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Investment in New Manufacturing Systems: An Italian-based empirical analysis

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Abstract

This study reports the findings of a survey investigation into investment decision making practices, especially in relation to investment in advanced manufacturing technologies (AMT), of Italian manufacturing companies.
The results from a large scale questionnaire survey indicate that non-financial/investment criteria are very important in justifying AMT, while little evidence emerge of non-financial criteria for capital investment decision making in non-AMT. Expectations that investments in AMT firms use more sophisticated financial appraisal and risk analysis techniques than non-AMT firms were not supported by the data. The method differs from prior studies because it test three hypotheses considering (fully integrated) CIM firms versus all other firms. Expectations that CIM firms use more investment appraisal sophistication than all others firms were supported by the data. In particular, the data and the interviews confirm that large firms use in percentage more CIM, the justification approaches for CIM tend to use more than all other investments, a combination of sophisticated financial and risk analysis techniques and non-financial investment criteria, especially in relation to strategic benefits such as improved flexibility, quality and capability.

Keywords: Investment decisions theory, Advanced manufacturing technologies (AMT), Computer Integrated Manufacturing (CIM), Justification approaches for Advanced Manufacturing Systems, Survey.

1 – Introduction

This study reports the findings of a survey investigation into investment decision making practices of Italian manufacturing companies. The aim of the researchers, basically motivate by the lack of information in Italy in this topic, was in what way companies justify investment in different levels of advanced manufacturing technologies (AMT) and if the techniques used are different from those used for justify investment in non-AMT. In addition the aim of the research was in the manner in which firms justify investment in fully integrated AMT, especially Computer Integrated Manufacturing (CIM) investment, and whether the methods used are significantly different from those used in justifying the other investments. The interest in the topic is strong because AMT investment is a key element of a new manufacturing strategy. Meredith and Hill (1987) note: "the systems' most important benefits are often strategic and difficult to quantify – so managers face a near-impossible task when they must justify a system on the basis direct return on investment". The literature supplies many theoretical frameworks in the manner in which AMT investment decisions should be taken. For example, some authors have suggested that conventional financial techniques for investment in AMT may have been of secondary importance having established that non-financial criteria are most important in investment decision-making (Butler *et al*., 1991). Slagmulder *et al*. (1995, p.128) suggested that: "Recently, there is a growing awareness in the literature that strategy and finance are intertwined and thus should not lead to conflict. More and more authors are convinced that good investment appraisal requires that strategic and financial considerations be reconciled and integrated". Nixon (1995) pointed out that new technology investment decisions are both highly complex and political. While, Grant, *et al.* (1991) found that the choice of manufacturing technology is contingent upon the firm's strategic goal, resources and business environment.

The particular aim of this study was to test some research questions first considering AMT firms versus non-AMT firms and then considering fully integrated CIM firms versus all other firms. While, the research questions consider the gaps identified in the existing literature, and implicitly signalled the need for the present research, the method differs from prior studies because it test three hypotheses considering CIM firms versus all other firms not previously explored.

The remainder of the paper is organized as follows. Section 2 reviews the existing literature on cur-

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rent understanding of decision making practices in AMT, in order to develop arguments supporting the research questions. Section 3 outlines the research method employed for this study. Section 4 reports the results. The last section concludes and suggests avenues for future research.

2 – Current understandings of investment decision making practice in AMT

Most survey studies has been previously carried out on investment decision making practices in AMT. However, a review of the literature in Europe reveals different research findings, little comparisons between AMT e non-AMT investment appraisal and little investigation on the appropriateness of different justification techniques for level of integration. The following literature provide a summary of the main streams of current understandings of investment decision making practice and the research questions signalled for the current study in Italy.

2.1 – *The quantitative approach: conventional financial appraisal techniques and risk analysis*

In financial theory literature on investment decisions the conventional financial appraisal techniques can be divided into two different theoretical approaches: (1) unsophisticated and (2) sophisticated. The former includes payback [PB] and accounting rate of return [ARR], while the sophisticated financial appraisal techniques (or discounted cash flow analyses) include the following methods: net present value [NPV]; profitability index [PI]; internal rate of return [IRR] and discounted payback period [DPP]. Furthermore, considering the management accounting literature, to these groups we can add: Economic Income (e.g. Lee, 1986); Residual Income (e.g. Tomkins, 1973); and Economic Value Added (e.g. Bennet Stuard, 1991)

As Northcott (1992, p.76) argued, "an integral part of using discounted cash flow analyses to assess CI (capital investment) proposals is the determination of a required rate of return (RRR) .....the RRR should reflect the opportunity cost of committing funds to a CI". Approaches to determining the RRR for discounted cash flow analyses include: (1) the cost of funds approach: WACC; (2) the risk-adjusted return approach: CAPM (and extensions of the CAPM for corporate policy); (3) a pragmatic approach: adjusted required rates of return. Also, risk is an important determinant of an appropriate required rate of return (RRR). In literature there are alternative approaches to assessing risky capital investments (e.g. Brealy and Myers, 1996), which can be categorised into two basic groups: (1) unsophisticated; and (2) sophisticated. The unsophisticated approaches primarily consider: (a) adjusted required payback period; (b) adjusted required accounting rates of return; (c) adjusted discount rate to allow for risk and (d) adjusted forecast cash flows to allow for risk. On the other hand, the more sophisticated approaches to assessing risky capital investments are: (e) probability analysis; (f) sensitivity/scenario analysis; (g) simulation (Montecarlo)[1].

Survey investigation into investment decision making practices in the use of conventional financial and risk analysis techniques, especially in relation to investment in AMT, reveals different results. For example, Abdel-Kader and Dugdale's (1998, p. 274) study of large UK manufacturing firms report that financial directors attributed the highest importance to relatively unsophisticated financial techniques (PB and ARR), while "the results do not support the hypothesis 7: that more sophisticated treatments of risk are employed in the evaluation of AMT investments". Lefley's study (1994) also points out that the most popular method of investment appraisal is the payback [PB] method, whereas Alkaraan and Northcott's (2006, p.159) study of large UK manufacturing companies found that practitioners placed great emphasis on sophisticated financial analysis techniques: "NPV is the most used analysis technique for both strategic and non-strategic projects, while ARR is much less utilised across the board (consistent with Pike (1996) and Arnold and Hatzopoulos (2000)". Further, Alkaraan and Northcott's (2006, p.163) survey results also discovered that: "there is no evidence that more sophisticated methods are supplanting intuitive and simple approaches to analysing strategic project risk".

These results from previous studies present us with a confusing picture concerning the quantitative approach. Furthermore, it can be seen that the quantitative approach, based on traditional financial appraisal techniques and risk analysis, concentrates on quantifiable variables (tangible benefits) with less effort to include the qualitative variables (intangible/strategic benefits) in the decision analysis.

2.2 – *The qualitative approach: Non-financial/investment criteria*

The qualitative approach considers the evaluation methods of investment decisions in AMT that concentrate on the non-financial/investment criteria (or qualitative variables) in the analysis[2]. For example, Meredith and Hill (1987, p. 49) point out that: "Forcing manufacturing managers to justify new manufacturing

[1] The literature on financial analysis techniques include also the Expected Utility Criterion (EUC).

[2] Meredith and Suresh (1986) describe a qualitative analysis (or strategic analysis) through four variables (concepts): technical importance; business objectives; competitive advantage; research and development.

systems solely on the basis of financial formulas is, we feel, a misapplication of these techniques". In management accounting literature the application of conventional financial and risk analysis for evaluating investment alternatives in AMT reveal many flaws even when managers apply sophisticated quantitative approaches. More specifically, Kaplan and Aktinson (1998, p. 594) suggest that: "the flaw occurs when managers: 1. require payback over arbitrary short time periods; 2. use excessively high discount rates; 3. adjust inappropriately for risk; 4. compare new investments with unrealistic status quo alternatives; 5. emphasize incremental rather than global opportunities; 6. fail to recognize all the costs of the new investment; 7. ignore important benefits from the new investment". In literature (e.g. O'Brien and Smith, 1993) there are various assumptions about the strategic (or intangible) benefits that are associated with AMT investments. For Bromwich and Bhimani (1991, p. 45) "the aim is to identify areas where AMT will be beneficial not only in relation to precise short-term incremental cash flows but also in terms of longer-run strategic benefits".

A good approach to the appraisal of AMT (see Adler, 2000), is to use quantitative approaches with a complementary evaluation of contribution to the competitive strategy of the firm based on strategic consideration.

Many authors (e.g. Elango and Meinhart, 1994) have identified a significant number of tangible and intangible (or strategic) benefits from new manufacturing technologies. The tangible benefits, considered financially in relation to precise incremental cash flow, include: (a) reduced labour costs; (b) reduced material costs; (c) reduced rework costs; (d) reduced inventories level; (e) savings from set-up costs; (f) reduced logistic costs; (g) floor space reduction. On the other hand, the strategic (intangible) benefits, which are often considered non-financially and identified in terms of longer-run contributions to the competitive strategy, are evaluate on the basis of non-financial/investment criteria[3]. The most common non-financial/investment criteria in literature are : (a) better service; (b) improved product quality; (c) faster response to markets needs; (d) greater manufacturing flexibility; (e) improved production scheduling; (f) consistency with corporate strategy; (g) improved competitive position; (h) reduced lead times; (i) reduced after-sale costs; (j) better safety at work; (k) better employee learning.

Survey investigation findings on the application of non-financial/investment criteria vary especially in relation to investment in AMT. For example, Lefley's (1994, p. 2772) study in the UK shows that in evaluating AMT projects the management prefers "a basic financial appraisal method, such as PB, possibly linked to some form of qualitative evaluation". In Van Cauwenbergh's *et al.* (1996) study in Belgium the formal financial and risk analysis appears to be limited to strategic investment, and the qualitative process was relevant for decision-making. Again, Abdel-Kader and Dugdale's (1998) survey results revealed the importance of non-financial/investment criteria in evaluating AMT. More specifically, they found that four non-financial criteria became more significant in AMT investment. Moreover, the Alkaraan and Northcott's (2006, p.165) survey findings showed that "non-financial/strategic criteria are of particular significance in strategic investment decision-making".

2.3 – *The integrated approach: Scoring models and the Analytic Hierarchy Process (AHP)*

In literature Scoring models and the Analytic Hierarchy Process (AHP) can be categorised as two groups of the integrated approach. As suggested by (Abdel-Kader, 1997, p.199) "these methods of evaluating investment decisions in AMS (AMT) take into account a wider range of variables, both qualitative and quantitative, in the decision analysis".

Scoring models include three main techniques: (1) the unweighted 0-1 scoring model (e.g. Meredith and Suresh, 1986); (2) the unweighted factor scoring model (e.g. Nelson, 1986; Noble, 1990); and (3) the weighted factor scoring model (e.g. Parsaei and Wilhelm, 1989).

On the other hand, Saaty (1994, p.5) note: "the AHP is based on the innate human ability to use information and experience to estimate relative magnitudes through paired comparisons. These comparisons are used to construct ratio scales on a variety of dimensions both tangible and intangible. Arranging these dimensions in a hierarchic network structure allow a systematic procedure to organize our basic reasoning and intuition by breaking down a problem into its smaller constituent parts". According to Apostolou and Hassel (1993) the AHP technique is useful for decisions with qualitative aspects and many factors simultaneously considered[4].

Since little research studies has been carried out on the topic, we should expect that a survey investigation into the application of scoring models and AHP techniques, especially in relation to investment in AMT, need to be examined. In this study the intent was to examine the integrated approach, however, we shall not investigate the application of the integrated approach in Italy because, as evidenced by interviews with 4 pilot firms, managers focus more on financial

[3] See also O'Brien and Smith (1993).

[4] See also Datta *et al.* (1992) and Accola W.L. (1994).

and risk analysis and non-financial investment criteria than on scoring models and AHP.

2.4 – *The emergent approach: Real options, fuzzy set and value chain analysis*

These methods of evaluating investment decisions in AMT take into account a range of analysis tools. In particular, emergent approach literature refers to three tools: (1) real options analysis; (2) fuzzy set analysis; (3) value chain analysis.

Real option analysis derive from the modern financial option theory (Black and Scholes, 1973; Cox, Ross, Rubinstein, 1979). In comparison to conventional investment appraisal based on a quantitative approach (financial and risk analysis), the real option analysis applies techniques that incorporate the value of flexibility to expand, extend, contract, abandon, or defer a project (e.g. Kester, 1984; Dixit and Pindick, 1994; Trigeorgis, 1999; Copeland, 2001; Copeland and Howe, 2002). There is minimal empirical evidence to show the extent to which real option analysis is applied to strategic investment (MacDougall and Pike, 2003).

Fuzzy set analysis derive from the fuzzy set theory (Zadeh, 1965). As suggested by Abdel-Kader, Dugdale and Taylor (1998, p. 246), "Two approaches have been proposed in the literature that use the concepts of fuzzy set theory for the evaluation of capital investment projects. The first approach is based on the concept of fuzzy number and extends traditional discounted cash flow analysis into fuzzy cash flow analysis (Ward, 1985, 1989; Chiu and Park, 1994) while, the second approach is based on the concept of linguistic variables (Wilhelm and Parsaei, 1988 and 1991)". Empirical research (e.g. Abdel-Kader, Dugdale and Taylor, 1998) indicates that in practice fuzzy set analysis is rarely used.

Value chain analysis stems from the Strategic Cost Management (SCM) framework (Shank, 1996; Shank and Govindarajan, 1992). In comparison to conventional financial analysis, the value chain analysis, as a component of the SCM framework, considers that "the value chain for any firm in any business is the linked set of value-creating activities from raw basic materials through component supplier, to the ultimate end-use product delivered to the customers, and perhaps through recycling to the beginning of a new value chain cycle (Shank and Govindarajan, 1992, p.46)"

While Carr and Tomkins (1996) and Alkaraan and Northcott (2006) examined respectively the application of value chain analysis in UK and West Germany and its use in UK firms, no research on value chain analysis for evaluating investments in AMT exists in Italy. In this study the intent was to examine the emergent approach, however, we shall not explore the application of the emergent approach in Italy because, as evidenced by interviews with 4 pilot firms, the financial directors "believe that the models appear complex and this is a deterrent for its use in practice, especially in relation to real option analysis and fuzzy set analysis"[5].

2.5 – *The research questions*

The previous discussion on current understandings of investment decision making practice, especially in relation to investment in AMT, has showed at least two key issues.

The first key issue reveal that the manner in which companies justifying investment in AMT remain the use of conventional financial appraisal and risk analysis and the financial appraisal have been integrated with non-financial investment criteria. The research reported in this study aimed to investigate this first issue and the research questions addressed, extracted by the gaps identified in extant literature and considering the investment decisions theory, can be categorised as follows:

RQ1. Do AMT firms place more emphasis on non-financial criteria in investment appraisal than non-AMT firms?
RQ2. Do AMT firms tend to use more sophisticated financial appraisal techniques in investment appraisal than non-AMT firms?
RQ3. Do AMT firms tend to use more sophisticated risk analysis techniques in investment appraisal than non-AMT firms?

The second key issue reveal that sophistication of financial and risk analysis and non-financial investment criteria appear to differ for each level of integration, especially in relation to more advanced forms of AMT. In this study the method differ from prior studies especially in looking for the relationships between sophistication of the justification approaches and investment in CIM, as highly integrated manufacturing system.

Abdel-Kader and Dugdale (1998, p. 264) note: "large companies tend to use more sophisticated techniques it might be expected that companies investing in more advanced form of AMT might employ more sophisticated investment appraisal techniques". These considerations implicitly reveal that the level of integration in new manufacturing systems differ, so different justification approaches tend to be most appropriate. The system at level 4 that include all level 3 systems and links the entire manufacturing function is

[5] See, for example, Scapens *et al.* (1996) in relation to the discussion on the gap between management accounting theory and practice.

commonly known as CIM. For Meredith and Hill (1987, p. 57) such a manufacturing system: "allows the new production strategy to became a true competitive weapon in the marketplace. Such extensive integration also, however, typically demands a major change in the way the business is run, including purchasing, finance, marketing, and even top management functions. That is, to utilize the benefits that integration brings requires major organizational changes in the firm. Of course, this involves major risk as well". Since the purpose of investment in CIM is to realize the change in strategy we should expect that the justification process needs to recognise the diverse impact of this change. In particular, we develop explicitly hypotheses on justification approaches, considering only CIM firms versus all other firms. The research questions can be categorised as follows:

RQ4. Do CIM firms tend to place more emphasis on non-financial criteria than all other firms?;
RQ5. Do CIM firms tend to place more emphasis on sophisticated financial appraisal techniques than all other firms?
RQ6. Do CIM firms tend to place more emphasis on sophisticated risk analysis than all other firms?.

3 – Research method

3.1 – *Survey questionnaire*

The research evidence was collected in two ways. First, an interview with 4 pilot firms was conducted in order to test the questionnaire responses and to seek collaboration on their strategic capital investment decision making practices. Second, a survey was conducted using a mailed questionnaire. The survey instrument was designed to identify the differences between the evaluation of AMT and non-AMT projects and to explore the relationship between the sophistication of investments, such as CIM, and the sophistication of the techniques used for the evaluation. Of particular interest was to investigate the qualitative factors, reported in the exiting literature, and their impact into investment decision making practices.

The questionnaire design was adapted from previous surveys investigation (Abdel-Kader and Dugdale, 1998; Alkaraan and Northcott, 2006) and most questions required respondents to assign a score on a five Likert scale.

In designing the study we used the list supplied by the Italian Confederation of Industry (ICI). The sample of 359 manufacturing companies was considered as being representative of the population that operates in the manufacturing sector. The financial directors were selected as respondents because they appear a high level of responsibility in their organization's investment in AMT and the motivations for the implementation.

The questionnaires were sent by e-mail to the financial directors of the 359 firms included in the sample. The respondents were also asked to indicate if they whished to receive a copy of the results; 83% of the respondents indicated that they did.

The sample size dropped from 359 to 308 because 51 questionnaires were returned unanswered. After three reminders, 74 questionnaires had been received, giving a response rate of 24%. The sample companies (308) and the responding companies (74) in each sector are show in table 1.

The possibility of non-response bias was examined by comparing the responding companies (74) to the total companies (308) in relation to the number of firms per sector. The results of the parametric test (Fischer's test) indicate that there is no statistically significant difference between the responding and the total number of companies (P-value=0.2749). A statistical test in terms of turnover and total assets was not obtainable

However, when we consider the sectors, a cross tabulation indicated that the composition of the 74 responding companies differed from the universe of 308 sample companies, in so much as there were proportionally fewer firms in the textile, chemicals and computer science and I.C.T. sectors. In these sectors in particular the results indicated that the responding firms were larger in terms of turnover. The response rate of 24% is a satisfactory figure for survey questionnaires in Italy. However, when our sample is compared with similar studies carried out elsewhere the number of firms is smaller than the average for earlier studies, but our response rate is (almost) at the same average level[6]. In order to establish the turnover range of the large firms, the responding companies were measured according to turnover into three groups[7]. If the turnover was between 25,8 - 515,9 million euro (€), the unit was classified as small-middle sized, a turnover of 516,0 – 2582,2 million euro (€) was regarded as middle-large, while a turnover of more than 2582,2 million euro (€), the unit was classified as large. On the basis of turnover, the typical sample unit was a middle-large, and about 19% of the responding firms were large. Most of the respondents had university degrees (85.1%), mainly in the fields of business administration.

[6] Prior corresponding studies are, for example, Chen (1995) in the USA with a response rate of 20% and Abdel-Kader and Dugdale (1998) with a response rate of 23%. While, in Alkaraan and Northcott's study (2006) in the UK the response rate was of 41,25%.

[7] The classification was adapted from the Central Institute of Statistics.

Table 1 – Sample companies and responding companies by sector.

Sectors	Sample Companies	%	Responding companies	%
Engineering	95	30.9	25	33.8
Car and components	29	9.4	8	10.8
Electrical appliances	8	2.6	6	8.1
Food	20	6.5	6	8.1
Pharmaceutical	16	5.2	6	8.1
Textiles and clothing	24	7.8	5	6.8
Chemicals	38	12.3	4	5.4
Computer science and I.C.T.	19	6.2	4	5.4
Wood and furniture	16	5.2	3	4.0
Eyewear	4	1.3	2	2.7
Other	39	12.6	5	6.8
Companies	N = 308	100.0	74	100.0

3.2 – *Data analysis methodologies*

The types of investment were divided into two categories of firms: (1) non-AMT firms; and (2) AMT firms. The AMT firms, categorised according to their level of integration, included three groups of companies: (1) stand-alone AMT firms; (2) less integrated AMT firms; and (3) fully integrated AMT firms.

For each set of data we performed descriptive analysis with a univariate statistical test (Kruskal-Wallis one-way Anova). In the Kruskal-Wallis (KW) rank sum test the P-value was displayed.

A 5% significance level was used in this study. All the results were carried out on the Stat graphics computer programme (version XV).

4 – Survey findings

4.1 – *Investment in AMT*

Respondents were asked to specify the types of investment in AMT and non-AMT they had launched in the last 10 years.

Analysis of the nature of the investment clearly revealed that the application of AMT is expanding: 81.1% had approved al least one AMT project and 18.9% of the units were non-AMT.

Specifically, 14 non-AMT (18.9%) and 60 AMT companies (81.1%).

Table 2 summarizes the application of AMT in production according to type of new manufacturing systems.

The results showed that most of the units use less integrated systems (CAD, CAM). Almost two thirds of the units apply stand-alone systems, such as CNC and robotics.

While, the application of CIM and FMS appears limited, large firms tend to implement such fully-integrated systems more extensively.

Comparison of the results with those of earlier studies, that must be interpreted with caution because were developed in different time and use different sample sizes and institutional contexts. revealed that no relevant differences could be found with regard to Abdel-Kader and Dugdale's study (1998) in the UK, especially in the case of less integrated systems.

Table 2 – Types of AMT projects invested in

(sample N = 60)	N.	%
Computer Aided Design (CAD)	51	85
Computer Aided Manufacturing (CAM)	44	73
Computer Numerical Control (CNC)	42	70
Robotics	34	56
Automated Guided Vehicle Systems (AGVS)	28	46
Computer Integrated Manufacturing (CIM)	27	45
Flexible Manufacturing Systems (FMS)	26	43
Group Numerical Control (GNC)	25	41

Sections 4.2, 4.3 and 4.4 give: (a) the mean score of the qualitative (non-financial criteria) and quantitative (financial appraisal and risk analysis) approaches used for each categories of the four groups of firms; (b) the KW test results for AMT firms versus non-AMT firms.

Section 4.5, on the other hand, shows the mean score of the qualitative and quantitative approaches and KW test results for CIM firms versus all other firms.

4.2 *The qualitative approach: Non-financial/investment criteria*

In table 3 a five item Likert scale, is used to compare the level of application of the non-financial/investment criteria for the four groups of companies considered. In order to test research question 1 (RQ1), which considers AMT firms versus non-AMT firms, table 3 also summarizes the results of the KW test.

The data suggest that managers favour non-financial/investment criteria when it comes to more strategic projects (AMT).

Specifically, assuming that any P-Value under 5% is significant, table 3 reveals that three non-financial/investment criteria were significant: (1) greater manufacturing flexibility (P-Value = 0.002); (2) consistency with corporate strategy (P-Value = 0.035); and (3) reduced lead times (P-Value = 0.043).

It can be concluded that AMT firms tend to place more emphasis on non-financial criteria in investment appraisal than non-AMT firms. The results corroborate research question 1 (RQ1) regarding the existence of interaction among strategic factors when firms invest in AMT. The implication of our findings indicates a relationship between competitive advantage and more strategic consideration in justifying AMT.

Comparison, with caution for the reasons before identified, of the results in Italy with those of earlier studies reveals that non distinct differences can be found with regards to Abdel-Kader and Dugdale's (1998) study in the UK.

However, in this UK study there are four significant non-financial criteria: (1) quality of reliability of outputs; (2) reduced lead times; (3) greater manufacturing flexibility; and (4) reduced inventory levels.

On the other hand, without carrying out a formal KW test, Alkaraan and Northcott (2006) suggest that the following five non-financial criteria are of particular significance in strategic investment decision-making: (1) requirements of customers; (2) the quality of and reliability of outputs; (3) keeping up with competition; (4) the ability to expand in the future; (5) greater manufacturing flexibility. The study of Pike, Sharp and Price (1989, p. 25) suggested that: "interviews have confirmed that executives from middle management level upwards pay considerably more attention to an investment's fit with corporate strategy than they do to its financial performance".

4.3 – *The quantitative approach: Financial appraisal techniques*

In table 4 the mean score for each financial appraisal technique is show for each category of firms.

This analysis promoted the statement of KW test results considering AMT firms versus non-AMT firms.

Table 4 shows that there are no significant differences (at the 5% level) among the four groups of firms as regards traditional financial appraisal techniques.

Table 3 – A comparison of non-financial/investment criteria for the four groups of firms and results of the Kruskal-Wallis test

Mean Comparison					KW test Results		
	Non-ATM	stand-alone AMT	Less integrated AMT	Fully integrated AMT	chi-squared	d.f.	P-Value
Non-financial/investment criteria:							
Consistency with corporate strategy	4.36	3.83	4.55	4.60	8.601	3	**0.035**
Faster response to market needs	4.14	3.67	4.02	3.20	3.070	3	0.381
Improved competitive position	4.43	4.00	4.59	4.20	3.473	3	0.324
Greater manufacturing flexibility	3.21	3.33	4.41	4.30	14.474	3	**0.002**
Improved manufacturing capability	3.07	2.83	3.89	3.50	6.819	3	0.078
Improved product quality	4.14	3.83	4.39	3.90	1.907	3	0.592
Better employee learning	2.71	2.17	2.84	2.40	2.154	3	0.541
Reduced lead times	3.43	3.50	3.84	2.70	8.136	3	**0.043**
Reduced inventories level	3.36	3.17	3.48	2.40	4.472	3	0.215

Table 4 – A comparison of financial appraisal techniques for the four groups of firms and results of the Kruskal-Wallis test

	Mean Comparison				KW test Results		
	Non-ATM	Stand-alone AMT	Less integrated AMT	Fully Integrated AMT	chi-squared	d.f.	P-Value
Financial appraisal techniques:							
Payback (PB)	3.29	2.33	2.75	2.80	1.146	3	0.766
Discounted Payback (DPB)	2.07	2.83	2.73	1.80	3.241	3	0.356
Return on investment (ARR)	1.50	0.67	1.09	2.00	4.743	3	0.192
Internal rate of return (IRR)	2.14	4.33	2.89	3.10	5.595	3	0.133
Net present value (NPV)	2.14	3.83	2.59	3.90	7.228	3	0.065
Profitability index (PI)	2.00	1.17	2.39	3.10	4.568	3	0.206

The KW test indicates that we were unable to find significant evidence to show that AMT firms tend to use more sophisticated financial analysis than non-AMT firms.

The results in Italy do not corroborate positive response to the research question 2 (RQ2).

Again we can make some comparisons with earlier studies. Alkaraan and Northcott in the UK (2006, p. 159) reveal that "NPV is the most used analysis technique for both strategic and non-strategic projects".

However, when Alkaraan and Northcott used the T test to examine the difference in technique usage for strategic vs. non-strategic investment project, the results "support the view of Abdel-Kader and Dugdale (1998)".

Indeed, Abdel-Kader and Dugdale in the UK (1998, p. 273) note: "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".

Considering only strategic investments in flexible manufacturing technology, the results reported by Slagmulder and Bruggeman (1992, p.13), point out that "although all companies in the sample performed a detailed DCF or pay-back calculation for their investments, the outcome of the financial analysis was not considered to be the key decision criterion in all the cases".

4.4 – *The quantitative approach: Risk analysis techniques*

In table 5 the mean score for each risk analysis technique is given for each category of the four groups of companies: non-AMT; stand-alone AMT; less integrated AMT and fully integrated AMT.

Once more, table 5 summarises the KW test results in order to determine whether there were significant statistical differences in AMT firms versus non-AMT firms.

The data show that there are no significant differences (at the 5% level) among the four groups of firms as regards risk analysis techniques. The results do not corroborate a positive response to research question 3.

Indeed, the KW test results indicates that we were unable to find significant evidence that AMT firms tend to use more sophisticated risk analysis approaches than non-AMT firms.

The results of Abdel-Kader and Dugdale (1998) indicate that the situation in the UK is at least partially similar to that in Italy.

Consistent with Abdel-Kader and Dugdale, the study of Alkaraan and Northcott in UK (2006, p. 162) suggest that " the mean usage score for the more sophisticated risk analysis techniques (probability analysis, computer simulation, beta analysis and sensitivity/scenario analysis) were not significantly different for strategic and non-strategic projects.

This is surprising, since we might expected complex, strategic investment projects to call for greater use of sophisticated risk analysis methods".

So survey results appear to support RQ1: AMT firm place more emphasis on non-financial/investment criteria than non-AMT firms. On the other hand, survey results appear to reject RQ2 and RQ3: AMT firm use more sophisticated financial appraisal and risk analysis techniques than non-AMT firms.

With caution, for the reason before indicate, similar results have been reported by some research studies in Europe (e.g. Slagmulder and Bruggeman, 1992; Abdel-Kader and Dugdale,1998; Alkaraan and Northcott, 2006).

Table 5 A comparison of risk analysis techniques for the four groups of firms and results of the Kruskal-Wallis test

Mean Comparison					KW test Results		
	Non-ATM	**Stand-alone AMT**	**Less integrated AMT**	**Fully integrated AMT**	**chi-squared**	**d.f.**	**P-Value**
Risk analysis techniques:							
Approaches to determining the required rate of return:							
The cost of funds approach	3.21	3.50	2.91	3.00	0.839	3	0.840
The risk-adjusted return approach:							
CAPM	1.79	2.67	1.98	2.00	0.761	3	0.859
The pragmatic approach	1.86	1.50	2.09	2.70	2.544	3	0.467
Approaches to assessing risky capital investments:							
Adjust payback period	3.07	2.50	2.43	2.80	1.201	3	0.753
Adjust return on investment	2.29	0.67	1.11	1.50	7.296	3	0.063
Adjust discount rate	2.21	0.83	1.98	1.70	2.896	3	0.408
Probability analysis	2.21	1.50	1.55	2.10	1.883	3	0.597
Cash flows forecast	2.71	1.83	2.66	2.90	1.168	3	0.761
Sensitivity analysis	1.50	2.50	2.02	2.70	2.271	3	0.518
Simulation (Montecarlo)	0.79	0.33	0.61	1.70	5.455	3	0.141

4.5 – *The qualitative and qualitative approaches in the case of CIM firms versus all other firms*

In order to test research questions 4, 5 and 6, the firms were classified into the following two groups: (1) CIM firms (those adopting only Computer Integrated Manufacturing); (2) all other firms. Table 6 summarizes the results of the T test for the two groups considered.

We have found evidence that firms which have invested in CIM place more emphasis on non-financial criteria (strategic factors) into the investment decision making practices than all other firms.

The data are supported especially as regards the following three non/financial investment criteria: (1) greater manufacturing flexibility (P-Value = 0.050); (2) improved manufacturing capability (P-Value = 0.014): (3) and improved product quality (P-Value = 0.044). A possible explanation is that the strong emphasis on strategic factors (non-financial criteria), as a emergent analysis tool for a more strategic consideration of the business objectives, seem to play a crucial role into the strategic capital investment decision making. The results support RQ4: CIM firms tend to place more emphasis on non-financial/investment criteria than all other firms.

While strategic analysis becomes more important for CIM firms this is not at the expense of sophisticated financial appraisal techniques. Indeed, we have found evidence that CIM firms tend to place more emphasis on sophisticated financial appraisal techniques than all other firms.

The data offer support for the following four techniques: (1) discounted payback (P-Value = 0.006); (2) internal rate of return (P-Value = 0.014); (3) net present value (P-Value = 0.040); and (4) profitability index (0.026). In this study CIM firms are primarily large companies. Abdler-Kader and Luther (2008, p. 7) note: “Organizational size is an important factor that is reported to affect structure and control arrangement. Larger organizations have resources to adopt more sophisticated MAPs (managerial accounting and finance practices) than smaller organizations”. This consideration support our evidence that large firms investing in more advanced forms of AMT use more sophisticated techniques. During the interviews the Finance Director of a large firms commented is preference for sophisticated financial appraisal analysis, for example:

“We believe that sophisticated financial analysis to be the most rigorous capital budgeting techniques for strategic investment appraisal. In particular, the benefits are evaluated, the costs are determined and the time value of money concept is well known and familiar in the organization”.

Table 6 – Results of the KW test for the two considered groups, firms in Italy which have invested in CIM versus all the rest.

Mean Comparison			t-test Results		
	All The rest	CIM	T	d.f.	P-Value
Non-financial/investment criteria:					
Consistency with corporate strategy	4.36	4.63	1.008	72	0.317
Faster response to market needs	3.74	4.19	1.277	72	0.206
Improved competitive position	4.47	4.44	-0.100	72	0.920
Greater manufacturing flexibility	3.89	4.41	1.982	72	**0.050**
Improved manufacturing capability	3.32	4.07	2.528	72	**0.014**
Improved product quality	4.02	4.59	2.054	72	**0.044**
Better employee learning	2.57	2.93	1.103	72	0.274
Reduced lead times	3.45	3.81	0.993	72	0.324
Reduced inventories level	3.11	3.59	1.211	72	0.230
Financial appraisal techniques:					
Payback (PB)	2.94	2.63	-0.712	72	0.479
Discounted payback (DPB)	2.02	3.30	2.830	72	**0.006**
Return on investment (ARR)	1.04	1.63	1.983	72	0.051
Internal rate of return (IRR)	2.49	3.59	2.522	72	**0.014**
Net present value (NPV)	2.43	3.41	2.092	72	**0.040**
Profitability index (PI)	1.96	2.93	2.275	72	**0.026**
Risk analysis techniques					
Approaches to determining the required rate of return:					
The cost of funds approach	2.74	3.52	1.905	72	0.061
The risk-adjusted return approach:					
CAPM	1.51	2.85	3.391	72	**0.001**
The pragmatic approach	2.09	2.07	-0.028	72	0.978
Approaches to assessing risky capital investments:					
Adjust payback period	2.43	2.93	1.127	72	0.263
Adjust return on investment	1.36	1.33	-0.079	72	0.937
Adjust discount rate	1.87	1.93	0.130	72	0.897
Probability analysis	1.66	1.89	0.592	72	0.556
Cash flows forecast	2.38	3.07	1.634	72	0.107
Sensitivity analysis	1.64	2.78	2.643	72	**0.010**
Simulation (Montecarlo)	0.62	1.04	1.692	72	0.095

The results support RQ5: CIM firms tend to place more emphasis on sophisticated financial appraisal techniques than all other firms.

This study, also offer evidence that firms which have invested in CIM tend to place more emphasis on sophisticated risk analysis techniques than all other firms, in determining the required rate of return (RRR) and in assessing risky capital investments. While, the data support the risk-adjusted return approach: CAPM (P-Value = 0.001), as a sophisticated approach to determining the required rate of return, the sensitivity analysis (P-Value = 0.010) emerged as the most widely employed sophisticated technique for assessing risky capital investments. The results is consistent with the previous consideration that large firms investing in more advanced forms of AMT tend to use more sophisticated financial analysis techniques.

During the pilot interviews the finance directors of a large firms commented on their preference for CAPM and sensitivity analysis as sophisticated risk analysis techniques, for example:

"I prefer CAPM and sensitivity analysis, over unsophisticated risk analysis techniques, because it

allows us to determining, more rigorously, the required rate of return and dealing with risk. Indeed, the investment in CIM is the more advanced form of AMT, the risk is substantial, and an intensive and rigorous risk analysis must be conducted before the decision is made".

The results support RQ6: CIM firms tend to place more emphasis on sophisticated risk analysis techniques than all other firms.

Few studies have concentrated solely on the problem of justifying CIM. For example, Slagmulder *et al*. (1995) analyzed the ways in which manufacturing firms go about controlling major investments in new process technologies. However, with regards to the testing of different justification techniques considering only investments in CIM technologies versus the other levels of integration of AMT and investments in non-AMT, as far we know, contradictory results have not been presented in earlier studies.

In conclusion, considering together KW test results and interviews with finance directors, the findings suggest that CIM investment decision making practices, as strategic investment appraisal, do involve non-financial criteria, or strategic analysis, but not at expense of sophisticated financial and risk analysis. Indeed, finance directors of large firms tend to integrate sophisticated financial and risk analysis techniques and strategic consideration of investments with non-financial criteria.

5 – Conclusion

The difficulties of justifying AMT are becoming legendary and research studies do not really converge on some plausible reasons in this topic. The interest in the topic is strong because AMT investment is a key element of a new manufacturing strategy and there is a lack of information concerning the current state of investment decision making practices, for different levels of integration, in Italian manufacturing companies.

The first aim of the researchers was in what way companies justify investment in different levels of advanced manufacturing technologies (AMT) and if the techniques used are different from those used for justify investment in non-AMT.

1. Expectation that AMT firms tend to use more strategic analysis (non-financial criteria) in investment appraisal than non-AMT firms is supported. Basically, the research confirmed the results of some prior study in Europe. However, the comparisons must be interpreted with caution because the various empirical studies were developed in different time and use different sample size and institutional contexts.

2. As regards the application of financial appraisal techniques this research, consistent with Abdel-Kader and Dugdale's (1998) study in the UK, reveal that there is no significant difference between the use of appraisal techniques for analysing AMT and non-AMT investments. The results, despite the differences between the non-AMT and AMT investments, do not support the expectation that AMT firms tend to use more sophisticated financial appraisal analysis than non-AMT firms.

3. As concerns the use of risk analysis techniques, the KW test did non reveal any significant differences in the behaviour of the four groups of firms. Therefore, despite the different characteristics of traditional and new manufacturing systems, the results do not support the expectation that AMT firms tend to use more sophisticated risk analysis techniques than non-AMT firms. The results of this study also appear, in particular, consistent with Alkaraan and Northcott (2006).

The second aim of this study was in the manner in which firms justify investment in CIM (CIM firms) and whether the method used are significantly different from those used in justifying the other investments (all others firms). The method differ from prior studies especially because report the test results into the investment decision making practices of Italian manufacturing companies, especially in relation to investment in CIM technologies versus all other investments in advanced and non-advanced manufacturing technologies.

The findings of the current study, considering CIM firms vs. all the other firms, are summarized in table 7.The second column shows that CIM firms in Italy tend to use more sophisticated methods in evaluating capital investment projects. This suggest that the higher level of technologies, often implemented by large firms, have strategic business objectives and consequentially tend to use more sophisticated investment decision making practices. Furthermore, the interviews with the Finance Directors of 4 pilot companies show that, in comparisons with all other firms, evaluation approaches of investment decisions in CIM firms tend toward a combination of sophisticated financial and risk analysis techniques and non-financial/investment criteria, especially strategic analysis techniques based on business objectives and competitive advantage (such as improved flexibility, quality and capability). By implication, it may be argued that an investment in CIM is considered a strategic investment decision that advocates integrated strategic-financial models. With the caution before identify about comparisons with prior studies, our results do not support the authors that emphasise only the central role of strategic considerations in evaluating an investment in new manufacturing technologies (e.g. Elango and Meinhart, 1994). Conversely, the findings support the authors that propose an integrated approach in order to go beyond the DCF analysis and consider the strategic issues on investments in CIM (e.g. Accola, 1994).

Table 7 Results of the tests for the research questions developed in the survey.

AMT firms versus non-AMT firms	CIM firms versus all other firms
Research Question 1 (RQ1). Do AMT firms place more emphasis on non-financial criteria than non-AMT firms?. **Test result** **Supported:** Especially flexibility, reduced lead times, consistency with corporate strategy.	Research Question 4 (RQ4). Do CIM firms place more emphasis on non-financial criteria than all other firms?. **Test result** **Supported:** Especially flexibility, capability, quality of output (product).
Research Question 2 (RQ2). Do AMT firms use more sophisticated financial appraisal techniques than non-AMT firms? **Test result.** **Rejected**	Research Question 5 (RQ5). Do CIM firms use more sophisticated financial appraisal techniques than non-AMT firms? **Test Result** **Supported:** Especially IRR, NPV and PI.
Research Question 3 (RQ3). Do AMT firms use more sophisticated risk analysis techniques than non-AMT firms? **Test result** **Rejected**	Research Question 6 (RQ5). Do CIM firms use more sophisticated risk analysis techniques than non-AMT firms? **Test result** **Supported:** Especially risk-adjusted return approach (CAPM) and sensitivity analysis.

6 – Area of interest for further academic study

This study has identified some areas of special interest for further academic study: (i) observations based on further interviews with managers and finance directors to enhance the survey findings; (ii) use of the integrated approach (e.g. Score Models and Analytic Hierarchy Process) and the emergent approach (e.g. real options analysis, fuzzy set analysis, value chain analysis) for evaluating AMT capital investment projects; (iii) the impact of different AMT characteristics (such as purpose, benefits, organizational impact and risk) on evaluation approaches; (iv) factors influencing the choice of evaluation approaches in organizations (such as: firm size, firm industry; firm capital structure, firm age, firm governance, firm current/post performance).

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