

Justification of Investment into Advanced Manufacturing Technology

Josef Hynek and Václav Janeček

Abstract—Manufacturing companies worldwide strive hard to stay competitive and efficient utilization of advanced manufacturing technology (AMT) is amongst the key factors in achieving this goal. The problem is that AMT projects are usually expensive and as it is rather difficult to estimate its real impact and various company-wide benefits, it is hard to make the relevant decisions whether invest in such a project. That is why our paper recapitulates commonly used justification approaches and their advantages as well as disadvantages have been summarized here. Thereafter we have concentrated on economic justification approach and we have focused on financial and accounting methods utilized by managers in order to decide about the economic feasibility of AMT projects. Furthermore, we have been concerned about managerial attitudes towards conventional financial methods and the influence of experienced judgment of senior management in respect to the AMT investments was examined too. The results of two surveys carried out in the Czech Republic have been compared with outcomes of two analogical surveys that were realized earlier in the UK and the USA. Whereas some major differences have been found in the various financial methods utilization and the perceived importance of these methods within the relevant decision making processes, we have ascertained that other problems are rather universal and managers of manufacturing companies worldwide have to cope with them.

Keywords—advanced manufacturing technology, project justification, survey results.

I. INTRODUCTION

EFFICIENT utilization of advanced manufacturing technology (AMT) is considered as a very important tool for manufactures worldwide to maintain and strengthen their ability to compete on extremely competitive international markets. It is widely understood that AMT has a great potential to provide the respective companies by many tangible as well as intangible benefits. Reduced labor, reduced cost, improved product quality, higher flexibility and increased throughput are usually amongst the most cited examples of these benefits. On the other hand it is also well known that the adoption of AMT often requires a high level of initial investment, the payback period is usually longer than it

is traditionally required by business enterprises and therefore the investment may initially result in an increase in the cost of manufacturing [1]. Moreover, the level of risk associated with the implementation of the AMT project is in general higher than the risk related to traditional and usually less expensive technology. And it is clear that the level of risk is even higher when the particular company lacks relevant experience concerning AMT projects evaluation and implementation.

The high level of investment in as a rule rather expensive AMT together with indispensable up to very high risk adherent to AMT motivated the interest of researchers as well as practitioners worldwide to study and examine the relevant processes of evaluation of AMT projects. Several approaches for justifying investment in AMT have been proposed and numerous studies were published in order to assess them. In general terms, there are three groups of investment appraisal techniques (see [1], [2], or [3]):

1. The economic approach.
2. The analytic approach.
3. The strategic approach.

The economic justification approach seems to be very natural and straightforward one and perhaps that is why it is so wide-spread in relevant companies worldwide. AMT investment has to be financially sound and viable because such a project competes for limited resources with many other projects. Therefore various financial and accounting justification techniques such as payback period (PP), return on investment (ROI), net present value (NPV), and internal rate of return (IRR) are frequently used by managers in order to assess the economic aspects of the project. However, many researchers argue that these methods support decisions that are sensible when viewed in isolation and they do not always indicate the best action when we take into account the whole organizational context [1]. Furthermore, these methods could be misleading when employing too short payback periods or too high discount rates, neglecting various benefits of the new AMT system or being unable to quantify them properly in financial terms. To overcome the problems inherent in using purely economic appraisal approaches, analytic and strategic appraisal approaches have been promoted.

The analytic justification approaches are predominantly quantitative but more complex than the economic techniques. It is believed that especially when intangible benefits are taken into account, these techniques can be far more appropriate by being more realistic, offering better reflection of reality and taking more factors into consideration [4]. Various scoring

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and ranking models could be used including some traditional optimization techniques as well as risk analysis approaches. It is clear that the transformation process from the decision problem to the particular model involves a great deal of simplification and many important factors could be easily overlooked. Furthermore, models involving various weights of individual factors are rather vulnerable to bias brought along with subjective judgments.

The strategic justification approaches tend to be less technical than economic and analytic methods, but it should be stressed that they are quite often used in combination with them. The main advantage of the strategic approaches is their direct linkage to the goals of the company. Criteria such as meeting the business objectives, comparison with competitors, the retention or attainment of competitive advantage and industry leadership might be utilized as suitable factors for the relevant decision making processes where AMT projects are scrutinized. Of course, it would be unwise to assign too much importance to strategic justification methods and to overlook the economic and tactical impact of the project. That is why the recent studies have promoted hybrid approaches based on suitable combination of economic, analytic and strategic appraisal techniques (see [5]).

It is clear that the relevant decision making processes are quite interesting and complicated at the same time. Taking into account the scale of worldwide investment into AMT we can see that further research in this field is needed and its outcomes might be beneficial and helpful for theory as well as for industrial practice.

II. PROBLEM DEFINITION AND RESEARCH METHODOLOGY

We have already pointed out that the economic justification techniques seem to be very common and widely used in manufacturing companies when the decision about AMT investments should be made. Furthermore, we have indicated that there are some problems inherent to these techniques and some researchers have even claimed that traditional economic justification techniques are inappropriate for evaluating AMT projects [6].

The ongoing research in this field in technologically developed countries stimulated our interest to find out more details about the situation in the Czech Republic. Our country was regarded as one of the top industrial countries worldwide before the World War Two but then its industry was neglected by communist leaders for long decades. The new era started in 1989 after the fall of totalitarian regime and it was clear that our manufacturing companies would have to pass through necessary transformation processes in order to regain their ability to compete on developed and highly competitive markets. Besides the transformation of ownership, economic and structural changes, it was also needed to utilize a great deal of new technology including AMT. And here the obvious question arises whether our new managers and company owners would be able to build on the experience already available in western countries regarding the relevant decision

making processes or whether they would undergo the same process of gaining experience from scratch.

We started our co-operation with the group of researchers that carried out two postal surveys concerned 'the state of art' of AMT projects in the United Kingdom and the United States of America ([7], [8]). Their work motivated our further research in this field and we were extremely interested in comparison with the situation in the Czech Republic. We prepared and conducted the first survey in our country in 1999. We validated our hypothesis that technological competitiveness of our country is not as good as it might be expected. Moreover, based on our research results we claimed that Czech companies were lagging behind their western competitors and there was still a long way towards massive adoption of advanced manufacturing technology. In order to identify the likely changes that happened in Czech manufacturing companies between 1999 and 2005 we decided to repeat the survey in the Czech Republic again in 2005.

Of course, our interest went far behind the simple levels of technology adoption that were achieved in the surveyed countries. We strongly believe that it is important to study the respective processes when the crucial decisions about AMT projects justification resulting into their practical implementation or on the contrary their rejection are made. Being able to comprehend the fundamentals of these processes we might be able to derive appropriate pieces of knowledge that could turn out to be helpful to technology specialists. Based on our earlier papers [9, 10, and 11] we suppose that technology specialists empowered in advance by broader insight of what kind of difficulties to anticipate they should be able to prepare their AMT projects accordingly and to improve their chance to get the management approval for the project financing and its implementation. On the other hand, managers and financial directors of manufacturing companies should be more aware of the drawbacks and limitations of various techniques used in the process of AMT projects evaluation. Providing empirical evidence on the AMT justification processes we wanted to bridge the gap between technology specialists and decision makers in order to help them to work closely together with the aim of the best decisions from the point of view of their company as a whole.

Of course, as we were able to utilize the experience acquired by our predecessors the utmost compatibility with the former surveys carried out in the UK and the USA was of paramount importance to our research. That is why we translated the original English questionnaire (see [12]) into Czech language and we also verified its localization by means of a pilot survey.

The original questionnaire comprised of three sections. Questions in the first part were intended to establish the level of implementation of AMT that had been achieved to date. Three levels of AMT were identified which correspond to the levels of sophistication proposed by [13] and [14]. Level 1 systems cover stand-alone projects e.g. robots, NC machines, CAD etc. Level 2 systems are linked systems e.g. linking together of a number of CNC machines, CAD/CAM etc., and

Level 3 systems are fully integrated systems including computer integrated manufacturing (CIM) and flexible manufacturing systems (FMS).

In part number two of the survey the respondents were asked which techniques and criteria were used in capital project appraisal and what methods, if any, were used to measure and take into account project risk. Information was obtained about the measures used to assess the performance of senior executives as it appears that management in general is reluctant to make long-term risky investments (such as those in AMT) and prefers to invest in short-term projects that show early profits and low risk [7].

The third part of the survey was designed to explore opinions about the need for AMT investment, the efficacy of the investment criteria used and the extent to which other factors and considerations had a bearing on capital investment decisions.

We decided to subjoin one additional section to the questionnaire that was used in the Czech Republic in 2005. The annex was devoted to the utilization of EVA (economic value added) indicator in the surveyed companies as there were some suggestions that there might be a relationship between utilization of this concept and investment behavior of manufacturing companies.

In order to assure a straightforward comparison of collected data in concerned countries we carefully followed the methodology used by our predecessors. The survey was aimed at those companies who, it was believed, would have had some experience in the appraisal of AMT projects and that the person who was asked to complete the questionnaire should have had a significant contribution to make in final investment decision. A number of databases were reviewed (with the main stress on data acquired from EDB and Czech business register) to identify the largest manufacturing companies. As we wanted to restrict the survey to 'large' Czech manufacturing organizations, we finally chose sample size of 416 firms in 1999. Within our last survey we have decided to include also the middle sized Czech manufacturing firms and so we have increased the sample to 1030 in 2005.

Our first postal survey started at the end of 1998 and of the 416 questionnaires sent out 92 was returned giving a response rate of 22.12 %. A usable sample of 79 completed questionnaires with a response rate of 19.0 % was considered to be reasonable under the existing circumstances.

The second postal survey has been conducted from January till April 2005 and 1030 questionnaires were sent out and 135 returned, 3 of them were unusable. We can see that the rate of response is 12.8 % only which is significantly lower rate than the one we achieved in 1999. The reason that we did not reach comparable numbers with our former survey could be explained by the fact that in our current survey the middle sized firms were addressed as well.

The main focus of this paper is on economic justification of AMT projects and that is why we will present and discuss selected outcomes of the first part of the questionnaire in the next section only. We hope that these findings could be useful

for management of manufacturing companies and that it could stimulate further discussion regarding their perception of AMT projects and the tools commonly used for their evaluation. The complete results of both surveys concerning advanced manufacturing technology adoption and utilization in the Czech Republic were comprehensively described in [15].

III. SURVEY RESULTS

At the beginning it is necessary to mention that the outcomes of our survey demonstrated that the level of AMT evaluation as well as its utilization in the Czech Republic is lower than the levels observed earlier in the UK and the USA. Furthermore, we have indicated that the process of AMT adoption might be influenced by management attitudes towards technology investment in general. Of course, there are some significant differences between attitudes of managers working under conditions of transforming Central European economy on one hand and the attitudes of managers representing two of the most developed countries in the world. It is interesting that despite of many variations we have found several issues that those two groups of managers have in common [16].

First and foremost, it is a widely accepted opinion that Anglo-American managers tend to promote projects which give short term results in the interest of their own career development. They usually stay in one job for a short period of time and this influences them to favor short-term projects. It was interesting to reveal the same level of "short-termist" behavior amongst Czech managers although the motives for this kind of behavior are diverse. It would be too easy to blame anticipated lack of investment funds for such a behavior only and it is assumed that short-termist orientation of Czech managers relates strongly to the transition and the current state of the art of Czech economy in general.

Subsequently, if such a behavior is perceived as natural by majority of managers there are many ways how to influence the justification and decision making processes in order to achieve the desirable outcome. Above all, it is very easy to reject any project when using an inappropriate method.

Being more specific, it is obvious that AMT projects tend to be long-term and rather expensive projects. From table number 1 we can see, for example, that more than 60 % of Czech and British managers employ the simple non-discounted cash flow payback period (non-DCF PP) as the criterion to decide whether to finance such a project or not (the data describing the situation in the UK and the USA were obtained from [8], [17], and [18]). The chance of getting financed for such a project is easily predictable then because the payback criterion indisputably prefers short term projects. Indeed, many argue that the use of the payback method virtually guarantees the rejection of projects such as AMT, which involve the introduction of capital intensive technologies that tend to be slow to generating positive net cash flows [18].

It is interesting that regarding the Czech Republic, the discounted PP was found to be the most popular and important method in 1999 and in 2005 too (used by 71.6 % and 76.6 %) closely followed by the non-discounted PP (used by 63.5 % and 62.1 % respectively). British managers preferred the non-discounted payback period (68.5 %) and the IRR took the second place there (used by 55.2 %). And as far as the USA were concerned, the discounted PP was seen to be the most popular method (used by 65 %) followed by the internal rate of return (56.4 %).

Anticipating that many companies would use more than one criterion we have also made inquiries regarding the number of financial appraisal criteria being used and their importance. The respective responses are summarized in tables 2 and 3. It should be noted that percentages given in table 3 add up to more than 100 % because some respondents gave equal first ranking to more than one technique.

Table I. Financial appraisal criteria

Financial appraisal criteria used	UK [%]	US [%]	CZ 1999 [%]	CZ 2005 [%]
IRR/yield	55.2	56.4	31.1	35.5
NPV	52.4	41.0	45.9	38.7
DCF Payback	53.8	65.0	71.6	76.6
Other DCF	4.9	3.4	5.4	10.5
non-DCF	68.5	39.3	63.5	62.1
ARR ^k	20.3	18.8	35.1	23.4
Other non-DCF	4.9	5.1	1.4	2.4

Table II. Number of Different Financial Appraisal Methods Used

Number of methods used	UK [%]	US [%]	CZ 1999 [%]	CZ 2005 [%]
1	17.5	23.1	23.0	22.6
2	29.4	34.2	32.4	33.1
3	32.9	34.2	20.3	25.0
4 or more	20.3	8.5	24.3	19.3

It is a positive ascertainment that overall three out of four financial directors in all three concerned countries use more than one financial criterion when assessing an AMT project proposal. More than 40% of companies (UK 53.2 %, USA 42.7 %, CR 44.6 % in 1999 and 44.3 % in 2005) use more than three financial appraisal methods in the evaluation of AMT projects, which suggests that no one method gives sufficient financial information to justify such an investment.

On the other side, we have found that there are some important differences regarding the importance given to individual criterion there. We can see, for example, that the above mentioned and criticized non-discounted cash flow payback period (non-DCF PP) has been ranked as the most important one in the Czech Republic (43.2 % in 1999 and even 62.1 % in 2005) and in the United Kingdom too (38.5 %). On the contrary, American managers tend to use more sophisticated methods that make allowance for the time value of money and that is why DCF Payback (ranked first by 33.3 % of managers) was closely followed by internal rate of return (IRR) that was preferred by 28.2 % of US managers. From this point of view it is rather interesting, that IRR is rather popular amongst British managers too (28.0 %), whereas only 5.4 % of Czech managers in 1999 and 9.7 % in 2005 marked it as the most important criterion.

Table III. Percentage of Companies Ranking Criteria First

Financial appraisal criteria used	UK [%]	US [%]	CZ 1999 [%]	CZ 2005 [%]
IRR/yield	28.0	28.2	5.4	9.7
NPV	20.3	13.7	28.4	17.7
DCF Payback	28.0	33.3	51.4	58.1
Other DCF	3.4	2.7	1.8	4.0
non-DCF	38.5	26.5	43.2	62.1
ARR ^k	11.2	3.4	13.5	8.9
Other non-DCF	3.5	4.3	0.0	1.6

One or both of the DCF methods - IRR and NPV were used by 67.5 % of USA companies and 69.9 % of UK companies but only 48.1 % of CR companies in 1999 and 48.4 % in 2005. It is clear that Czech manufacturing companies seems to be less sophisticated in their approach to AMT investment appraisals, with less than 50 % using one of the above mentioned DCF methods. Moreover, no change has been noticed between two surveys carried out there.

Some researchers as well as practitioners would argue against the use of the IRR in favor of the NPV, but despite this the IRR continues to be the most popular and important DCF method used by USA (used by 56.4 % and ranked first by 28.2 %), and UK (used by 55.2 % and ranked first by 28 %) manufacturing companies. Czech manufacturing companies, however, support the opposite and less common approach by adopting the NPV in preference to the IRR (NPV used by 45.9 % and ranked first by 28.4 % in 1999 and used by 38.7 % and ranked first by 17.7 % only in 2005).

It was anticipated that conventional criteria are still widely used and therefore the respondents were asked to indicate, based on their own experience and judgment, whether or not they agreed with the statement that, "conventional appraisal methods such as Payback, NPV and IRR favored short term

projects". We can see at table number 4 that more than 70 % of companies in the UK and USA agreed with the statement, whilst significantly fewer in the CZ (55.6 % in 1999 and 53.2 % in 2005) were of the same opinion. We can see that there is no significant change in the relatively lower proportion of Czech managers who thought conventional techniques favor short term investments. This is interesting, in that the Czech view seems to support the earlier views of Lefley and Sarkis [8] that conventional financial appraisal methods do not favor short-term projects and, possibly, that it is only when short payback periods and high discount rates are used that a short-term bias can occur.

On the other hand, taking into account that more than fifty percent of respondents in all three countries expressed their agreement with the statement, we can see that there might be some space for exploitation of non-financial criteria and rather strategically oriented criteria in order to compensate the influence of conventional techniques. Some researchers believe that there is too much importance attached to conventional techniques and that is why the respondents were asked to express, based on their own experience and judgment, whether or not they agreed with the statement that, "too much importance is attached to conventional techniques". Their responses are presented in table 5 and it is evident that there are no significant differences there.

Table IV. Conventional Techniques Favor Short-term Investment

Statement: "Conventional techniques favour short term projects"	UK [%]	US [%]	CZ 1999 [%]	CZ 2005 [%]
Agree	73.2	71.4	55.6	53.2
Disagree	26.8	28.6	44.4	46.8

Table V. Too Much Importance is Attached to Conventional Techniques

Statement: "Too much importance is attached to conventional techniques"	UK [%]	US [%]	CZ 1999 [%]	CZ 2005 [%]
Agree	42.3	48.7	51.4	44.4
Disagree	57.7	51.3	48.6	55.6

There were certain concerns that in some companies the role of senior executives might be a rather dominant one and thus using their formal as well as informal authority these executives could influence the relevant decisions related to AMT investment in both directions. In order to assess this issue the respondents were asked to express their level of agreement with the statement that more importance is attached to the experienced judgment of senior management than to

financial indicators. The results are shown in table 6 and we can see that six out of ten American managers agreed with the statement while slightly over fifty percent of Czech respondents did so in 1999 and their number declined further in 2005. Nevertheless, it should be stressed that the number of managers who agreed with the statement is relatively high overall and it is clear the concerns expressed by some researchers as well as practitioners seems to be legitimate.

Table VI. More Importance is Attached to the Experienced Judgment of Senior Management than to Financial Indicators

Statement: "More importance is attached to the experienced judgement of sen. management than to fin. indicators"	UK [%]	US [%]	CZ 1999 [%]	CZ 2005 [%]
Agree	54.5	60.3	51.9	45.7
Disagree	45.5	39.7	48.1	54.3

It was also observed and described in [16] that a rather high proportion of companies in all three countries (more than four out of five companies overall) referred back for re-appraisal those proposals that had failed the initial financial appraisal (see table 7 for detailed results). It is necessary to say, however, that the impact of introduction of a referral process into the investment justification procedure is very difficult to assess. On one hand, it creates an opportunity for better examination of all the background assumptions as well as data collected. Moreover, taking into account the repeatedly confessed inability of managers to assess various benefits of advanced manufacturing technology in general and expressing these benefits in financial terms in particular (see, for example, [15], [16], or [18]), here comes the chance to co-operate more closely with technology specialist in order to overcome these difficulties and to prepare a sound project proposal.

On the other hand, it is rather easy to realize that the introduction of a referral process into the investment justification procedure can allow managers to adjust the figures and possibly manipulate the accept/reject outcome. If this is the case, then the formal appraisal procedure may be seen as a ritual with the actual decision being based on other influences, which may be of a political, rather than an economic nature.

Of course, we could recall here the above discussed short-termist orientation of managers that has been observed in all three surveyed countries and to pose a question to which extent it plays an important role in this phase of the project justification. Secondly, it is necessary to say that we have seen a clear trend in all three countries indicating that at the beginning many projects were assessed on a higher technological level (for example, as a fully integrated system)

but then a less sophisticated system has been deployed (for example, linked systems or even standalone machines). This phenomenon might be closely related to the widespread re-evaluation of AMT project proposals and we can easily imagine the situation when the project with more sophisticated technology does not meet the financial criteria and that is why it is necessary to reduce its initial cost by narrowing its scope as well as the level of technology being proposed. Such a compromise decision could help the technology sponsors to push the project through the approval procedure and at the same time it could help managers to keep the cost of the project as well as the risk associated with new technology within reasonable margins. However, it is hard to say whether such a change is the best one from the strategic point of view.

Table VII. Percentage of Proposals Re-appraised

Project proposals re-evaluated	UK [%]	US [%]	CZ 1999 [%]	CZ 2005 [%]
Agree	84.2	80.3	89.2	81.5
Disagree	15.8	19.7	10.8	18.5

The application of various financial criteria, the number of criteria employed, as well as the percentage of proposals being re-appraised might be closely related to the level of the appropriate decision support software tools utilization. Therefore, companies were also asked if spreadsheet packages, dedicated software or other computer aids were used in the process of evaluating advanced manufacturing technology investment proposals. The results confirmed that majority of companies use spreadsheet software whereas the use of dedicated computer software was less common (see [16] for details).

IV. CONCLUSION

The aim of this paper was to point out some typical problems related to the economic justification of AMT. First of all, we put the economic justification into context of other commonly used approaches and then we have concentrated on selected problems of economic justification of AMT and these problems were illustrated by the relevant results of four AMT surveys focused on the specific issues of advanced manufacturing technology adoption and utilization that were conducted in three different countries.

We have shown some pieces of empirical evidence that AMT projects might be easily knowingly as well as unknowingly disadvantaged because of short-termist behavior of managers as well as unsuitable selection criteria utilization. Based on our results and comparison with the findings of former surveys carried out in the United Kingdom and the United States of America it is clear that managers exploit

rather unsuitable financial criteria and too much importance is given to the simplest methods such as payback period that clearly prioritize short-term outcomes and thus short-term projects. British and American managers seems to be more aware of this fact and perhaps it is the reason why they tend to utilize more sophisticated criteria than managers in the Czech Republic do.

On the other hand it has been proved that only less than one in four surveyed companies use a single financial criterion when assessing an AMT project proposal. More than 40 % of companies in all three countries utilize more than three financial appraisal methods in the evaluation of AMT projects and therefore it might be assumed that inappropriateness of one criterion might be partly balanced by the use of the other methods. Of course, this assumption holds only when the combination of different methods is well-balanced including the right level of importance being attached to these methods.

It was demonstrated that significantly higher percentage of Czech managers than British or USA managers rank the payback method as being the most important in the appraisal of AMT projects. The payback method by definition is a short-term financial measure and its use militates against investments in AMT, for which a longer term and more strategic outlook is needed. There is therefore some concern over the greater importance attached to the payback criteria in the Czech Republic compared with the UK and USA.

We have also discussed the management perception of conventional financial methods in relation to the AMT investment projects in particular, the importance of these methods as well as the degree of influence of experienced judgment of senior management in this respect. We have demonstrated that more than four fifths of the projects in all three surveyed countries are re-evaluated after the initial proposals failed to meet the relevant financial criteria. It seems to be a very common situation in most of the companies and that is why the corresponding pros and cons were outlined here too.

It is necessary to stress, that economic justification of investment into advanced manufacturing technology is one of the three commonly used approaches and that is why its importance should not be overestimated. We would strongly support the view that if the economic approach is used, the strategic and analytical implications should also be taken into account and utilized in combination with it for a better understanding of the impact of the project.

We believe that the results from this research are very important not only for the Czech economy but also for any country that is struggling with economic transition. Economic growth cannot be measured only in measures emphasizing short-term performance and a more long-term view of the future is also needed. Moreover, we have to bear in our mind that the present advantage of relatively low labor cost will disappear in years to come. In this respect, the adoption of advanced manufacturing technology could give us a chance to produce more sophisticated products with higher added value,

so that we can compete in the markets of the economically developed countries.

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