

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Table 2 (continued)

Underlying these	Relevant literature	hypotheses
Project risk has a number of separate underlying 'dimensions' which 'should' be taken into account.	Accola (1995)	H6: Practitioners consider three risk 'dimensions' to be important: impact of the project on company liquidity, variability of project outcomes, and possibility of massive loss.
The large outlays involved in AMT investment and the delayed benefits from such investments make AMT investments risky and therefore sophisticated risk analysis techniques 'should' be employed in their evaluation.	Ho and Pike (1991 and 1992), Walker and Klammer (1984).	H7: More sophisticated treatments of risk are employed in the evaluation of AMT investment as opposed to non-AMT investments.
Traditional economic/ financial analysis penalise AMT investment proposals through omission of 'intangible' benefits and use of stringent discount rate and payback criteria.	Kaplan (1986), Kaplan and Atkinson (1989), Dugdale and Jones (1995), Abdel-Kader (1997).	H8: The same financial criteria are applied to AMT investments as other (non-AMT) investments. H9: AMT investments are difficult to justify because of failure to recognise all their "strategic" or "intangible" benefits.

Table 3

Types of AMT projects invested in

	No.	%
Computer Aided Design (CAD)	65	86
Computer Numerical Control (CNC)	48	63
Automated Material Handling (AMH)	43	57
Computer Aided Manufacturing (CAM)	42	55
Robotics	33	43
Flexible Manufacturing Systems(FMS)	32	42
Computer Integrated Manufacturing (CIM)	27	36

Table 4

Level of AMT in the company

	No.	%
Non-AMT companies	23	23.2
Less integrated AMT companies	33	33.3
Fully integrated AMT companies	43	43.4

Table 5

A Comparison of Investment Decision Factors for the Three Group of Companies

	Non-AMT		Less integrated		Fully integrated	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Panel A: Financial appraisal techniques						
Return on Investment	4.09	1.11	3.83	1.31	4.17	1.07
Payback	3.73	1.20	4.23	0.77	4.06	0.96
Discounted Payback	3.10	1.34	3.42	1.28	3.31	1.37
Net Present Value	3.50	1.36	3.55	1.27	3.84	1.21
Internal Rate of Return	3.70	1.42	3.78	1.31	4.06	0.94
Panel B: Non-financial investment criteria						
Quality and reliability of outputs	4.17	0.94	4.13	0.87	4.63	0.49
Requirements of customers	4.00	1.07	4.13	0.71	4.40	0.77
Consistency with corporate strategy	4.00	0.95	4.03	0.71	4.36	0.74
Obtaining greater manufacturing flexibility	3.86	1.04	3.97	0.91	4.24	0.97
Reduced lead-times	3.52	0.93	3.93	1.01	4.17	0.85
Keeping up with competition	3.50	0.80	3.78	1.18	4.05	0.94
Reduced inventory levels	3.38	1.12	3.70	0.99	3.78	1.01
The ability to expand in the future	3.30	1.13	3.52	0.85	3.63	1.26
Improved company image	3.14	0.77	2.97	0.93	2.95	1.15
Employee morale	2.91	0.97	2.94	0.85	2.84	0.86
Experience with new technology	2.78	0.80	2.93	1.05	2.72	1.09
Panel C: Risk analysis techniques						
Sensitivity analysis	4.36	0.95	3.71	1.24	4.24	0.89
Use of conservative cash flow forecasts	3.50	1.05	3.27	1.22	3.37	0.96
Adjust required payback period	2.86	1.31	3.35	1.19	3.13	1.31
Adjust required return on investment	2.80	1.20	2.77	1.27	3.03	1.32
Adjust discount rate	2.67	1.06	2.70	1.22	3.00	1.02
Computer simulation	2.05	0.97	1.81	1.03	2.19	0.98
Capital asset pricing model	2.06	1.16	1.50	0.76	2.00	1.27
Probability analysis	2.30	1.22	1.65	0.88	2.19	1.08
Panel D: Accola's risk aspects						
Impact on company liquidity	3.62	1.02	3.17	1.50	3.48	1.19
Variability of project outcome	3.70	1.13	2.65	1.37	3.65	1.05
Possibility of massive loss	3.68	1.29	2.70	1.58	3.07	1.34

Table 6

Results of Kruskal-Wallis One-way ANOVA for Investment Decision Factors

	Mean Rank			Kruskal-Wallis Statistic	D.F.	P-Value
	Non-AMT	Less integrated	Fully integrated			
Panel A: Financial appraisal techniques						
Return on Investment	44.11	39.83	46.16	1.1827	2	.5536
Payback	40.39	50.65	46.75	2.1210	2	.3463
Discounted Payback	37.17	42.38	41.21	0.6614	2	.7184
Net Present Value	40.67	41.17	46.85	1.2582	2	.5331
Internal Rate of Return	39.67	40.20	43.54	0.5006	2	.7786
Panel B: Non-financial investment criteria						
Quality and reliability of outputs	36.82	41.19	59.32	15.0012	2	.0006
Requirements of customers	47.17	44.20	53.65	02.5874	2	.2743
Consistency with corporate strategy	47.55	44.74	50.64	00.9561	2	.6200
Obtaining greater manufacturing flexibility	31.26	44.45	55.17	13.1440	2	.0140
Reduced lead-times	32.33	45.53	54.46	10.8215	2	.0045
Keeping up with competition	53.15	44.87	46.26	01.5043	2	.4713
Reduced inventory levels	35.20	47.73	53.18	06.4487	2	.0398
The ability to expand in the future	42.77	43.89	52.77	03.1020	2	.2120
Improved company image	50.41	45.58	46.24	00.5187	2	.7716
Employee morale	47.68	47.10	44.13	00.3750	2	.8290
Experience with new technology	44.37	47.95	42.94	00.7098	2	.7012

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Table 6 (Continued)

	Mean Rank			Kruskal-Wallis Statistic	D.F.	P-Value
	Non- AMT	Less integrated	Fully integrated			
Panel C: Risk analysis techniques						
Sensitivity analysis	50.39	36.05	46.22	5.1265	2	.0771
Use of conservative cash flow forecasts	41.63	37.00	37.72	0.6135	2	.7358
Adjust required payback period	33.98	41.76	37.94	1.4792	2	.4773
Adjust required return on investment	35.47	33.75	38.07	0.5973	2	.7418
Adjust discount rate	34.40	34.74	39.52	1.0235	2	.5994
Computer simulation	34.29	28.67	36.83	2.3758	2	.3049
Capital asset pricing model	33.67	25.95	32.05	2.5409	2	.2807
Probability analysis	37.60	27.05	36.48	0.1320	2	.1320
Panel D: Accola's risk aspects						
Impact on company liquidity	38.60	33.22	36.35	0.8072	2	.6679
Variability of project outcome	42.88	26.87	41.92	8.6996	2	.0129
Possibility of massive loss	44.68	30.85	35.65	4.8458	2	.0887

Table 7
The Most Frequently Used Payback Period in the Companies

	Non AMT (n = 20)	Less integrated (n = 30)	Fully integrated (n = 39)	All companies (n = 89)
Less than 1 year	-	3	3	2
1 - 3 years	70	73	80	75
4 - 5 years	25	23	15	20
More than 5 years	5	-	3	2

Table 8
The Minimum Required Rates of Return or Discount Rates

	Non AMT (n = 17)	Less integrated (n = 23)	Fully integrated (n = 32)	All companies (n = 72)
Less than 10%	6	17	9	11
10 - 15%	53	30	31	36
16 - 20%	41	22	44	36
21- 25%	-	22	10	11
More than 25%	-	9	6	6

Table 9

Opinions of Respondents Regarding to Three Propositions

	% of respondents					Mean	Std. dev.
	Score 1	Score 2	Score 3	Score 4	Score 5		
a. It is difficult to get AMT investment proposals approved because of stringent financial criteria.	15	34	37	12	3	2.54	0.97
b. Some of the potential benefits of AMT are <u>not</u> taken into account because they are difficult to express in financial terms.	3	22	24	46	5	3.29	0.96
c. It is possible to implement an AMT investment proposal based <u>only</u> on potential non-financial benefits.	41	32	12	12	4	2.07	1.17

Score 1: Strongly disagree, Score 2: Disagree, Score 3: Neutral, Score 4: Agree, Score 5: Strongly agree

Table 10

Benefits of AMT Investments (% of Respondents)

	Considered financially	Considered non-financially	Not considered at all
Reduced labor costs	97	1	2
Reduced material costs	96	4	-
Reduced inventories level	92	6	2
Reduced scrap and rework costs	89	11	-
Increased sales volume	79	8	13
Savings from less frequent set-ups	69	23	8
Increased manufacturing capacity	52	38	10
Improved product quality	14	86	-
Faster response to market needs	11	86	3
Consistency with corporate strategy	10	78	12
Improved competitive position	20	77	3
Greater manufacturing flexibility	17	75	8
Reduced lead times	22	74	4
Improved company image	-	71	29
Easier production scheduling	12	65	23
Retention of market share	22	58	20
Increased market share	28	54	18
Reduced after sale costs such as warranty	41	27	32
Floor space reduction	27	39	34
Effects on employee morale	1	59	40
Obtaining experience of new technology	6	49	45