INCORPORATING HUMAN FACTORS INTO THE AMT SELECTION: A FRAMEWORK AND A PROCESS

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"Research is formalized curiosity. It is poking and prying with a purpose"

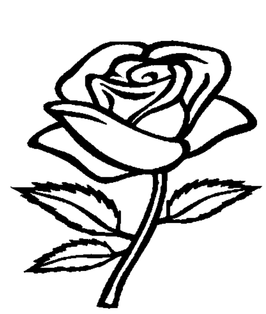
(Zora Neale Hurston)

For my mom Sueli

Whose love and kindness know no boundaries. Source of my perseverance and object of my eternal love and gratitude.

Para minha mãe Sueli

Cujo amor e bondade não conhecem limites. Fonte da minha perseverança e objeto do meu eterno amor e gratidão.



ABSTRACT

This thesis is concerned with the assessment of human factors relevant to the selection of AMT (Advanced Manufacturing Technologies). Human factors such as employee morale, labour flexibility and workers skills should be evaluated during the pre-installation planning, since they greatly influence the implementation outcome. For newly industrialised countries, in particular, incorporating human factors into the selection seems paramount. These economies are in the critical early stages of AMT adoption. Selection practices are often incompatible with the complexity of these technologies. Moreover, low rates of secondary education, scarcity of technicians, and problems with workforce flexibility reinforce the importance of assessing human factors before the actual technology installation. Although some methods have been proposed to evaluate intangible aspects such as the human factors, the lack of a structured approach to identify and quantify these items still constitutes a major obstacle. Furthermore, this approach should be easy to use and establish a common measure for the comparison of options. It should involve key stakeholders and seek consensus on the decision. Aiming to address this gap, the research was undertaken in three phases: theory building, refinement and testing. A preliminary framework was devised from the review of literature, interviews with experts, and a pilot case study. A process was developed to operationalise the framework. The approach was applied using action research in nine case studies in Brazil: a pilot case study in the theory building phase, four cases for refinement, and four firms constituted the final testing. Three main categories of human factors were proposed: labour flexibility, individual capabilities, and employee relations. Grouping these items was crucial to create a definition for these factors and facilitate their identification. Taguchi's Loss Function was used as evaluation method for the human factors and available AMT. The strategies developed for identification and evaluation represented an important theoretical contribution. The in-company applications corresponded to the main practical contribution of the research. Very positive feedback was obtained on the appropriateness of the approach to address identification and quantification issues.

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LIST OF ABBREVIATIONS

ABC	Activity-Based Costing
AHP	Analytical Hierarchy Process
AMT	Advanced Manufacturing Technologies
AR	Action Research
ARR	Accounting Rate of Return
AS/RS	Automated Storage/Retrieval System
CAD	Computer-Assisted Design
CAE	Computer Aided Engineering
CAM	Computer-Assisted Manufacturing
CAPP	Computer Aided Process Planning
CIM	Computer Integrated Manufacturing
CNC	Computer Numerical Control
FMS	Flexible Manufacturing Systems
GT	Group Technology
HFE	Human Factors Engineering
HRM	Human Resource Management
IBGE	Brazilian Institute of Geography and Statistics
IM	Integrated Manufacturing
IPL	Integrated Planning Model
IRR	Internal Rate of Return
IT	Information Technologies

JIT	Just-In-Time
MAPI	Machinery and Allied Products Institute
MRP II	Manufacturing Resources Planning
NC	Numerical Control
NIC	Newly Industrialised Country
NPV	Net Present Value
OM	Operations Management
PB	PayBack Period
ROI	Return On Investment
SP - NPV	State-Price - Net Present Value
TLF	Taguchi's Loss Function (s)
TQM	Total Quality Management
VW	Volkswagen
WH	Workshop
WS	Worksheet

CHAPTER 1

INTRODUCTION

Chapter 1 introduces the background to the study and defines the research focus. The research objectives and the proposed contributions are presented and described. Finally, the structure of the thesis is explained and represented.

1.1 BACKGROUND

The adoption of Advanced Manufacturing Technologies (AMT[1]) has been driven by global competition. "Shortening product life cycles, increasingly sophisticated consumers, increasing labour costs and volatility in input prices has created an environment where manufacturers must be flexible, adaptive, responsive and innovative (Sohal *et al.*, 1999, p. 310)". In this context, the AMT have played a major role in terms of a necessary adjustment to changes in the competition arena of manufacturing products (Dimnik and Johnston, 1993; Boyer *et al.*, 1997; Small, 1998). These resources are broadly defined as equipments or apparatus, numerical or computational to support manufacturing tasks (Small and Chen, 1995). Technologies such as the Computer-Assisted Design (CAD), the Computer-Assisted Manufacturing (CAM), the Computer Numerical Control (CNC) and the Flexible Manufacturing Systems (FMS) have become important instruments for the development of the manufacturing strategy and the achievement of a firm's objectives. Their impact can be verified throughout organisational functions; and may represent a full integration as in the implementation[2] of the Computer Integrated Manufacturing (CIM). In fact, AMT have been classified by literature according to level of integration (Figure 1.1).

Level 1 **Stand-alone**	**Level 2** **Cells**	**Level 3** **Linked Islands**	**Level 4** **Full Integration**
NC Machine Tools Robot	GT FMS CAE	MRPII CAD/CAM AS/RS GT/CAPP	CIM

Source: Adapted from Meredith and Hill (1987)

Figure 1.1 - AMT classified by level of integration

[1] Advanced Manufacturing Technologies are broadly defined in the scope of the thesis. However, the present definition does not include the so-called 'managerial technologies' such as JIT (Just-In-Time) and TQM (Total Quality Management) or address the combination of those designated as IM (Integrated Manufacturing) as reported by Sargent and Matthews (1997). Those 'best practices' are excluded from the scope of the study due to the fact that they do not encompass equipments *per se*. The thesis will use AMT solely as the acronym to represent the Advanced Manufacturing Technologies. For a comprehensive classification of those manufacturing technologies, refer to Appendix A.

[2] The terms adoption, installation and implementation related to AMT are used interchangeably in the thesis content. Similarly, the term technology and AMT are used as synonyms. These definitions are supported by references from literature (Voss, 1988; Chen and Small, 1994; Small and Yasin, 1997b).

The AMT are used to improve competitiveness through the benefits and capabilities they help to build such as improvement of the ability to respond to product, mix and volume changes, increased conformity and product consistency, and increased manufacturing throughput ability (Saleh, Hacker and Randhawa, 2001). Companies in developed and emergent markets[3] have turned to these technologies to obtain the benefits associated with their adoption (Noori, 1997; Marri, Irani and Gunasekaran, 2007; Singh and Khamba, 2009). In the United States, General Electric modernized its locomotive plant by installing a FMS, reducing the machining time from 16 days to 16 hours. The MAZAK factory in Kentucky used the same technology to produce 180 different parts with only two operators; the delivery lead time on machine tools was reduced from six to one month (Chen and Small, 1996). In the developing world, countries such as India have adopted AMT extensively (Narain, Yadav and Antony, 2004). Reportedly, productivity increased 46%, output 43% and machine utilisation increased by 45% while processing times were reduced by 42% and rework by 45% in Indian companies that implemented AMT (Narain and Yadav, 1997). Advanced manufacturing technologies change the structure of industrial costs by improving flexibility without sacrificing productivity (Beaumont, Schroder and Sohal, 2002).

Despite the benefits provided by technology adoption, empirical studies show that 50% to 75% of AMT initiatives in the U.S., for example, fail or do not achieve the expected benefits (Jaikumar, 1986; Saraph and Sebastian, 1992). And the lack of attention towards human issues in the AMT implementation is one of the primary causes for failure in obtaining expected benefits (Hayes and Jaikumar, 1991; Chung, 1996; Small and Yasin, 1997a). Voss (1988) highlighted the critical role of the human factors in the AMT implementation. According to the author, the adoption of AMT comprises three different phases: (1) pre-installation, (2) installation and commissioning, and (3) post-commissioning. Considering this general process, groups

[3] The terms 'emergent market', 'newly industrialised country' (NIC), and 'developing country' are used as correspondent in the designation of the countries cited in the thesis. Although the definition of 'developing' or 'in development' has suffered some criticism, this is done for simplicity. In addition, it aims to communicate more easily certain limitations present in their industrialisation and context.

of success factors should be identified and understood, according to their impact on each phase. Human factors, labelled as organisational factors in the study, such as workforce involvement and participation, acquisition of appropriate skills, training, and human resource policy should be assessed. In the life-cycle definition proposed by Voss (1988), this evaluation is particularly important in the pre-installation phase, i.e., when the strategic and technical planning is taking place and the workforce is being consulted. It is argued that several conditions and actions, which influence the implementation success, take place prior to the AMT purchase and installation.

1.2 RESEARCH FOCUS

The implementation of advanced manufacturing technologies and human factors are connected, firstly, because workers need to want to use the AMT for a successful adoption (Markus and Keil, 1994). As highlighted by Millen and Sohal (1998), resistance to change can be expected, but can be managed if addressed during the planning stage. Second, technology adoption requires significant change in policies of the human resources (Goldhar and Lei, 1994; Upton, 1995; Lefebvre, Lefebvre and Harvey, 1996). According to Boyer *et al.* (1997), softer infrastructural issues such as employee empowerment are crucial to unlock the potential of AMT. Mainly, because greater demands related to decision-making are required from employees working with advanced technologies (Adler, 1986; Meredith, 1987a). The known difficulties in dealing with aspects harder to quantify, the so-called intangible aspects, using traditional AMT justification methods (Kaplan, 1986; Meredith and Hill, 1987; Wilkes and Samuels, 1991; Small, 2006) may represent one of main reasons why this process is troublesome. Nonetheless, practitioners and academics believe that the factors affecting the selection of technologies should be considered for a sound decision and implementation issues should be anticipated (Choudhury, Shankar and Tiwaria, 2006). Human factors such as employee morale and commitment, reward systems, and working conditions should be included in the AMT appraisal (Udo and Ehie, 1996). Given the importance of the inclusion of human factors in the planning of the

AMT adoption, the pre-installation phase defines the limits of the research focus. In particular, the evaluation of these factors to be incorporated into the selection of manufacturing technologies is regarded as necessary and addressed by the study.

Furthermore, in the case of developing countries, they "have little choice but to adopt the new technologies if they are to have any chance of engaging in a sustained process of industrialisation and technical change (Alcorta, 1995, p. 2)". According to Mora-Monge *et al.* (2008), the adoption of AMT is a strategic option for survival under the global competition. Developing countries such as Brazil and India have become industrialized due to that pressure (Burke and Ng, 2006). Practitioners in developing countries have recognized that the "timely positioning of advanced manufacturing technologies and improvements in the management of human resources are key elements in competing favourably in the world market (Zhao and Co, 1997, p. 7)". Considering the importance of these aspects, the need to include human factors in the AMT selection seems even more important for emergent industrial economies. First, because those countries are still in the critical early stages of implementation of advanced technologies (Sambasivarao and Deshmukh, 1995), where often the technological acquisition relates to only adapting existing methods to local circumstances (Tybout, 2000). In consequence, current selection methods do not seem to be adjusted to the appraisal of state-of-the-art technologies. Secondly, the workforce in developing countries presents distinctive characteristics with low rates of secondary education, scarcity of technicians, problems with the flexibility in production processes, and difficulties to absorb new technologies (Joia, 2000).

After surveying medium and large enterprises in Northern India, Sethi, Khamba and Kiran (2007) concluded that human factors represent the most significant elements to achieve flexibility from AMT implementation. Technical expertise, employee involvement and attitude (motivation), and employee education (formal and training) influence the process of building technological capabilities and collaboration for AMT adoption success. According to the study, in newly industrialised countries such as

India and Brazil, the adaptation of technologies is necessary to make processes and products more effective in local environments. Local practices and firm-specific factors are needed to strengthen the adopted technologies and should be targeted as such (Laosirihongthong and Dangayach, 2005; Parhi, 2005). The installation of a Volkswagen plant in the state of Rio de Janeiro in Brazil can illustrate the importance of assessing human factors relevant to the AMT selection for developing countries.

Built in 153 days and with an investment of 250 million dollars from Volkswagen and the same amount from partners, a modular consortium[4] for the production of automobiles was regarded an innovative enterprise (Marx, Zilbovicius, and Salerno, 1997). The consortium was advertised the 'world's most advanced automobile industry'. The major part of its production of estimated 30,000 bus-chassis and trucks a year would be exported to the Mercosur[5], the USA and Europe (Abreu, Beynon and Ramalho, 2000). Nonetheless, as reported by Joia (2000), even with the investment in a training centre to prepare employees for the production network. The labour force did not possess the structuring skills to build knowledge from training. As a result, the quality levels remained inferior to those of their European counterparts. Problems with labour organisation are still an incognita in the implementation after four years of installation; some activities are redundant and realized by VW and its partners (Correa, 2001). Issues related to the welfare of workers were not considered before the installation. This represented four years of conflict and negotiations that culminated with several industrial stoppages and a strike of one week in August of 1999 (Ramalho and Santana, 2002). As noted, the context of developing countries enhances the relevance of the appraisal of human factors in the selection of

[4] A modular consortium consists of separating "the product into sub-assemblies (modules) which are delegated to and entirely provided by a specific module supplier. The module supplier has the responsibility of assembling its module directly on the automaker's assembly line (Pires, 1998, p. 225)".

[5] The Mercosur (Common Market of the South) is the common market established amongst Brazil, Argentina, Uruguay and Paraguay, and Bolivia and Chile as associates. It was created in 1991 in response to several challenges and developments (Mecham, 2003).

technologies. This reality is also explored by the current study. The research focuses on the AMT pre-installation phase, considering the context of developing economies.

1.3 RESEARCH QUESTION AND OBJECTIVES

The identification, classification and evaluation of factors involved in the AMT adoption are regarded as vital for a sound judgement of alternatives and appraisal of the available options (Irani, 2002). As explored by Voss (1988) and further elaborated by Chen and Small (1994), the pre-installation is constituted by the identification and analysis of the factors that may have a positive or negative impact on the implementation outcome. It ends with the decision of going ahead or not. If there is no go ahead, there is no implementation. In this phase, two processes are necessary for the AMT selection: strategic planning and AMT justification. The strategic planning aims to match the company's business objectives with the technologies; a manufacturing plan that supports the strategic orientation of the company is developed (Chen and Small, 1994). During the process, information is gathered from several sources and the technology alternatives are identified (Shehabuddeen, Phaal and Probert, 2006). As for the justification, the step involves the evaluation of the options based on strategic, operational, and economic benefits versus their cost (Small and Chen, 1997). Ultimately, the selection of AMT involves the prioritisation of technology alternatives considering involved factors (Stacey and Ashton, 1990).

A number of appraisal methods have been proposed to assess intangible aspects such as the human factors over the years (Airey and Young, 1983; Primrose, 1988; Bromwich and Bhimani, 1991; Grundy and Johnson, 1993; Efstathiades, Tassou and Antoniou, 2002). However, there are significant limitations to those approaches (Kaplan, 1986; Raafat, 2002; Tan *et al.*, 2006). Shank and Govindarajan (1997) indicated that existing justification approaches "do not go as far as giving meaningful orientation to managers regarding the evaluation of technology investments". Moreover, existing AMT justification approaches tend to focus on economic and financial measures, which are more easily quantified (Jones and Lee, 1998;

Ordoobadi and Mulvaney, 2001; Hoffman and Orr, 2005). According to Small and Yasin (1997b), investment justification should be attempted only after a firm has identified the benefits that they require from the technology adoption and investigated alternative AMT that can bestow those benefits. Nonetheless, "managers either do not recognize or choose to ignore the potential synergies among facets of integrated manufacturing as they pertain to human resource management (Snell and Dean Jr., 1992, p. 495)".

Literature and practice reveal that there is a need to incorporate involved human factors into the selection of technologies, i.e., in the evaluation of AMT alternatives and prioritisation of available options. The main challenge related to the human factors in the selection of technologies seems to be linked to the following question:

"How to incorporate human factors into the AMT selection decision?"

This study aims to fill in this gap by proposing an approach to the identification, classification and evaluation of human factors for the AMT selection. Furthermore, it seeks to associate this contribution to a particular setting by applying the approach in a developing country, Brazil. In order to address the research question and achieve the proposed contributions, four main objectives are envisaged:

1. Investigate technology selection practices and appraisal techniques currently used (people, criteria, characteristics);
2. Develop a framework and a process to identify and evaluate human factors relevant to the AMT selection;
3. Apply and refine the proposed approach;
4. Test the applicability of the approach to the AMT selection decision.

The research aims to address the identified gap in two dimensions: theoretical and practical. The theoretical dimension involves the development of a framework and associated process for the identification and evaluation of human factors relevant to the selection of technologies. As the research also involves a particular setting, the practical dimension involves the test 'in the field' of the appropriateness of the approach to companies located in that context. The applicability of both framework and process is tested through three main criteria: feasibility (the approach can be followed), usability (the approach is easily followed) and utility (the approach produces useful results for managers) as proposed by Platts (1993).

1.4 STRUCTURE OF THE THESIS

The thesis is divided in 8 (eight) distinctive chapters (Figure 1.2):

- Chapter 1 introduces the research background, focus and objectives. The organisation of the thesis is also described and represented;
- Chapter 2 presents the conducted review of relevant literature, highlights the identified gap and introduces the concepts which underpin the proposed approach;
- Through Chapter 3, the research methods which organise and operationalise the study are described and the research design justified;
- Chapter 4 corresponds to the development of a preliminary framework. The framework is developed through semi-structured interviews with experts and a pilot case study;
- Chapter 5 contains a detailed description of the process developed to apply the framework;
- Chapter 6 presents the refinement of the proposed approach based on the feedback from four case studies;
- Chapter 7 describes the final testing of the approach in four companies;
- Chapter 8 concludes the thesis by discussing the research outcomes and findings, the accomplishment of research objectives and contributions. It also addresses the limitations of the study and proposes future research.

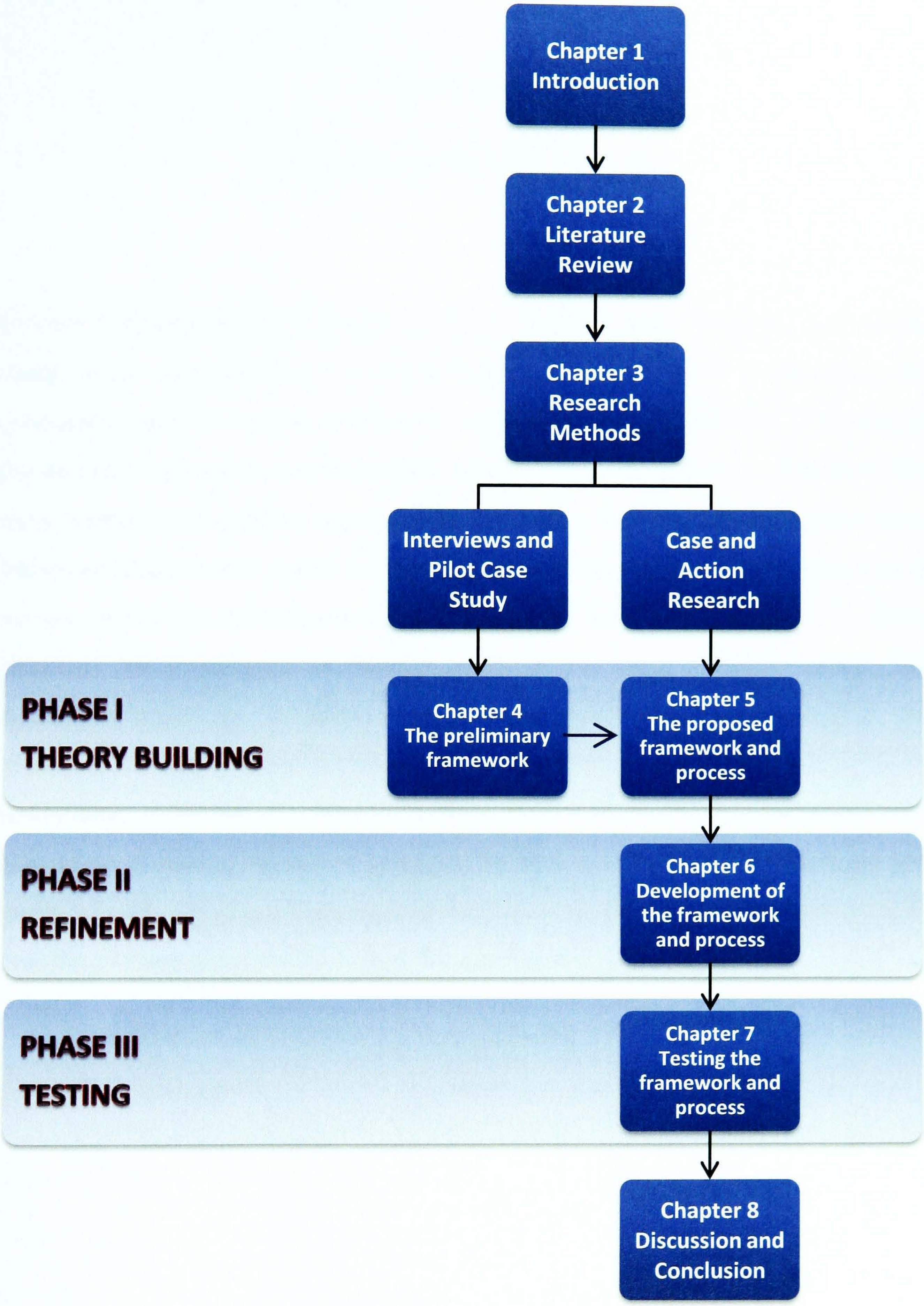


Figure 1.2 - The structure of the thesis

CHAPTER 2

LITERATURE REVIEW

Chapter 1 established the background to the research, describing the focus of the study, main objectives and proposed contributions. Chapter 2 presents the conducted literature review and highlights the identified gap. Section 2.1 introduces the definition of human factors and briefly describes current research related to the topic. Section 2.2 highlights the importance of human factors in the selection and in implementation of AMT. Based on this evaluation of impact; three main categories of human factors are identified and described within Section 2.3. Section 2.4 briefly discusses the importance of human factors in the AMT selection decision for developing countries. In Section 2.5, existing AMT adoption approaches are reviewed, seeking to understand how the identification of human factors is currently undertaken. In Section 2.6, the appropriateness of AMT justification methods to the evaluation of human factors is analysed. Section 2.7 discusses the identified gap represented by issues and challenges found in the review of literature, elaborating on how the present study aims to add to the existing body of knowledge.

2.1 INTRODUCTION TO HUMAN FACTORS

The combination of the terms 'human' and 'factors' has been used in different disciplines with different significances. The first step to explore the topic is to establish the scope of the concept within the thesis. The definition adopted is related to the human-related issues treated as factors in the selection and the implementation of advanced manufacturing technologies (Adler, 1988; Saraph and Sebastian, 1992; Sambasivarao and Deshmukh, 1995; Efstathiades *et al.*, 2000). As suggested, it refers to "facts or situations which influence the result of something" (Cambridge Dictionary, 2005). In this case, factors related to the human element, which influence the AMT adoption. Table 2.1 presents a list of human factors.

Table 2.1 - Human factors research cited in literature

	Ferdows *et al.*, 1986	Voss (1986)	Weatherall (1988)	Beatty and Gordon (1988)	Troxler and Blank (1990)	Ghosh and Wabalickis (1991)	Datta *et al.*, (1992)	Demmel and Askin (1992)	Hin , Leong and Gay (1993)	Mohanty (1993)	Sambasivarao and Deshmukh (1995)	Udo and Ehie (1996)	Efstathiades, Tassou and Antoniou (2002)	Sethi, Khamba and Kiran (2007)
Employee co-operation	■				■	■				■	■			■
Employee relations		■	■	■	■		■	■		■	■		■	
Employee motivation		■	■				■	■		■	■	■		■
Manpower planning		■							■	■	■		■	
Reward systems		■		■								■	■	
Safety and ergonomics							■				■			
Training, multi-skilling, education										■		■	■	■
Technical expertise		■		■								■	■	■

The implementation of AMT has been associated with a number of competitive benefits for companies such as a faster response to the market changing needs and the ability to offer products with improved quality and reliability (Small, 1999). These technologies are associated with a higher degree of flexibility of product, process or production (Pfeffer, 1982; Zammuto and O'Connor, 1992; Burcher, Lee and Sohal, 1999; Cagliano and Spina, 2000; Heijltjes, 2000; Machuca, Diaz and Gil, 2004). Advanced manufacturing technologies have been linked with high quality without sacrificing cost, delivery and flexibility performance (Siegel, Waldman and Youngdahl, 1997). Nonetheless, many cases of firms that failed to achieve expected benefits provided by AMT, especially in terms of flexibility, are known (Gerwin, 1993; Sohal, 1994). Unsuccessful implementation experiences have been reported in literature, e.g., the account on the considerable negative return of the investment in programmable manufacturing technologies in British companies (Primrose, 1991), the automation in Japan described by Takanaka (1991), and the discussion on the adoption of Information Technologies (IT) by Lillrank, Holopainen and Paavola (2001).

Many critical factors associated with the failures have been explored by researchers. However, according to Co, Patuwo and Hu (1998), the human factors alone are the determinants of differentiating companies that are successful because they address these issues, and, companies that are not so successful, because they lack such consideration. That notion resonates with Small and Yasin (1997a) who state that the human factor should be given higher priority, since it has a more significant impact on the successful experiences. Addressing human factors has been recognised as critical to the adoption of advanced manufacturing technologies (Currie, 1989; Sheridan, 1990; Hayes and Jaikumar, 1991; Chung, 1996; Siegel, Waldman and Youngdahl, 1997; Ghani and Jayabalan, 2000). It has been suggested that intangible attributes such as employee co-operation, motivation and employee relations should be considered in the selection of AMT (Mohanty, 1992). Sambasivarao, Deshmukh and Mohanty (1995, p. 17) remarked that, "there is certainly no shortage of identification and classification of the attributes and issues affecting decisions about automation projects". Conversely, the human factors have been somewhat neglected in this process. Adler (1988, p. 46) pondered that, "of all the implementation issues, labour requirements are among the least well-managed". The author states that:

> "Internally, the assessment of the skill impact of the new technology is a low priority task; the choice of the new equipment is itself motivated by technological capabilities and cost savings: the skills required to make it function effectively are rarely examined".

While technical aspects and economic benefits involved in automation have been widely researched, human aspects are less discussed (Parasuraman and Riley, 1997). As suggested by Swink and Way (1995), manufacturing strategy researchers have addressed human factors superficially and further research is needed. Similarly, in practice, firms should acknowledge the interdependency between the human element and advanced technologies to obtain improved performance (Mital and Pennathur, 2004). In order to explore the relationship between human factors and the successful adoption of AMT, the impact of the installation of technologies on the human resource management and the human factors engineering is explored next.

2.2 THE IMPORTANCE OF HUMAN FACTORS

The installation of new technologies influences the human resource management (HRM) practices and policies. First, because advanced manufacturing technologies lower the demand for low-skilled and clerical workers (Siegel, Waldman and Youngdahl, 1997; Chennells and Van Reenen, 1999). The reduction in the workforce and the uncertainty related to the change may lead to considerable resistance as reported in Beatty and Gordon (1988). The authors described the implementation of a new robotic welding line in an automotive company as a practical example of that impact. An automated welding line with six operators was placed beside a manual welding line with more than 30 employees. As a result, not only the new robotic line never worked (and it was abandoned), but the new automated system began to run smoothly just when installed in another factory and after new employees were hired.

Similarly, the prospective of job losses may generate the demoralization of the labour, which in consequence may increase absenteeism and turnover (Liker, Roitman and Roskies, 1987). Consequently, firms usually have to adjust the role of compensation and appraisal systems already in place (Ghehart and Bretz, Jr., 1994). The compensation corresponds to the encouragement employees need to think proactively. At the same time, it means the company is willing to compensate employees for the new sets of skills required because of the technology adoption (Womack *et al.*, 1990). It was suggested that organisational agility is benefited when individuals feel like partners in the implementation. They should be rewarded for the learning and adaptation necessary in the technological change (Crocitto and Youssef, 2003). Although the AMT generate what Kozlowski and Hults (1987) named 'updating climate'; organisations should take advantage of this potential by rewarding employees for acquiring new skills. This strategy aims to guarantee their commitment through the sharing of gains (Liker and Majchrzak, 1994). Even high skilled employees will be limited if not motivated to perform efficiently as indicated by Huselid (1995).

The acquisition of new skills represents another link in the relationship between automation and the human resource management. The understanding of skills, in this sense, is related to a "wide-range of human abilities and characteristics that are required in a modern manufacturing environment (Kidd, 1994, p. 171)". Many accounts of unsuccessful adoptions of AMT have been related to the inability of workers to cope with the new technologies, considering their current job skills (Mital and Pennathur, 2004). In that regard, recruitment of capable individuals paired with a reliable selection regimen (Huselid, 1995) and continuous training (Love and Walker, 1986) have been regarded as crucial in the implementation of new manufacturing technologies (Efstathiades *et al.*, 2000). Considering the AMT as forms of knowledge transfer as suggested by Sargent and Matthews (1997), the human resource practices represent structuring platforms that encourage participation and allow employees to improve the way their job is performed (Huselid, 1995). The latter author exemplifies those practices with initiatives such as cross-functional teams, job rotation, and quality circles. Although there is still significant controversy on whether AMT promote organisational change, there is but little doubt on their influence over the operational skills of employees (Sun and Gertsen, 1995). In many cases, the self-education or education of others (training of users, managers) correspond to 90% of the implementation effort (Meredith, 1987b). In the car manufacturing industry, for example, Mori and Kikuchi (1993) managed to identify five clusters of productive skills introduced by technological innovations: technical knowledge, operation of controlling equipments, preparation abilities, analysis and judgment abilities, and measurement. As indicated by Adler (1988), flexible automation increases the opportunity for a company to match the new technologies with new skills. Furthermore, the close relationship between technology and the need for new skills may even trigger the acquisition of the advanced technologies (Sohal *et al.*, 1999).

Another set of aspects bearing considerable influence on the technology implementation is the employee relations framework. The power exerted by unions, for instance, can affect the success of the AMT adoption. Beatty and Gordon (1988, p. 31) exemplify this influence, "at one company, unionized draftsmen resisted having some tasks put onto the CAD system because they were 'owned' by a senior draftsman who did not want to learn the new system". The reactions from the union leadership may range from encouragement to complete opposition (Small and Yasin, 2000). Although the role unions play in the advent of a new technology has changed to a more cooperative approach recently (Jackson and Schuler, 1995). It is still up to the firms to devise strategies to avoid or overcome pitfalls (Beatty and Gordon, 1988). McLoughlin (1993) concluded from the British Workplace Industrial Relations Surveys (1984 and 1990) that over 40% of industries introducing new technologies change simultaneously working practices, supervisory functions or management structures. The introduction of technological change may establish a new HR philosophy (Clark, 1993). Efstathiades *et al.* (2000) argued that fear of redundancy and job losses can be expected, but should be handled through consistent human resource policies. In the end, the approach taken in the management of employee relations becomes the critical determinant of the treatment of the technology in the adoption process (McLoughlin, 1993). "Pleasant relations with employees play a significant role in implementing AMT. Employees are concerned with job satisfaction, job security and welfare (Sambasivarao and Deshmukh, 1995, p. 51)".

Still related to the framework of employee relations a firm possesses, human factors and ergonomics are linked with the implementation of AMT. Human Factors Engineering (HFE) is related, in its own right, to the application of the data and principles of human factors, especially, protection and performance, to the design of equipments, subsystems and systems (Salvendy, 1987). Moreover, it relates to the design of equipments in accordance with the mental and psychological characteristics of operators (Perrow, 1983). As explored by Kara, Kayis and O'Kane (2002), the improvement of ergonomics relates to an opportunity for the achievement of the flexibility desired by companies. In the same sense, Forsythe (1997) argues that ergonomics play a vital role in the accomplishment of objectives for the agile manufacturing, for example. Because ergonomics relate to human-machine interactions in the work environment (Foley and Moray, 1987) and safety and health hazards considerations (Wilson *et al.*, 2004), these factors become part of the decision on the most appropriate manufacturing technology (Mohanty, 1992; Choudhury, Shankar and Tiwaria, 2006). In fact, considerations on safety conditions and ergonomics and their relationship with the efficiency of workers have been used to compare different systems available for the selection decision (Datta *et al.*, 1992).

2.3 CATEGORIES OF HUMAN FACTORS

Human factors have a significant impact on the decision to implement advanced technologies. As many of the determinants of success in the adoption of technologies, these factors refer to conditions and actions prior to the purchase and installation of the technologies (Gerwin, 1982; Bessant, 1990; Chen and Small, 1994). Considering this influence, it is possible to identify at least three main groups of human factors described in the literature. The first category of human factors seems to be related to the labour flexibility the technology adoption requires. The AMT attribute multi-focusedness to manufacturing companies (Cagliano and Spina, 2000). Multiple goals can be envisaged and the shift in manufacturing priorities becomes facilitated through the adoption of AMT (Lei, Hitt and Goldhar, 1996). In addition, those technologies tend to integrate the different functions, processes and equipments (Brandyberry, Rai and White, 1999). The potential of achieving multiple goals and the integration provided by the AMT generate and require a more flexible labour force. The notion of job 'enlargement' with more options is associated with this category (Karuppan, 2004). Delegation and involvement in the decision-making can also be associated with the labour flexibility (Cagliano and Spina, 2000). This group of human factors is one of the crucial components of a successful experience in the implementation of advanced technologies (Hyun and Ahn, 1992; De Toni and Tonchia, 1998; D'Souza and Williams, 2000; Zhang, Vonderembse and Cao, 2006).

The second category of human factors is related to the individual capabilities employees require for the installation of AMT. They involve the skills, the knowledge and the attitude workers need to develop and acquire to operate the new technologies (Chung, 1996). Waldeck and Leffakis (2007) cite basic, managerial and technical skills as pertaining to the development of the workforce for the introduction of technologies. This category of human factors refers to training and development activities related to the new skills required by the AMT (Lewis and Boyer, 2002). Many companies have not achieved benefits from AMT (e.g. quality and flexibility), because they failed to upgrade the skills of employees to match the acquired technologies (Mital *et al.*, 1999). Empowerment of the labour force can also be included in this category. The new capabilities associated with modern technologies tend to empower the workers by enriching their jobs (Dean Jr., Yoon and Susman, 1992). The adoption of AMT offers an opportunity for the workforce to match the new technologies with new skills (Adler, 1988). According to Womack *et* *al.* (1990), 'skill breadth' is required from employees. The workers should be able to fill in for each other and solve problems quickly when dealing with AMT.

A third category of factors reflects the relationship between the company and its employees in the installation of technologies. It involves the mechanisms and incentives the company needs to put in place to guarantee a successful implementation (McLoughlin, 1993). Better working practices, job security and welfare, reward systems, and ergonomic conditions represent other examples (Sambasivarao and Deshmukh, 1995). The overall quality of work life resultant of the learning about the technologies and decrease of safety hazards is associated with this category of human factors (Ordoobadi, 2009a). The importance and influence of unions is also related to the employee relations factors. For instance, unionised employees tend to receive greater training than non-unionised workers (Mital *et al.*, 1999). Furthermore, the unions influence the acceptance or rejection of automation initiatives (Small and Yasin, 2000). In many cases, the relationship between workers and company is mediated by unions; and relates to the resistance to the technical change (Tchijov, 1989; Beatty and Gordon, 1991). The general attitude towards the implementation of advanced technologies may even prevent the adoption, therefore should be considered during the planning process (Efstathiades *et al.*, 2000).

As discussed, the labour flexibility category mainly refers to the human factors associated with the manufacturing process affected by the AMT adoption. While the individual capabilities factors relate to the skills and attitudes, which employees acquire or develop through the acquisition of new technologies. The employee relations category defines the relationship between a company and its workers in the AMT adoption. Despite the importance of human factors, interactions between human, organisational and technical elements are not usually assessed in the implementation approaches (Bessant, 1993; Ramamurthy, 1995; Panizzolo, 1998). It has been suggested that an inadequate planning of infrastructural adjustments before the actual installation of technologies is responsible for AMT implementation failures (Chen and Small, 1996). This reality has affected companies in developed and developing countries alike (Mora-Monge *et al.*, 2006). However, human factors and organisational issues seem to bear a more significant impact on newly industrialised countries (Noori, 1997). This influence is summarised next. Figure 2.1 presents graphically the three main categories of human factors identified in literature. Three examples are shown to represent each category. A more comprehensive list of examples pertaining to each category can be found in Table 5.2 (Chapter 5).

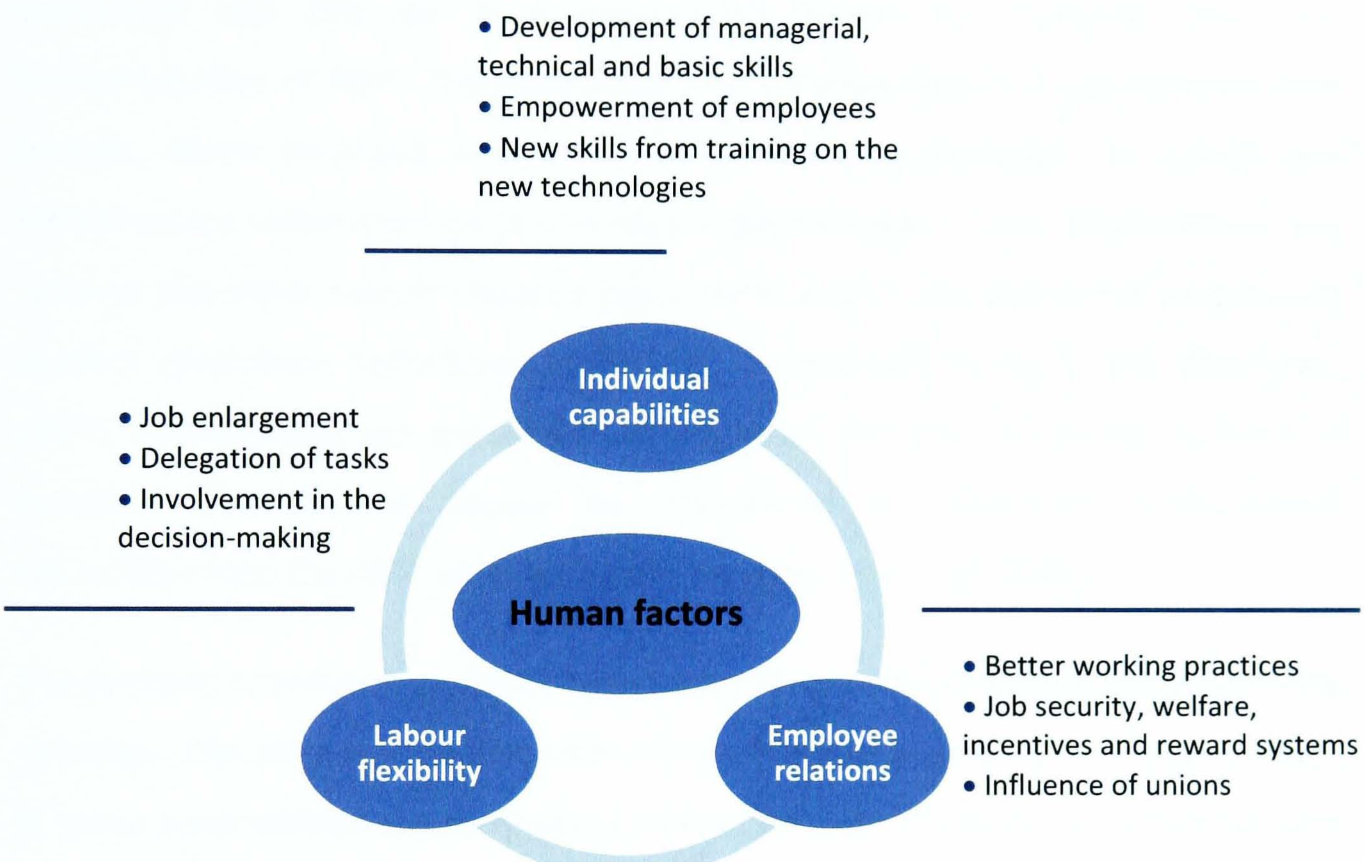


Figure 2.1 - The identified categories of human factors

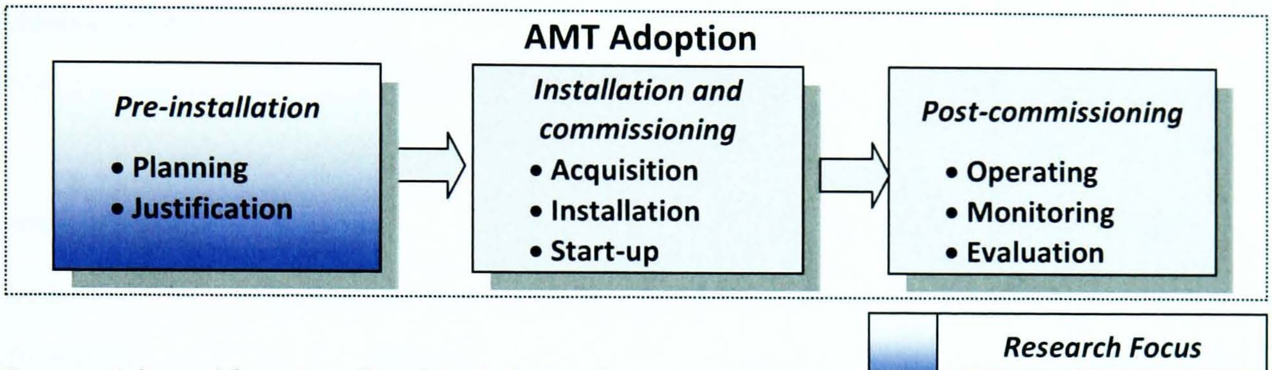
2.4 THE IMPACT OF HUMAN FACTORS IN DEVELOPING COUNTRIES

The importance of the assessment of human factors involved in the selection of technologies is emphasized in the case of developing countries. Dunning (1994) indicated the transference of technology, intellectual capital, learning experience and organisational competence to subsidiaries of transnational companies located in the 'developing world'. As argued by Fleury (1999), companies in developing countries are seeking to adjust their strategies and local policies to new globalisation needs and market conditions. In consequence, manufacturing firms located in these countries have faced the challenge of a pluralistic market through investments in AMT (Sambasivarao, Deshmukh and Mohanty, 1995). However, developing countries are still in the early stages of the implementation of technologies and the identification of human factors becomes paramount in this context (Sambasivarao and Deshmukh, 1995). According to Dangayach and Deshmukh (2001), Indian companies still rely on a people-centred search for flexibility from the implementation of AMT. The importance of the human factors is highlighted in this context. More emphasis is put on the software represented by people and infrastructure rather than on the hardware (technologies). Skills development, pay systems and other human resource practices in many ways define the adoption of modern production techniques in Mexico, for example (Sargent and Matthews, 1997). Furthermore, the specificities of countries and their particular patterns of industrial development should be considered to strengthen technological capabilities from the AMT adoption (Sethi, Khamba, and Kiran, 2007).

The contexts of technology development are different for developed and developing countries. The current state of workers skills and knowledge present in each context in many ways defines the technology choice. As such, it should be compared with the potentialities of a candidate system (Kahen, 1996). Different emphasis should be placed on important factors for the successful AMT implementation (Narain, Yadav and Antony, 2004). Existing conditions and technology diffusion patterns make developing countries unique (Alcorta, 1999). Modern technologies have been skill-based for the past 60 years. In this sense, the level of education and profusion of technicians influences the capacity of an economy to adopt and effectively implement technologies (Mayer, 2001). In Brazil, the successful adoption of new production systems has been prevented by low levels of education and training and poor labour relations as reported in Humphrey (1995). This occurs because the level of human resource development influences the absorption of technical knowledge by Brazilian subsidiaries (Sparkes and Miyake, 2000). As the authors alert, firms should assess this relationship to guarantee an effective transference of knowledge and use of production technologies. The evaluation of AMT alternatives is a critical task for companies in the developing world due to the high investments and high degree of uncertainty related to the decision (Dangayach and Deshmukh, 2005). Nonetheless, studies on the adoption of technologies tend to focus on industrialised countries (Dangayach and Deshmukh, 2001). Considering the specific context of countries in development and the importance of human factors, the demand for proposed approaches to identify and evaluate these aspects seems to be magnified.

2.5 THE IDENTIFICATION OF HUMAN FACTORS IN THE AMT ADOPTION

The adoption of AMT involves a series of activities following a life-cycle model as proposed by Voss (1988) and further elaborated by Small and Yasin (1997b). The implementation process is represented by Figure 2.2. The pre-installation phase is constituted by the factors that may have a positive or negative impact on the adoption outcome. It ends with the decision of going ahead or not. If there is no go ahead, there is no implementation. The installation and commissioning phase is accomplished when the process is regarded as successful in technical and utilisation terms. The post-commissioning relates to technical improvements, moving beyond the technical success and achieving the business success. Different adoption approaches have been proposed by the literature (Voss, 1988; Chen and Small, 1994; Small and Yasin, 1997b; Lin and Nagalingam, 2000; Efstathiades, Tassou and Antoniou, 2002). In this case, two main aspects are analysed while reviewing the models. First, the phase in which the human factors are assessed is observed. This is justified by the importance of considering the human factors prior to the actual AMT installation as indicated by Voss (1988) and Chen and Small (1994). Secondly, the strategies employed to identify 'softer' issues such as the human factors are explored. Many researchers have indicated the inability of current models to deal with intangible aspects (Meredith and Suresh, 1986; Kaplan, 1986; Meredith and Hill, 1987; Shank and Govindarajan, 1992; Jones and Lee, 1998; Ordoobadi and Mulvaney, 2001; Irani and Love, 2002; Cil, 2004; Tan *et al.* 2006; Small, 2007). Hence, it is necessary to understand how models proposed for the AMT adoption assess human factors during the technology selection and the implementation processes.

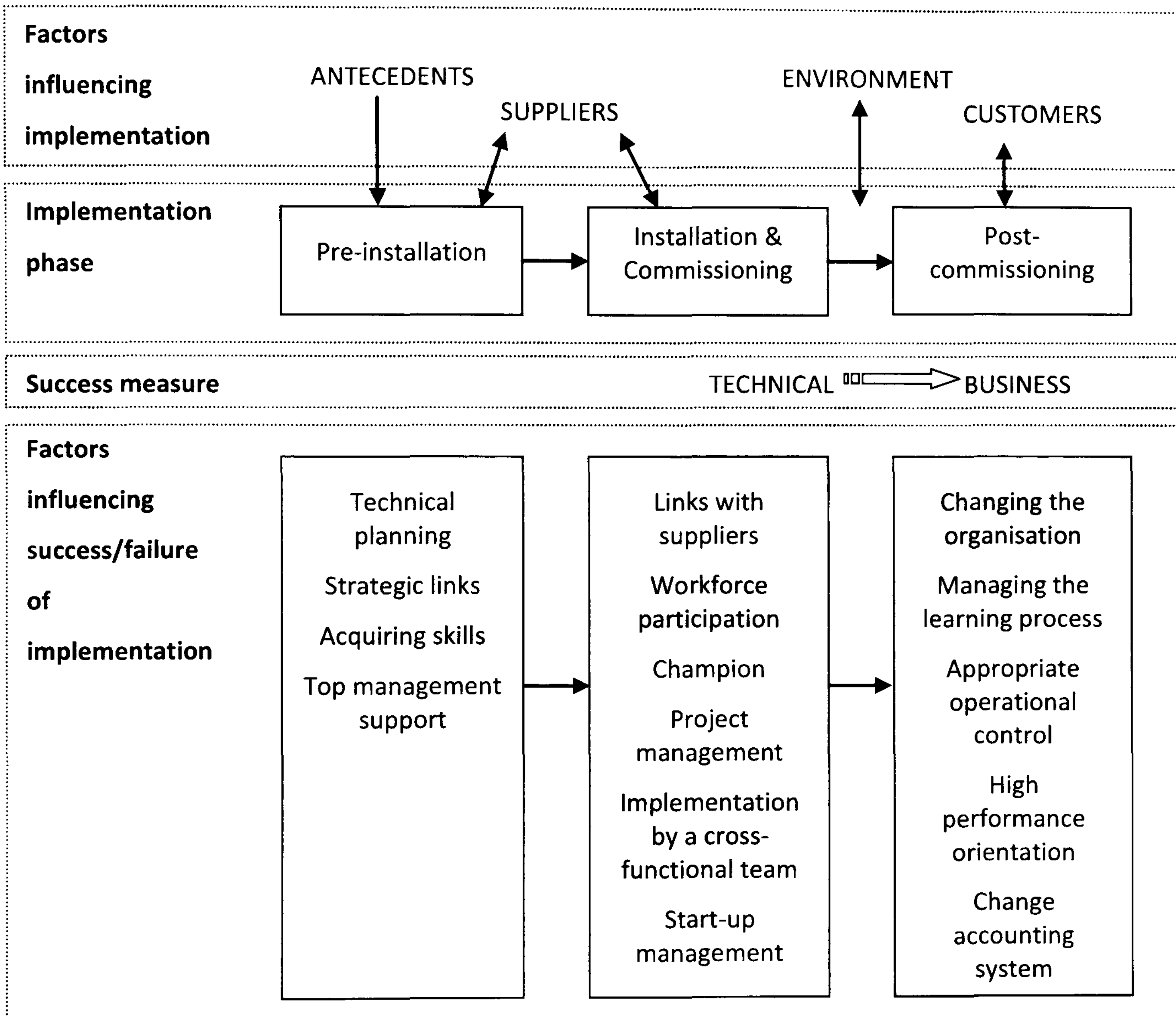


Source: Adapted from Small and Yasin (1997a)

Figure 2.2 - The AMT adoption process

2.5.1 The Process of Implementation - Voss (1988)

The framework proposed by Voss (1988) explored AMT adoption success factors. The author claimed successful implementation experiences were being reported based on a technical dimension only. In the model, another level of success is envisaged through the implementation of advanced manufacturing technologies, the business success. This is achieved when all the technology benefits are fully realised both internally and in the market place. Voss (1988) sought to propose the implementation should move beyond a 'defensive' view of AMT to incorporate strategic implications and possibilities. Aiming to obtain the business success, some factors should be addressed in different phases of the implementation process. Three characteristics are considered vital for a life-cycle model of adoption of technologies. First, develop the knowledge on the process, interaction with the environment, antecedents and others undergoing the same process. Secondly, it should be concerned with the change of definition from technical to business success. Third, it should identify and understand the factors that collaborate for the success and failure of the implementation process. Organisation, technical planning, business strategy and management figure among these factors. Figure 2.3 represents the model proposed by Voss (1988), highlighting concerns related to the human element.



Source: Adapted from Voss (1988)

Figure 2.3 - The process of implementation according to Voss (1988)

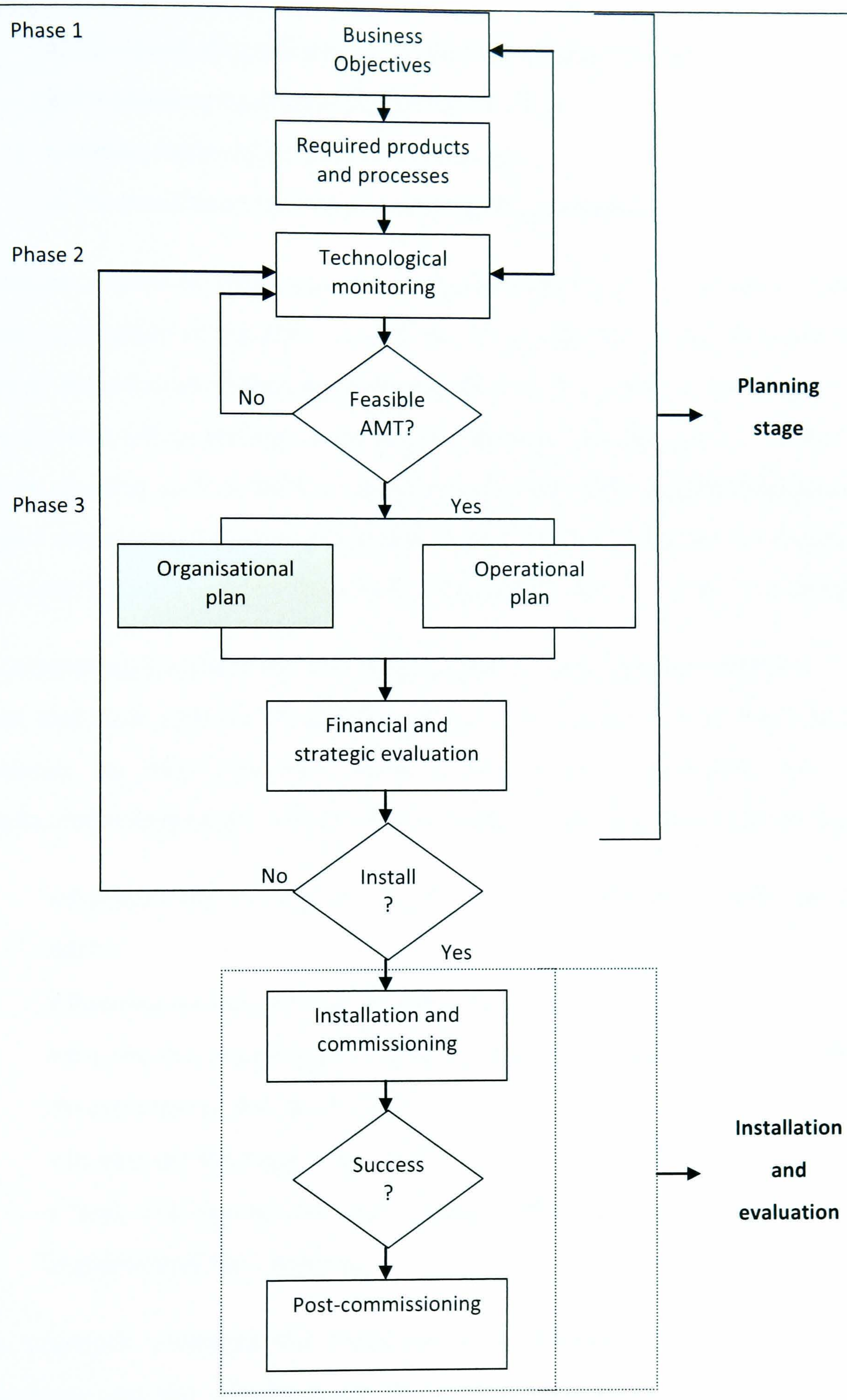
According to Ettlie (1984) and Voss (1986), the skills present and to be acquired with the adoption of technologies have to be considered during the pre-installation phase. The participation of employees and the use of teams are crucial to the installation of the AMT. In the last phase, the post-commissioning, organisational changes should take place. Although the author emphasizes the role of human resources as predictive factors of success in the AMT implementation, these factors are "considered as propositions rather than rigorously supported conclusions (Voss, 1988, p. 60)". Voss (1988) states that the implementation factors leading to technical and business success should be explored in further research to improve information and methods for the planning and the selection of AMT. The focus on the workers skills is regarded as necessary and the need to identify and understand the factors influencing the installation is highlighted. Nonetheless, no specific framework or structured approach for the identification of human factors is proposed. Suggestions are made in terms of factors that should be present for a successful implementation at a technical or business level. Amongst these factors, the human element should be addressed in preparation for the new advanced manufacturing technology.

2.5.2 The Integrated Planning Model - Chen and Small (1994)

Chen and Small (1994) proposed the Integrated Planning (IPL) model for the AMT adoption represented in Figure 2.4. The authors share a broader view of implementation with Voss (1988). Their focus is placed on the pre-installation phase of the AMT adoption when factors that have a positive or negative impact on the implementation are identified and analysed (Chen and Small, 1994). The framework proposed by the authors, as described by Small and Yasin (1997a), seeks to be useful for managers to:

1. Evaluate the matching of the current systems and capabilities with the new technology, the technology consistency factor;
2. Consider the required organisational preparation for the adoption, the worker preparation for the AMT adoption factor;
3. Establish the composition of the groups responsible for the implementation, the team-based project management factor.

These assumptions are based on the implementation literature, past experiences, policies and procedures, which were successful for adopters, 94 (ninety-four) companies in the United States covered by a survey conducted by the authors. The approach recommended that greater effort should be employed in the planning activities of some areas related to the human resources and organisational structure.



Source: Adapted from Small and Chen (1994)

Figure 2.4 - The integrated planning (IPL) model - Chen and Small (1994)

a) Communicating the impact of the AMT to all plant staff;

b) Emphasizing teamwork and group activities;

c) Having multi-skilled production workers;

d) Pre-installation training for all project participants.

Questions related to those aspects are posed and should be answered before the actual justification of the AMT acquisition. They cover the existence of the required level of technical personnel, training and development efforts and are part of the identification effort through a checklist approach. Success factors related to the human element such as worker preparation for the AMT adoption and team-based project management are present in the model. General areas for consideration are proposed, but no specific framework for the identification of factors is envisaged.

2.5.3 The Integrated Implementation Framework - Small and Yasin (1997b)

Small and Yasin (1997b) utilised a survey to investigate some of the relationships proposed by their integrated AMT implementation framework. The authors emphasized management action modes to combine planning and implementation:

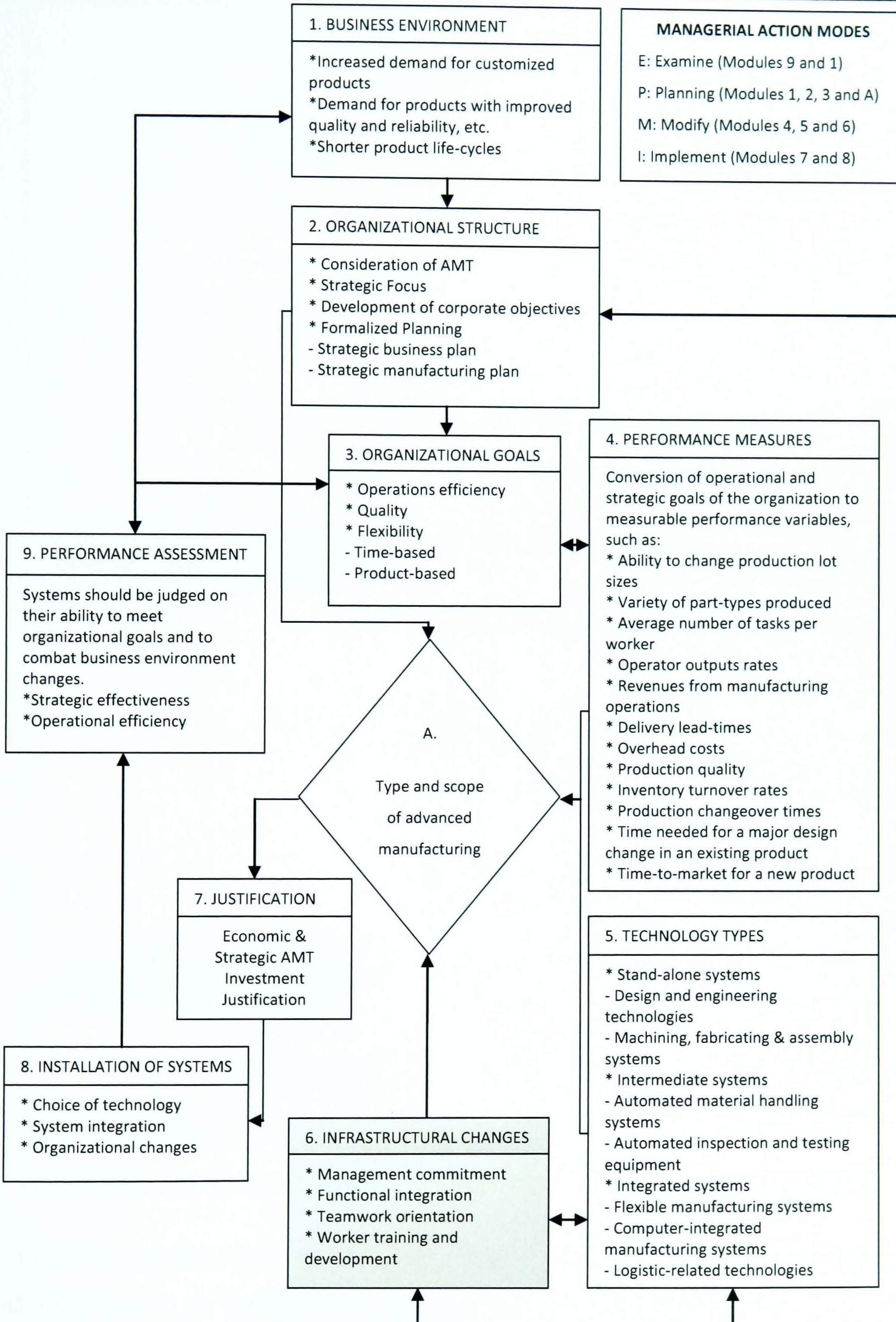
- Examine and investigate the strategic and operational needs for adopting AMT;
- Planning for the adoption of the right type of AMT;
- Modify the organisational infrastructure and processes in preparation for the adoption of the right type of AMT;
- Implement the appropriate AMT systems;
- Track the operational and strategic efficiency and effectiveness of the implemented AMT systems.

This approach proposed the existence of a relationship between the type of technology and the infrastructural changes needed for the AMT adoption (Figure 2.5). Addressing issues such as functional integration, teamwork orientation, worker training and development were recommended. This analysis leads to the type and scope of the AMT to be subsequently justified in economic and strategic terms. The importance of human factors is highlighted by the framework without indicating the range of factors in that category. As discussed by Schroder and Sohal (1999), the model focuses on planning and infrastructure variables that moderate the relationship between the AMT adoption and operations and business performance. The mentioned issues alongside investment in employee training and modification of reward systems represent success factors (Small and Yasin, 1997b). The consideration of human factors (termed as organisational factors in their study) is proposed as necessary for a successful implementation. However, no specific framework for the identification is found. The authors recommended actions and general items to be addressed without specifying an identification step or any classification of human factors for that matter. Finally, the correspondence between the type of technology and the changes in infrastructure is somewhat limiting in terms of contribution.

2.5.4 The Implementation Guidelines - Lin and Nagalingam (2000)

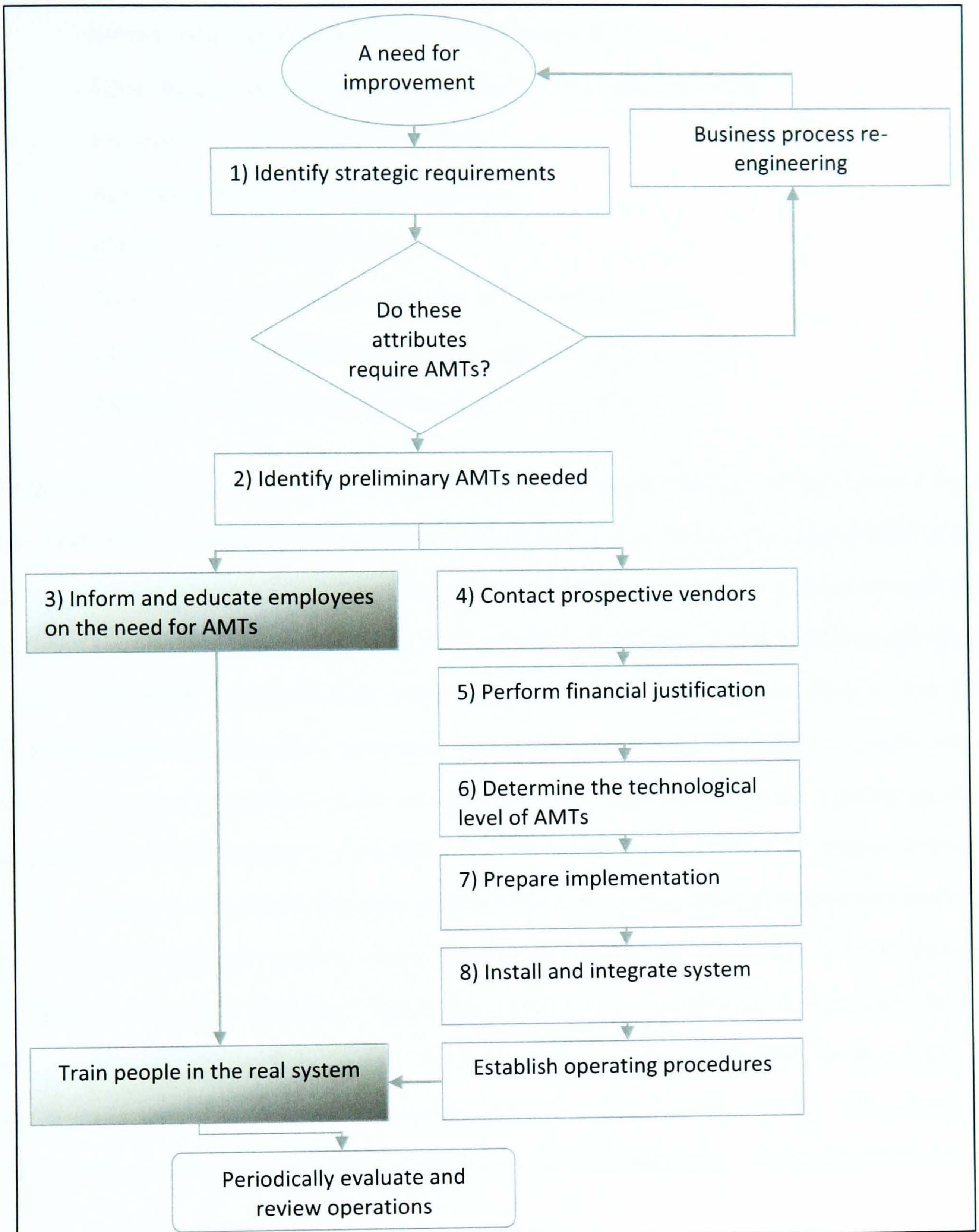
Lin and Nagalingam (2000) proposed a computer-based decision support system tool for the justification and optimisation of CIM. The authors also recognise the implementation of AMT as the process beginning with the pre-installation of the technologies. Some guidelines for the implementation of technologies are proposed. Eight actions are recommended:

- Step 1: Identify strategic requirements;
- Step 2: Identify preliminary AMT needed;
- Step 3: Inform and educate employees;
- Step 4: Contact prospective vendors;
- Step 5: Perform financial justification;
- Step 6: Determine the technological level of the AMT;
- Step 7: Prepare implementation;
- Step 8: Install and integrate system.



Source: Adapted from Small and Yasin (1997b)

Figure 2.5 - Integrated AMT implementation framework - Small and Yasin (1997b)



Source: Adapted from Lin and Nagalingam (2000)

Figure 2.6 - Flowchart for implementation guidelines - Lin and Nagalingam (2000)

The human-related factors relate to the education of employees for the introduction of AMT, that is, an employee-oriented approach is recommended (Figure 2.6). The authors suggest some actions to assist managers in the implementation effort:

- Inform employees about the introduction of AMT;
- Educate all employees to understand the benefits of AMT;
- Involve everyone in the company;
- Resolve any confusion and conflicts;
- Identify necessary new skills;
- Overcome any resistance to change by retraining;
- Identify and prepare learning facilities for key personnel;
- Plan continuous training programs for all employees.

These actions aim to identify new skills and knowledge that can be developed from the CIM, AMT studied by the authors. Ultimately, these measures should lead to full participation and improvement of the general morale of employees. Even though the authors recognised the importance of the human element in the implementation of CIM, a checklist approach was once again adopted. The human factors are not directly utilised for the AMT selection, but constitute a matching action to guarantee the involvement of workers in the process. Lin and Nagalingam (2000) highlighted the importance of the creation of multifunctional teams to overcome functional barriers in the adoption. The interpretation on the rationale of the approach suggests that the human factors do not require a specific identification step, since they are not directly involved in the AMT selection. The human element is involved in the process due to technical and preparation issues. The emphasis is placed on the participation of employees and their general commitment to the technical change. The selection decision proposed in the model encompasses the consideration of the some items:

- Costs of hardware, software, peripheral;
- After-sales vendor support;
- Size of the plant, available space for expansion, site preparation cost;
- Cost of direct/indirect labour;
- Costs/benefits of intangibles;
- Type of production, production rate, complexity of the product;

- Available automation technology to meet the demand;
- Desired degree of automation, and;
- Functional inter-relationships related to other AMT and functional units.

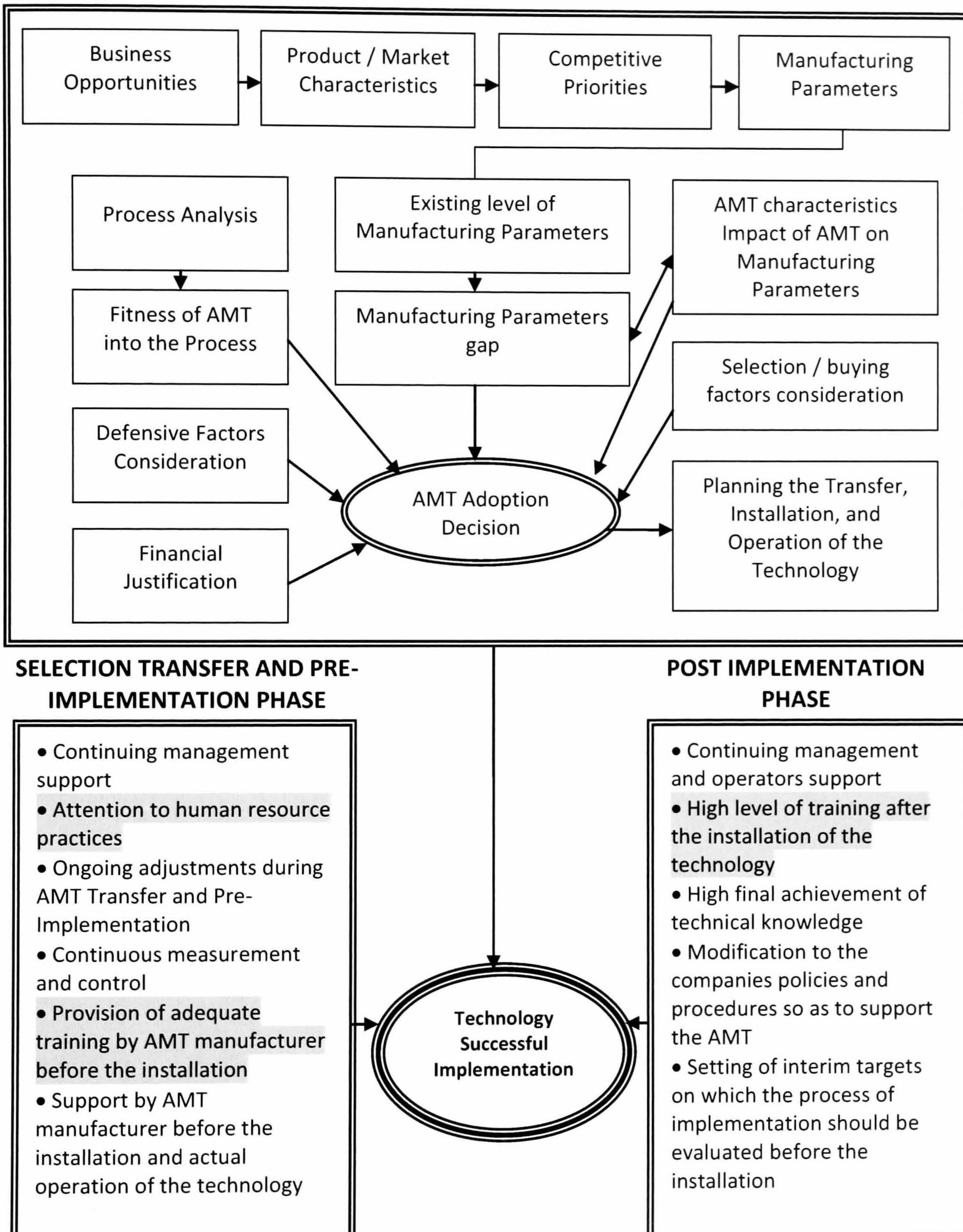
The framework is defined as a set of general procedures for the adoption of CIM to assist managers in understanding the benefits introduced with the system during the AMT justification. The identification of these issues is reserved for the financial justification of the investment in advanced technologies.

2.5.5 The Integrated Process Plan - Efstathiades, Tassou and Antoniou (2002)

In the case of the integrated process plan developed by Efstathiades, Tassou and Antoniou (2002), concerns with the human factors are emphasized during the installation phase of the AMT adoption (Figure 2.7). The approach suggests that human factors should be addressed after the financial justification and after a decision has been made. The authors recognise that companies experience higher levels of technical, manufacturing and business successes when the planning for the human resource development and the infrastructure preparation are focused. However, those concerns are raised only before the selection transfer and the implementation of the equipments. This phase includes the ongoing adjustments during the AMT transfer, the provision of adequate training by the manufacturer of the equipment, the support from the equipment manufacturer, and continuing management support and attention to supportive human resource practices.

The integrated process plan proposed by Efstathiades, Tassou and Antoniou (2002) is based on a survey of 40 (forty) companies, representing almost all the companies that had introduced AMT in the Cypriot Manufacturing Industry. Even though some human factors are mentioned during the selection of technologies, no framework of identification or classification is proposed. They mostly represent concerns to be addressed rather than a list of particular items. Little effort is employed to identify these factors before the actual transference of the selected advanced manufacturing technologies. Moreover, a more 'defensive' approach is adopted in the framework.

Only specific factors relating to the solution of issues such as problems with the skilled labour are taken into consideration for the selection of the new system.



Source: Adapted from Efstathiades, Tassou and Antoniou (2002)

Figure 2.7 - Integrated process plan for AMT implementation

2.5.6 Advantages and Disadvantages of Adoption Approaches

The AMT adoption approaches proposed by the literature include advantages and disadvantages for the identification and consideration of human factors (Table 2.2). Chen and Small (1994) pondered that managers should be assisted in the pre-installation of technologies for the identification of factors with a positive or negative impact on the implementation outcome. Similarly, Voss (1988) argued that the AMT adoption as a field of study and practice should gain further insights from research on the factors leading to technical and business success. Human factors are considered essential for a successful installation experience. Nonetheless, an identification framework is not indicated in the literature. No structured approaches are proposed for the identification or the classification of human factors involved in the selection.

Table 2.2 - Summary of advantages and disadvantages of adoption approaches

Approach	*Advantages*	*Disadvantages*
Voss (1988)	- Implementation as a life-cycle process; - It highlights the need to address the human factors.	- Mere suggestions of further research; - Too general in scope.
Chen and Small (1994)	- It aims to be useful for managers in the pre-installation planning; - Communication, multi-skilling and participation are emphasized.	- No specific framework is proposed; - General areas related to the human element are indicated without the classification of factors.
Small and Yasin (1997b)	- The approach combines planning and implementation; - It includes training and reward systems in the human factors scope.	- Limited scope of application depending on the type of technology; - No structured method for the identification of factors.
Lin and Nagalingam (2000)	- Employee-oriented approach; - Emphasis on actions for the preparation, aiming to encourage employee participation.	- Human factors are related to the acceptance of the technical change; - Employees are involved only in the execution of the implementation.
Efstathiades, Tassou and Antoniou (2002)	- Human resource development is recognised as fundamental to the implementation.	- Human factor considerations are included just in the installation phase; - A 'defensive' approach is envisaged for the pre-installation.

Small and Yasin (1997b) tried to combine planning and implementation of AMT. The authors highlighted the importance of training and reward systems as elements of organisational change for the installation of advanced technologies. Nonetheless, their approach is somewhat limited in scope due to the proposed correspondence between technology type and organisational change. Guidelines envisaged by Lin and Nagalingam (2000), although employee-oriented, regard the human factors as necessary for the AMT adoption, but not as factors bearing importance in the selection. Efstathiades, Tassou and Antoniou (2002) leave the concerns with the human resource developments for the actual installation of the AMT. The practices and policies related to the human element are considered crucial to the technology transfer after the AMT have been selected. This approach is, in fact, admittedly defensive, i.e., the AMT is limited to a local role for the provision of economic gains (Zairi, 1993). Thus, it seems rather incompatible with the strategic role these manufacturing technologies and the human factors share in the adoption decision.

The analysis of specific features of adoption models indicates that existing approaches do not present a framework for the identification of human factors. The need to include these factors is recognised and some factors are suggested in different phases of the implementation. Voss (1988) proposed that human factors such as the acquisition of skills should be addressed in the pre-installation phase of the AMT adoption. Workforce participation and teamwork for the implementation project should be reinforced during the installation and commissioning phase. Organisational change should be promoted during the post-commissioning when the business success is to be achieved. Chen and Small (1994) and Small and Yasin (1997b) stated that the concerns with the human element should be anticipated and addressed during the pre-installation. The development of workers and the training on the new technology were especially valued by the authors and the reward system was included as a critical human factor. Lin and Nagalingam (2000) suggested a similar approach, focused on the new skills required by the AMT and the importance of training. The human factors are part of the scope of matching actions that should be performed to reduce the resistance of employees to the technical change. Efstathiades, Tassou and Antoniou (2002) transferred those concerns to the installation, emphasizing the adjustment of human resources practices and the need for training on the selected advanced manufacturing technologies.

Actions related to the human factors are recommended in the analysed models without a specific effort towards the identification and evaluation of these aspects. Moreover, no robust approach is proposed to incorporate human factors into the selection of technologies. A limited view of human factors is assumed. Overall, these aspects are judged to be 'supporting actions' rather than important criteria for the decision. Often in the adoption approaches, the human-related issues are considered only during the justification of the AMT acquisition (Small and Yasin, 1997b; Lin and Nagalingam, 2000; Efstathiades, Tassou and Antoniou, 2002). A meaningful justification has been associated with the identification and assessment of the variables that determine the success of the AMT adoption (Small and Chen, 1995). The justification involves, apart from the comparison between costs and benefits of the technology investment, the evaluation of implementation issues (Choudhury, Shankar and Tiwaria, 2006). Usually, several categories of factors are assessed during the justification for the selection of the most appropriate AMT. Human, technological, social, and strategic factors are 'quantified' using justification methods and then incorporated into the decision-making (Mohanty, 1992; Sambasivarao and Deshmukh, 1995, Ordoobadi, 2009a). Considering the importance of assessing human factors, methods employed for this evaluation are reviewed next.

2.6 THE EVALUATION OF HUMAN FACTORS

Sambasivarao, Deshmukh and Mohanty (1995) remarked that many approaches have been proposed to address different sets of factors involved in the technology selection. Generally, these approaches are grouped in four main categories: economic, analytical, strategic, and combined approaches (also known as phased approaches) as summarised in Table 2.3. Justification methods are used to evaluate tangible and intangible factors relevant to the selection. Relationships involving qualitative and non-financial aspects should be explored and intangible factors should be quantified using these approaches (Saleh, Hacker and Randhawa, 2001).

Table 2.3 - Available justification approaches

STRATEGIC	***ANALYTIC***	***ECONOMIC***	***PHASED***
Technical Importance Business Objectives Competitive Advantage Research and Development	Value Analysis Portfolio Analysis *Non-numeric* Sacred cow Operating necessity *Scoring* Unweighted (0-1) Unweighted Weighted AHP Pairwise comparison Utility model Linear additive model System value mode *Programming* Integer programming Goal programming Linear programming Risk Analysis Stochastic programming Monte Carlo simulation	Break even analysis MAPI method IRR ARR NPV ROI PB Sensitivity analysis Benefit / cost ratio ABC system SP-NPV	Combination of two or more methods

Source: Adapted from Chan *et al.* (1999); Ordoobadi and Mulvaney (2001)

2.6.1 Economic Approaches

Traditional economic and financial approaches have been the focus of great criticism considering their ability to deal with softer aspects of the technology investment. When a company establishes its decisions on financial or economic justification, financial data may not be accurate or reliable since they are changing very rapidly (Chan *et al.*, 1999). The short term analysis of investments is especially present in the application of these methods. Considering that advanced manufacturing technologies are still part of a risky and expensive strategic investment (Sarkis and Sundarraj, 2001); a short term perspective can be deleterious to AMT investments (Small, 2006). By disregarding long term opportunities, economic approaches tend to present considerable bias against AMT investments (Krinsky and Miltenburg, 1991). Economic tools such as the Payback Period (PP) calculate the return per year from the start of the project until the accumulated returns are equal to the cost of the investment, at which time the investment is said to be paid back. However, there are projects associated with a long term nature in essence; whose benefits will not accrue until sometime in the future (Lefley, 1996a). Similarly, Primrose (1991) regarded the existent bias against slow build-up profits such as the AMT as the main disadvantage of economic approaches. They do not take into consideration the period after the payback and ignore the timing of returns. Moreover, the payback's popularity follows the tendency of managers to look for simple means of communicating information. These methods are mostly used in reaction to the pressures from the high administration. Faster responses to investments are required from companies' executives (Beatty and Gordon, 1988; Wilkes and Samuels, 1991; Lefley, 1996b).

Many of the economic methods or approaches can be extremely complex in nature (Mohanty and Venkataraman, 1993); and, yet inaccurate, by trying to reduce a complex decision into a 'single number' (Meredith and Suresh, 1986). Such focus may be caused by the management's desire to explain the AMT high costs through a purely quantitative perspective (Aravindan and Punniyamoorthy, 2002). The use of payback is constantly supported by its long use and simplicity of prediction, and, to some extent, its general indication of the involved risks (Lefley, 1997). However, considerable shortcomings regarding the prediction of risks are indicated by researchers and practitioners. The solely time-based measurement of risks constitutes the main limitation of the method. The approach tends to advocate that shorter payback periods involve lower risks whilst longer periods would indicate higher risks. This time-driven account of an investment project tends to overlook other important factors, which entail another series of risks that should be observed.

Justifying the investment in AMT should be linked with the consideration of aspects involved in the implementation. Managers have to be able to reap the advantages AMT can offer and quantify touted benefits difficult to measure (Chen and Small, 1996). Although traditional justification approaches have been regarded as suitable to evaluate tangible attributes of the decision, they have been considered incapable of dealing with the intangibility present in them (Kakati and Dhar, 1991; Wilkes and Samuels, 1991; Chan *et al.*, 1999; Aravindan and Punniyamoorthy, 2002). Furthermore, little formal attention has been paid to intangible aspects such as the human factors as stated by Beaumont (1998). Proposals are being justified in financial terms solely. Clearly, the justification of technology investment should not be limited to a tangible evaluation of involved factors. The focus on financial measures alone has been considered a misapplication of justification techniques (Meredith and Hill, 1987; Lin and Nagalingam, 2000; Chan *et al.*, 2001). As Wilkes and Samuels (1991) pondered there are many intangible factors related to the adoption of advanced technologies, which are not easily quantifiable or even estimated.

The case of the Peerless Saw Company demonstrates the inappropriateness of these techniques to evaluate human factors involved in the technology selection decision. Facing the growing competition that was offering low-priced products and high volume models of blades with similar quality, the industry was forced to replace its obsolete punch presses. The firm chose to design the blades in-company and download the design into a programmable controller-driven laser cutter, since no CAD/CAM software existed. The project costs after the financial evaluation did not come close as to be justified. However, the company's CEO firmly believed that the only chance of survival would be developing the expertise internally. As a result, the technology developed by the company not only helped the firm to survive; it totally changed the market in which it used to compete. A division to explore new markets was created, the Peerless Laser Processors Ltd (Meredith and Hill, 1987).

2.6.2 Strategic Approaches

Strategic approaches may appear to be more suitable for the appraisal of human factors. Nevertheless, an examination of literature reveals that these methods present considerable 'flaws' when dealing with softer aspects. Strategic models encompass the advantage of being directly related to the firms' goals, but other issues permeate their use (Chan *et al.*, 2001). First, a purely strategic consideration of benefits associated with the AMT is affected by numerous factors, which transform such task into a complex exercise (Lin and Nagalingam, 2000). Competitiveness, for example, can be a result of several items such as quality, flexibility, reduced inventory, etc., and a number of trade-offs is usually involved. Second, strategic investments such as the AMT generally require a careful analysis of intangible factors with the participation of people with a wide range of experiences (Sarkis and Sundarraj, 2001). Considering that technology choice is in general made by a group of people, the involvement of necessary stakeholders is not always carried out. The top level's participation is often limited, and the interdisciplinary teams are rarely formed (Kakati, 1997). By the end of the process, technical aspects may lead to a biased decision and strategy coherency may be left out of the scope of the decision.

On the other hand, when relying on strategic impact as a driver for selection, the economical and tactical influence of the alternatives may be overlooked (Chan *et al.*, 1999). By considering a new technology in comparison with a conventional one, that gain may overlook the potential of adopting a useful conventional technology instead (Small, 2006). For instance, a company can justify the strategic investment by attributing great importance to learning about a new technology related to a competitive advantage; however, it may be the wrong competitive advantage (Slagmulder and Bruggeman, 1992). The general practice demonstrates that projects related to a strategic perspective still try to solve existing manufacturing problems, e.g., low labour productivity and low machine utilisation (Kakati, 1997). Thus, a 'defensive' approach is adopted, ignoring strategic considerations such as the framework of human factors required to 'conduct' the technologies over time.

2.6.3 Analytical Approaches

Developed in the 70s, the analytical hierarchy process (AHP) derives from the work of Saaty (1980) in an attempt to assess tangible and intangible factors. Qualitative and quantitative methods are applied in the decision-making. Using an analytical approach to FMS justification, Srinivasan and Millen (1986) assigned weights to each alternative to indicate their strategic desirability in comparison with other FMS alternatives. The multiplication of the financial NPV (Net Present Value) by those weights of desirability ended up producing the final selection. The method is known for going beyond the financial consideration (Chan and Lynn, 1993). However, its reliance on cash benefits maintains an isolated perspective. Multi-criteria perspectives, according to Kakati and Dhar (1991), remain insufficient to clear the minimum expected return a company will consider to accept opportunities of AMT investments. Moreover, the complexity and scope of the choices becomes more overwhelming when analytical methods are applied. Even though, computational aids can be associated with this type of approach, the data collection is time consuming and complex in nature (Chan *et al.*, 1999). The authors also remarked that hierarchical approaches generally lack a theoretical framework to model decision problems, rely on subjective judgments, and lack a formal treatment of risks.

Similarly, as Ordoobadi and Mulvaney (2001) argue, pairwise comparisons take a tremendous amount of time, and as the number of alternatives increases, this time becomes even more substantial. Even in a successful simplification of the method with a user-friendly software tool, it depends on a set of qualitative factors and the strategic interconnections between them. As noted by Kearns (2004), in his evaluation of AHP models for IT investment selection, although considered adequate for those case studies, the problem of valuing intangibles was ameliorated but remained. Whilst a new sophisticated methodology, (referring to the good recognition the AHP has received), is acknowledged as an improvement, no appropriate answer was yet found (Nagalingam and Lin, 1997). The sophistication of methods is not useful or efficient, when one does not ask the right strategic questions (Hastie, 1974). While some importance of benefits related to a certain goal is attributed, other specific contribution levels for each benefit can be neglected in analytical approaches (Ordoobadi and Mulvaney, 2001). In the end, the analysis of competing options still requires a common measure to convert different magnitudes and establish a ranking based on the opinion of experts (Ordoobadi, 2009b).

To address the shortcomings related to the evaluation of intangible aspects, new approaches have been developed. Ordoobadi (2009a; 2009b) proposed the use of Taguchi's Loss Functions (TLF) to assess intangible factors involved in the AMT selection. The loss functions proposed by Dr. Genichi Taguchi, although used primarily to appraise quality in manufacturing, have been applied in other situations with the purpose of quantifying intangible factors (Ordoobadi, 2009a). Festervand, Kethley and Waller (2001) used the loss functions to identify and rank real estate properties that most closely matched the buyer's needs. Kethley, Waller and Festervand (2002) expanded this application intending to identify properties, choice criteria and needs involved in the selection of real estate. The Taguchi loss functions (TLF) were also used by Pi and Low (2005) to evaluate and select suppliers based on the quantification of service quality. Attavale, Bland and Kethley (2008) used the method to rank investment choices aiming to provide qualitatively superior and meaningful information relative to the traditional 'accept/reject' decision.

Ordoobadi (2009b) proposed the loss function for supplier selection. The loss score related to a set target value was utilised as a common measurement. According to Attavale, Bland and Kethley (2008), the TLF imposes the available options with a penalty for the deviation from a desired characteristic value. These features allow the decision maker to establish weights and determine the most appropriate option, based on specified measurements. The approach produces a ranking of alternatives, evaluated according to the deviation from a target value (Ordoobadi, 2009b). This method seems to represent a way forward for the appraisal of intangible factors during the selection of AMT. Thus, it will be explored further on the study.

2.6.4 Shortcomings of Justification Methods

It seems clear from the analysis of justification methods that there is a difficulty in evaluating intangible factors. Technical development and financial justification still receive far more attention than interactions of technology and the human element in the selection of AMT (Chan *et al.*, 2001). Udo and Ehie (1996) highlighted that technologies can represent a strategy to achieve strategic goals, but should not be considered as an end. These productive resources represent means to obtain business objectives. "Traditionally, approaches have tended to be bottom-up procedures for generating new equipment proposals, with narrow levels of analysis (Sarkis and Liles, 1995, p. 178)". According to Bessant and Rush (1995), the possession of a technological resource does not ensure its effective use. Although technology capabilities can be obtained from AMT and constitute the competence scope of a firm, they are not sufficient in themselves (Torkelli and Tuominen, 2002). Table 2.3 summarises the advantages and shortcomings of justification methods.

Table 2.4 - Summary of advantages and shortcomings of justification methods

METHODS	ADVANTAGES	SHORTCOMINGS
STRATEGIC	- Strategic perception of market and competitors; - Assessment of technical requirements; - Consideration of intangible factors.	- Limited perspective on the comparison: new technologies vs. conventional; - Limited participation of stakeholders; - Incremental regard for organisational impact.
ANALYTIC	- Hierarchical consideration of benefits and factors; - Focus on vertically integrated variables.	- Still relies on traditional economic tools; - Time-consuming and wide scope of data; - Disregard for horizontal relationships; - May ignore contribution levels; - Still dependent on subjective analysis.
ECONOMIC	- Simple and traditional; - Widespread and popular techniques; - Easy to communicate.	- Imprecision of measures; - Complexity of 'sophisticated' techniques; - Lack of consideration of intangible factors; - Short term bias.

Infrastructural adjustments should be considered for the successful adoption of advanced technologies (Small and Yasin, 1997a). Gunasekaran, Ngai and McGaughey (2006) concluded that more balanced and practical approaches are necessary for the evaluation of technology investments. Intangible and tangible attributes should be involved in AMT selection. Considering these limitations, a framework to account for intangible aspects such as the human factors is still required. In this case, however, the use of the Taguchi Loss Function, proposed by Ordoobadi (2009a; 2009b) seems to present a viable approach worth exploring.

2.7 DISCUSSION ON ISSUES AND CHALLENGES

The review of relevant literature indicated that a framework for the identification and the evaluation of human factors involved in the selection of AMT is deemed necessary. Combined justification approaches tried to assess the fluidity of technological investment (Marri, Gunasekaran and Grieve, 2000; Chan *et al.*, 2001; Borestein and Betencourt, 2005; Chan *et al.*, 2006). Nonetheless, the human factors are neglected in the process, perhaps due to the difficulties of quantification reported by theoreticians. In general, a rather limited perspective is related to the human factors involved in the implementation of advanced technologies. "Whilst a new methodology is an improvement on preceding approaches, an appropriate answer to quantify intangibles and to address the functional relationships has still not been found (Lin and Nagalingam, 2000, p. 47)". Given the importance of these aspects in the adoption of manufacturing technologies, they should be identified, evaluated and incorporated into the selection process. Concomitantly, this framework of analysis should be accessible to managers (Primrose, 1991; Small and Chen, 1995). Recent empirical investigation revealed that the complexity of justification techniques prevents many practitioners and industrialists from adopting these approaches (Small, 2006). Therefore, ease of use and the establishment of a common measure for the comparison of AMT alternatives are highlighted as key features for selection decision-making processes (Ordoobadi, 2009a).

Furthermore, the need to involve key stakeholders in the decision has been emphasized by researchers. The participation of stakeholders who will collaborate for the implementation of manufacturing technologies is still reduced. In the study of 584 plants in the U.S. (125 respondents), the involvement of different functional departments, marketing, for example, was found in only 8.6% of the plants. The implication of this lack of participation is the association of inappropriate performance benchmarks or expectations to automation projects. Conversely, plants involving production and operations management, finance and accounting, and management and information systems departments during the justification stage achieved higher levels of success (Small and Chen, 1997). The input from functional departments during the AMT justification has great impact on the quality of the adoption of those resources (Small and Chen, 1995; 1997). A narrow perception of opportunities due to the lack of participation of stakeholders influences the evaluation of AMT. Planners are unable to assign the right value to manufacturing technologies if they are left out of the decision-making (Kakati, 1997). This involvement is beneficial to the organisation as a whole. It provides a clear understanding on the objectives and implications of the AMT projects (Mora-Monge *et al.*, 2006). Alongside the participation issues highlighted by the literature, consensus on AMT selection is also regarded as important for a sound decision:

> "The modern organization depends on the participation, and increasingly on the consensus, of its principals, employees and interested others, all of whom are potential stakeholders in the innumerable business processes and decisions to create success. (Post, Co and Seattle, 1992, p. 34)".

The decision to adopt technologies involves a concrete 'choice', where a selection is made from alternatives (Shehabuddeen, Probert and Phaal, 2006). Even though the quality of decisions made by a group or an individual cannot be comparatively evaluated, scholars have shown that decisions are rarely made by one individual

(Crozier, 1964; Thompson, 1967; Simon, 1974). Seeking consensus forces the group to deal with differences of opinion instead of ignoring them (Holloman and Hendrick, 1972). In addition, consensus contributes to the sense of being a unified structure (Mohammed and Ringseis, 2001). According to Fiol (1994), when a decision-making group seeks consensus, its members also share an understanding of the scope of the issues involved, even though they may have different views of its contents. Although it is impossible to state if consensus produces decisions of better quality (Kraemer and King, 1988), the process of obtaining consensus and the negotiation amongst group members has been regarded as important and desirable.

2.8 CONCLUSION

The literature review indicated that human factors should be assessed for the AMT selection. This assessment should take place prior to technology implementation. In order to be incorporated into the decision-making process, these factors should be identified and quantified. Within this context, a framework for the identification and the evaluation of human factors was deemed necessary. Such an approach should contain desirable characteristics that will assist managers to make sounder decisions:

1. It should be able to identify and evaluate human factors relevant to the AMT acquisition;
2. It should be easy to use and establish a common measure to compare different technology alternatives;
3. It should involve key stakeholders in the decision-making;
4. It should provide consensus in the evaluation of the different options.

This study, therefore, aims to develop a framework for the identification and the evaluation of human factors. Furthermore, the proposed approach seeks to be compatible with the specificities of newly developed countries and the influence human factors carry in the adoption of advanced manufacturing technologies.

CHAPTER 3

RESEARCH METHODS

In Chapter 2, the conducted literature review was presented, highlighting the identified gap and the main objectives of the study. Aiming to establish the methods necessary to operationalise the research, Chapter 3 briefly describes two main traditions. The justification on the relevance of the chosen methods in terms of the object of study, field and main research objectives is presented. Finally, the initial process envisaged for the research is described according to the objectives for each phase and the outcomes expected from the study.

3.1 THEORETICAL FOUNDATION

In social research, the acknowledgement of ontological and epistemological assumptions assists in understanding the articulation between data and theory (Benton and Craib, 2001). Ontology refers to 'what reality is like and its associated basic elements'. Epistemological assumptions relate to the nature and the status of knowledge. There are two main traditions dealing with this articulation: the Positivist and the Phenomenological (Easterby-Smith, Thorpe and Lowe, 1991). Positivism constitutes a school of thought where the facts speak for themselves (May, 2001). An external and objective idea of the world is proposed. Deductive and quantitative approaches relate to this tradition. It involves the development of a conceptual and theoretical structure prior to its testing through empirical observation.

Phenomenology can be regarded as a subset of Interpretativism and Constructivism in terms of epistemology assumptions. While positivism seeks to explain reality, interpretativism and constructivism aim to understand it and construct it (Morrow, 2007). The phenomenological tradition believes in a socially constructed world where the researcher should understand and explain why people have different experiences (Easterby-Smith, Thorpe and Lowe, 1991). Qualitative approaches aim to deal with words and meanings; they are also concerned with measurement as highlighted by Pope and Mays (2006). This evaluation is carried out through taxonomies and classifications rather than figures. In qualitative research, the researcher works with research questions such as what 'X' is, how it varies in different circumstances and why, instead of hypotheses of how big or how many 'Xs' there are.

Both traditions encompass strengths and weaknesses. The qualitative research, for instance, can lead researchers to doubt assumptions and ideas taken for granted by asking fundamental questions about the nature of things (Pope and Mays, 2006). Moreover, as the authors elaborated, the qualitative research deals with individuals in their natural setting as opposed to artificial or experimental ones. The positivist tradition, however, does guide most academic social science (Chesler, 1991). It relies on the inquiry where hypotheses are stated and evaluated by empirical testing. Constructions used by phenomenologists are elicited by the interaction between investigator and participants (Coll and Chapman, 2000). Easterby-Smith, Thorpe and Lowe (2008) summarised the strengths and weaknesses of qualitative and quantitative approaches as shown in Figure 3.1.

	Quantitative	Qualitative
Strengths	Wide coverage of a range of situations Fast and economical	Ability to look at how processes change over time, to understand people's meanings, to adjust to new issues and ideas as they emerge Contribute to the evolution of new theories Way of gathering information that is natural rather than artificial
Weaknesses	Rather inflexible and artificial Not effective in understanding processes or meanings associated with things by people Not very helpful in generating theories Much of the data may not be relevant to real decisions	Data collection can take time and resources Analysis and interpretation of data may be difficult, depending on the tacit knowledge of researchers Harder to control in terms of pace, progress, and end points May be undermined (low credibility), because of the apparently subjective opinions attached to them

Source: Adapted from Easterby-Smith, Thorpe and Lowe (2008)

Figure 3.1 - Strengths and weaknesses of quantitative and qualitative approaches

3.2 METHODOLOGY IN OPERATIONS MANAGEMENT

The essence of Operations Management research is connected with instances of real life operational processes and the redesign of these processes to improve quality and productivity. Following the contribution of the analysis of empirical data, Operations Management has become a functional field of study like Marketing and Information Systems (Forza, 2002). According to Swamidass (1991), there is a need for a deductive-inductive balance. OM research has been subjected to renewed attention to its 'practical contribution' to scientific knowledge. To meet these new demands, a new approach has been proposed, the theory-driven empirical research (Handfield and Melnyk, 1998). As pondered by the same authors, this emphasis on theory is critical if operations management is to continue evolving into a field of scientific investigation. A good theory, in this context, provides a framework for analysis, a better understanding about events and patterns of a particular field, and clear explanations for the pragmatic world (Wacker, 1998).

A research community should respect the strengths of the several 'styles' or methodological beliefs used by its members while developing research skills from different genres, quantitative or qualitative (Seale, 1999). This discussion resonates with a much broader view of methodology described by Mangan, Lalwani and Gardner (2004) that regards the researchers' choice between qualitative and quantitative as, often, unnecessarily limiting. In the present study, the researcher operates with a methodological pluralism directed to adequacy instead of ontological and epistemological limitations. Although, two main philosophical traditions exist and encompass distinctive features, the investigation of a problem leads to ways to fill in identified gaps in knowledge. In this case, the theory-driven empirical research seems to be an appropriate approach for the accomplishment of the study objectives.

3.3 RESEARCH DESIGN

The purpose of the research is to address the question of "how to incorporate human factors into the selection of AMT". The central interest for the researcher is, first, to understand which selection practices and appraisal techniques are currently used by companies, the people involved in the process and the criteria used to make the decisions. Therefore, a qualitative approach is used to gather data from the actual context of application. The interpretations associated with AMT and selection practices are important to frame this understanding. The effects from the social context where the research takes place are considered. The study seeks data to compose a framework to assess human factors involved in the AMT selection. The theoretical assumptions of the study will be tested 'in the field' and then refined to achieve the established goal. A theory-driven empirical approach is adopted.

The use of qualitative methods has been extensively documented by literature. Its importance as a learning process, more open and flexible by nature, has been identified (Blaikie, 2000). The proposition of the study is to provide a more comprehensive view of the phenomena to advance knowledge (Symon and Cassell, 2006). Nonetheless, the choice of a mainly qualitative approach to the study does not involve the disregard for other methods. A balance between inductive and deductive is proposed. From the research question, different strategies will emerge as pondered by Morrow (2007). Although the study begins inductively, as topics emerge they are compared with previous data. The cycle of induction and deduction, known as iteration, constitutes an emergent research design (Morrow and Smith, 2000). Researchers have found that this method attributes flexibility in the research design and assures the results are rich and descriptive from a more complete set of data (Morrow, 2007). The different phases of the research represent an iteration process that aims to obtain a more comprehensive and robust analysis of the data.

Considering that, the research seeks to propose a framework for the identification and evaluation of human factors relevant to the AMT selection process, a process-oriented definition of research is required. A process approach is used to address a process problem. The 'Cambridge Approach' (Platts, 1993) is used to operationalise the data collection through the specification of five key elements: purpose, point of entry, procedures, participation and project management. The prescription of the 5Ps proposed by Platts (1993) and Platts *et al.* (1998), and related to case and action research, represents another reason behind the use of the approach. The strategy recommended by the authors matches the qualitative orientation of the research. A summary of the elements of the approach is represented in Figure 3.2.

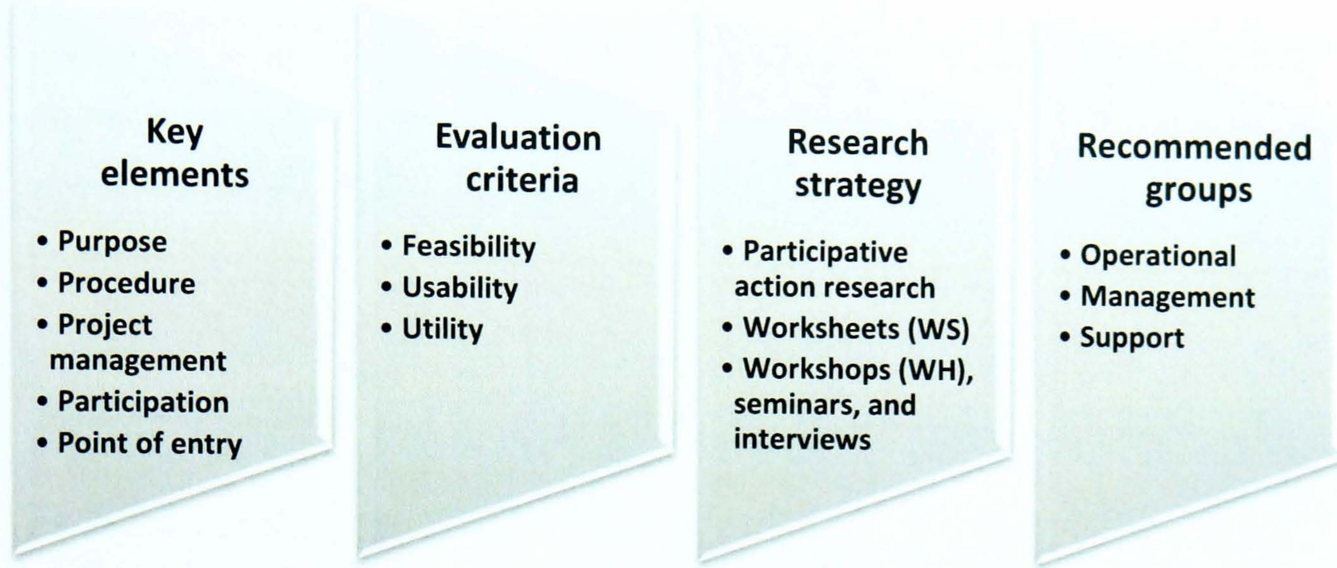


Figure 3.2 - The elements of the process approach

3.4 RESEARCH PROCESS

The design of the study defined in the previous section determines the research process envisaged for the thesis. As a theory-driven empirical approach is adopted, a life-cycle investigation is envisaged. This approach is compatible with the research approach suggested by Handfield and Melnyk (1998) and further developed by Voss, Tsikriktsis and Frohlich (2002). The study starts with a theory derived from past research rationalised from literature. The data is used to further build, test and modify the theory. The constant refinement of the theoretical assumptions aims to produce an 'improved' theory (Hanfield and Melnyk, 1998). Furthermore, it is important to mention that the research is a non-linear process and feedback points should be assumed; in this case, through iteration. The research process represented in Figure 3.3 applies the theory-driven empirical logic. The methods used for each phase are described and justified according to the research objectives, which are:

1. Investigate technology selection practices and appraisal techniques currently used (people, criteria, characteristics);
2. Develop a framework and a process to identify and evaluate human factors relevant to the AMT selection;
3. Apply and refine the proposed approach;
4. Test the applicability of the approach to the AMT selection decision.

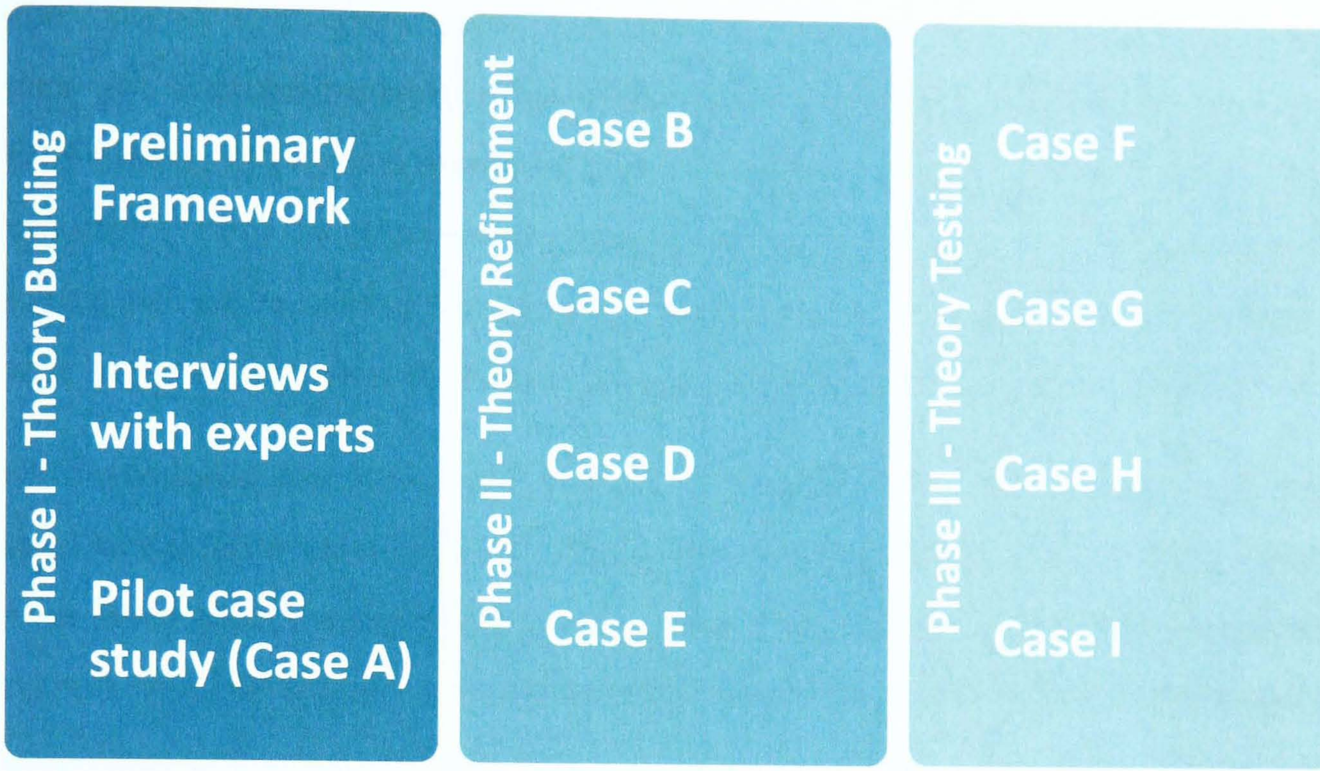


Figure 3.3 - The research process initially devised

3.4.1 Phase I: Theory Building

Initially, as the first objective suggests, a thorough literature review has to take place. From the 'conversation' taking place among academics in the field, the researcher will assemble the concepts in the scope of the human factors discussion. It is necessary to identify which factors are present in the topic's framework of analysis, common features and patterns amongst them. It is important to recognise how the literature deals with the human factors in the AMT selection, how they are identified, evaluated, and incorporated into the decision. This investigation is required to set the spectrum of existing strategies, methods and criteria currently used by practitioners.

In Phase I, a preliminary framework is used as a representation of the interaction among elements of the discussion of human factors. The framework "supports understanding and communication of structure and relationship within a system for a defined purpose (Shehabuddeen *et al.*, 2000, p. 2)". Berto and Nakano (1998) argue that the main goal of a conceptual framework is to produce, by capturing different ideas and opinions of different authors, a matrix of knowledge to solve a problematic, and compose a reference model. A framework is also less rigorous than a model and does not establish tradeoffs when dealing with theoretical relationships that may exist (Teece, 2007). The literature review is nothing more than a product of the reflections about the phenomenon being observed. It is used to propose a conceptual foundation and a context for the study. The framework is employed to establish a basis between the research and the current state of knowledge (Blaikie, 2000).

Semi-structured interviews with academics, industrialists and consultants are also used to compose the framework. The interviews have two purposes. First, obtain from researchers their opinions on the chosen methods and experiential insights on current research projects relevant to the problematic. The feasibility of the study is challenged and evaluated from their viewpoint. Due to the focus of the research on an empirical investigation of AMT selection practices and the human factors involved in the decision process, practitioners are interviewed. Initially, this aims to obtain their input on the variables involved in the AMT selection. An understanding of the way more intangible aspects such as the human factors are appraised in the process is sought. Secondly, the main objective behind a qualitative interview is envisaged, as proposed by Rubin and Rubin (1995), to obtain rich data to build theories that describe a setting or explain a phenomenon. In the theory building phase of the research, semi-structured interviews are used. The goal is to define the overall area of the study without being excessively structured (structured interviews) or without the focus attributed to depth interviews (Britten, 2006). Six interviews were conducted with academics from two universities (The University of Nottingham and The University of Cambridge); two interviews were conducted with industrialists and two realised with consultants. In total, ten interviews assisted in composing the preliminary framework, where the emphasis was placed on the desirable characteristics of an approach to the assessment of intangible aspects such as the human factors. A guide for the interviews with experts was developed (Appendix B).

Finally, a pilot case study is utilised to refine the data collection content and the use of the process approach elements. Yin (1994) explored the formatively use of pilot case studies where new lines of questioning may arise. The pilot case study (Case A) was conducted in Brazil, before the actual data collection. The convenience and the access were crucial points in determining the selection of the pilot test; some of the criteria for the selection of pilot cases suggested by Yin (1994). In addition, the research explores the human factors involved in the selection of AMT in developing countries, considering the specific characteristics of that context. Therefore, it was the appropriate choice of setting to conduct the pilot case study. After the case, the participants evaluated the application of the preliminary framework (Appendix C).

3.4.2 Phase II: Theory Refinement

The use of case studies is employed in Phase II for several reasons. Mainly, they constitute the most common research strategy used to penetrate the world of questions related to 'how' and 'why' phenomena occur. However, they allow the researcher with little control over a set reality to focus on contemporary real life situations. Case research constitutes a means to understand better social phenomena such as the selection of technologies for firms. In this sense, they are also adequate to situations when there are no clearly defined limits between phenomenon and context (Yin, 2003). In fact, the context-specific feature constitutes another reason behind the use of the technique. It generates a relatively full understanding of the nature and the complexity of a phenomenon by observing the actual practice (Voss, Tsikriktsis and Frohlich, 2002). Moreover, the case research allows the triangulation of information such as interviews, examination of documents and direct observation, to refine the content of the research and achieve the defined goals. In this research, different data sources are explored, including interviews with key decision makers, document analysis (budget forms, project reports, etc.) and observation. This research strategy provides a means of maintaining the unit of the study object and its characteristics of reality. Case research allows the comparison between the developed framework and the effective practice encountered inside companies.

As explored by Bryman (1989), one is not proposing to infer findings from a sample to a population, but engender patterns and linkages of theoretical importance. By using the case research, the study seeks to obtain, from the practice of selecting technologies, relationships and variables that impact on the evaluation of human factors. Case research allows the recognition of key variables, patterns, and reasons why those relationships exist, which is considered appropriate for the theory refinement phase. An approach of multiple case studies is adopted for the development of the proposed framework. The strategy is used due to its associated benefits such as enhancement of external validity and protection against bias. The number of case studies is also debated in the literature (Patton, 1990; Dyer Jr. and Wilkins, 1991; Perry, 1998). Eisenhardt (1989) suggests that the number of cases should be between 4 (four) and 10 (ten), to enable the researcher to justify the influence of the empirical data over the theory. Figure 3.4 shows the comparison of the different strategies, highlighting the approach chosen for the present study.

Choice	Advantages	Disadvantages
Single Cases	Greater depth	Limits on the generalisability of conclusions drawn. Biases such as misjudging the representativeness of a single event and exaggerating easily available data
Multiples cases	Augment external validity, help guard against observer bias	More resource needed, less depth per case
Retrospective cases	Allow collection of data on historical events	May be difficult to determine cause and effect, participants may not recall important events
Longitudinal cases	Overcome the problems of retrospective cases	Have long elapsed time and thus may be difficult to do

Figure 3.4 - Choice of number and types of case studies

Assessment interviews are conducted before the case studies. The interviews are part of the information gathering procedures in a case study (McCutcheon and Meredith, 1993). Key individuals are approached using, in general, open-ended questions. In this case, four cases preceded by assessment semi-structured interviews were conducted in Brazil. A guide for the assessment interviews was devised (Appendix D). The case research, however, also presents limitations, which are considered by the researcher. Often, the scientific rigour of the method is questioned due to the lack of structure attributed to many studies and the need for consideration of validity and reliability issues (Yin, 1994). McCutcheon and Meredith (1993) and Yin (1994) guide researchers in addressing those concerns. Figure 3.5 summarises these issues and the tactics suggested to deal with them.

Issues	Definition	Tactics
Construct and content validity	The extent to which the operational measure for a construct reflects the construct's observable effects, appears to describe a single construct and correlates with operational measures of the other constructs	- Use of multiple sources - Setting a chain of evidence - Review of preliminary versions of the final report by key-informants (data collection) - Use of multiple measures
Internal validity	It is concerned with whether the right cause-effect relationships have been established	- Pattern matching - Explanation building - Time-series analysis - Have more than one researcher assessing the information
External validity	The extent to which findings drawn upon studying one group are applicable to other groups or settings	- Replication logic through multiple case studies - Use of analytical generalisation not 'small-sample survey'
Reliability	The extent to which data would be duplicated if collected at another time or through other means	- Use of a research protocol - Development of a case study database - Use of more than one data gathering method - Return to check the reliability of the data

Source: Adapted from McCutcheon and Meredith (1993) and Yin (1994)

Figure 3.5 - Validity and reliability issues related to case research

In terms of construct and content validity, researchers have recommended that a clear chain of evidence should be maintained to establish how the researcher went from the initial assumptions to the proposed conclusions (Gibbert, Ruigrok and Wicki, 2008). In this case, the research benefits from the elements of the 'process approach' (Platts, 1993) to address this issue. By adopting procedures and utilising worksheets to record each step of the study, it is possible to preserve the sequence of events that took place in the data collection. Another tactic to deal with the construct and content validity issues is the review by key participants. In the study, the report on the findings is submitted for evaluation and approval. The internal validity is concerned with causal relationships established in the data analysis. Gibbert, Ruigrok and Wicki (2008) suggested the formulation of a clear framework to demonstrate how variables interact and influence each other. In addition, pattern matching, i.e., the comparison of empirical observations and studies in different contexts is used to address this issue. Similar studies in developed countries are utilised for comparison due to the equivalent logic of data analysis employed in those settings.

The external validity has to do with the generalisability of the results. Eisenhardt (1989) suggests the cross-analysis of multiple case studies to account for this concern. In the research, nine cases compose the analysis. One pilot case, four cases for the theory refinement phase and four companies are used in the testing phase. It is envisaged that the iteration exercise will also address this issue. Finally, the reliability represents a concern in case studies. For Healy and Perry (2000), reliability as a quality criterion for case research indicates it can be audited. The data collection should present what the authors named 'methodological trustworthiness'. The 'process approach' is applied to tackle this issue. Its dependency on the pre-development of a form of research protocol, containing the description of procedures and participation contributes to the reliability. Similarly, this strategy allows the creation of a small case study database, constituted by the worksheets used in the cases. The collected information is recorded and can be examined by the researcher and the participants to ascertain its reliability during the research process.

Concomitantly, action research (AR) was adopted for the refinement phase. It constitutes a recommendation by Platts (1993) when using the process approach as the study does. The strategy is adopted because, alongside the observation of a real setting, the researcher aims to propose a new framework. The approach is then evaluated by participants, according to its impact on the company. This feedback eventually leads to the development and refinement of the proposed approach. In this case, the researcher "imposes his conceptual frameworks on the tasks and interprets the events within these frameworks (Platts, 1993, p. 7)". Table 3.1 summarises the list of cases conducted in the theory building and refinement phases.

Table 3.1 - Case studies conducted in the theory building and refinement phases

Case study	Industry / Sector	Number of employees	Ownership	Turnover (£)	Size*
A	Metal-mechanic	1200	National (family)	24M	Large
B	Agro-industry	1600	National (family)	90M	Large
C	Automotive	5000	Transnational	1.2B	Large
D	Metal-mechanic	320	Joint-venture	14M	Medium
E	Metal-mechanic	101	National	7M	Medium

* The size of the firms was established according to the number of employees:
Less than 19 (micro), 20-99 (small), 100-499 (medium), more than 500 employees (large company).
Source: IBGE (The Brazilian Institute of Geography and Statistics)

Although action research (AR) is often seen as a variant of case research, the type of participation assumed by the researcher is different. The basic distinction is that the researcher involved in case research is an independent observer. The action researcher participates in the implementation of the system, evaluating the performance of the provoked change (Westbrook, 1995). The theory constitutes the starting point, but the practice leads to the revision of the initial theory. In this case, theory and practice collaborate to mould a practical framework for the assessment of human factors involved in the AMT selection. Both action and creation of knowledge and theory are sought (Coughlan and Coghlan, 2002). Furthermore, some of the AR characteristics contribute to the achievement of the study objectives. The technique is interactive, i.e., it involves the clients belonging to the studied system as co-researchers. A wider participation of actors set in a specific case study can enhance the study outcomes, making a more vivid and 'realistic' adaptation of encountered contingencies. A holistic understanding of reality is provided by considering the complexity present in a social environment (Coughlan and Coghlan, 2002).

Nonetheless, the method involves some issues. Coghlan (2001) describes three main challenges when using action research: pre-understanding, role duality and organisational politics. The pre-understanding refers to the knowledge, insights and experience of the researcher before conducting the study (Gummesson, 2000). It presents some advantages such as the knowledge on informal networks, critical events, and the way they influence the phenomenon being studied by the manager-researcher. The researcher can also use her/his insider's knowledge to obtain richer data (Coghlan, 2001). Simultaneously, these advantages can become drawbacks if too much is assumed from the data collection due to this familiarity with the organisational 'rituals'. In the present study, the researcher is an outsider, which partially accounts for this concern. However, according to Gummesson (2005), the experience of a single researcher may also attribute some bias represented by the researcher's subjectivity and personality. The role duality somewhat derives from the pre-understanding issues for insiders, when conflicts of loyalty, identification, and behaviour may be generated. The same with the organisational politics; the manager-researcher proposing the change should be capable of 'working the political system' (Coghlan, 2001). Considering the research is concerned with the development of a framework that will be used by managers, these drawbacks may negatively affect future applications. Thus, the principles of the process approach are used to establish a consistent set of procedures and evaluation criteria that can mitigate these issues.

3.4.3 Phase III: Theory Testing

Although, case research and action research are also adopted for the theory testing phase, a different objective is envisaged. In the second phase, the aim was to develop the proposed framework and the associated process through multiple case studies. The iteration present in that phase contributed to the identification of improvement points from the feedback of participants. In the third phase of the research, the performance of the refined approach is evaluated. The appropriateness and the practical relevance of its assumptions are once again assessed. Furthermore, it is important to highlight that one of the companies that had been previously used in the theory building phase was approached to test the modified framework. The contrast between the two experiences is analysed to enrich the feedback on the applicability of the approach after its first application 'in the field' and refinement.

Apart from testing the approach, in this phase, 'theoretical redundancy' (Lincoln and Guba, 1985) or 'data saturation' (Eisenhardt, 1989) is observed. According to the concept originally proposed by Glaser and Strauss (1967), theoretical redundancy occurs when no additional data emerges "to develop properties of a conceptual category (Harris, 2008, p. 39)". However, as argued by Guest, Bunce and Johnson (2006), there is little practical guidance on when the saturation is reached in terms of a sufficient number of case studies or interviews. Nevertheless, the authors highlighted three important features for qualitative field methods and the achievement of saturation. In the study, an adaptation of these items is proposed to accommodate the methods adopted in the research process. The saturation point depends on the structure and the content of the methods and the participants' homogeneity (Guest, Bunce and Johnson, 2006). The field methods should be well structured. Data saturation may never being reached if a constant stream of new elements is introduced during the process. Second, the more widely a phenomenon is known and has been experienced, the fewer individuals will be necessary to provide a meaningful understanding on its nature. Third, the similarity of the participants' experiences collaborates to reaching the saturation point. In the present research, a common framework is applied through a process across case studies. A structured set of assumptions is proposed, tested and evaluated by participants. Simultaneously, semi-structured assessment interviews are conducted. The firms selected for the refinement and testing phases have significant experience with AMT acquisitions. The participants are familiar with technology selection processes and employ specific decision-making practices to address them. Finally, participant companies are medium and large enterprises that belong to the same region of Brazil, sharing a similar development path that attributes sufficient homogeneity. Table 3.2 summarises the list of cases used for the final testing of the approach.

Table 3.2 - Case studies conducted in the theory testing phase

Case study	Industry / Sector	Number of employees	Ownership	Turnover (£)	Size
F	Industrial Equipments	152	National	£12M**	Medium
G	Hydraulic jacks	500	National	£19M	Large
H	Sound Equipments	380	National	£24M**	Large
I	Agro-industry	1600	National (family)	90M	Large

** It indicates profits per month multiplied by 12 months

3.4.4 Evaluation Criteria

The performance of the proposed approach is assessed. Platts (1993) prescribes three criteria for this evaluation. The feasibility relates to whether the process can be followed. Usability verifies how easy it is to use the process and utility assesses whether the process produces useful results for managers. Three questionnaires were employed to conduct this evaluation. The tool design is based on previous applications and developments by other researchers (Maslen 1996; Cáñez, 2000; Tan, 2002). From its application across several case studies, they were modified to deal with the specificities of the research (Appendix E). A questionnaire was applied after each stage of the process to collect the opinions of participants and collaborate to the refinement of the approach. In addition, two other questionnaires aimed to evaluate the general utility of the process (Appendix F) and the overall process (Appendix G) were utilised. The latter was adopted from Tan (2002). In that case, it was used to assess the process facilitation, since an independent facilitator was used to enhance the feasibility of the proposed approach. In the current research, however, the use of an independent facilitator was not possible. Nonetheless, the instrument was adjusted to assess the overall perception on the quality of the process, the impact of the facilitation, and gather suggestions on improvements and further feedback on the main difficulties encountered in the process. The criteria were divided into sub-criteria (Figure 3.6). The evaluation of the participants was collected through a four-point category scale (very, quite, somewhat and not at all).

Criteria	Sub-criteria
Feasibility	Participation
	Availability of information
	Timing
Usability	Clarity
	Ease of use
	Appropriateness
Utility	Relevance
	Usefulness
	Facilitation
	Confidence

Figure 3.6 - The evaluation criteria and sub-criteria

The feasibility relates to the information availability, the appropriateness of the time scheduled for the activities and the required mix of participants. Usability is composed by the clarity of concepts and activities, the ease of use and the appropriateness of the activity or stage for the desired outputs. Relevance, usefulness, facilitation and level of confidence compose the utility criterion. The relevance and usefulness relate to the achievement of the stage or overall process objectives through the performed activities. The facilitation refers to the facilitator's ability to assist in the performance of activities and the communication of concepts and expected outcomes. The level of confidence represents the confidence in the results in a percentage scale between 0 (zero) and 100% (one hundred percent). Using a separate evaluation form, the general utility of formal and informal outcomes and the quality of analysis and operationalisation were further assessed. This evaluation relates more specifically to the contribution the research aims to provide, being useful for managers to assess human factors involved in the AMT selection.

3.5 CONCLUSION

The research process involves three different phases for the study of the assessment of human factors involved in the selection of AMT. Phase I corresponds to the theory building phase, when concepts and variables related to the assessment of the human factors are investigated. From the exam of the literature, interviews with experts and a pilot case study, a preliminary framework is developed. Phase II involves the application of the framework 'in the field', seeking to develop the theory from case studies and action research. In Phase III, the developed framework is applied through case studies with action research to test its practical relevance, observing the saturation point of the theory-driven empirical investigation. It is important to highlight that especial attention is paid to validity and reliability issues and challenges related to the research methods. Strategies are adopted to address them. Alongside its emphasis on a practical application, the study requires scientific rigour to compose a 'good theory' and add to the Operations Management body of knowledge. As Lewin (1945, p. 129) summarised in the past, "nothing is as practical as a good theory", considering the research objectives and the proposed contributions of the study.

CHAPTER 4

THE PRELIMINARY FRAMEWORK

Chapter 2 elaborated on the need for a framework for the identification and the evaluation of human factors. Whereas in Chapter 3, the research methods used to operationalise the study were described and justified. Chapter 4 introduces the theoretical assumptions that underpin the preliminary framework. In addition, the input provided by the interviews with academics, industrialists, and consultants and a pilot case study is discussed. The feedback from the interviews with the experts and the learning from the case study were used to develop the approach. A modified version of the framework based on the initial empirical studies is also presented.

4.1 THE PRELIMINARY FRAMEWORK

The theory building phase of the research includes the development of a preliminary framework, interviews with experts, and a pilot case study. A framework is used to represent the elements involved in the analysis of the human factors relevant to the AMT selection. Considering the research focus on the pre-installation phase of the technology adoption, two steps compose the AMT selection: strategic planning and justification. After the initial planning, it is possible to identify the technologies that can fulfil the set objectives and the level of integration required for the manufacturing system (Chan *et al.*, 2001). The core of the planning is to develop an integrated systematic business plan based on the company's objectives (Small and Yasin, 1997b). AMT justification represents the second step towards the selection of technologies. It involves the evaluation of economic and strategic benefits, and implementation factors associated with the technology alternatives (Voss, 1988).

While economic benefits are more easily quantifiable, the strategic and human factors are regarded as intangible by the nature (Kaplan, 1986; Sambasivarao and Deshmukh, 1995). However, as explored in the literature review, the identification and the evaluation of human factors is necessary to reap the benefits expected from these advanced manufacturing technologies. The impact of involved factors is anticipated for the evaluation of technology alternatives (Choudhury, Shankar and Tiwaria, 2006). After the identification and application of the evaluation criteria, companies usually establish performance measures to audit the system (Small and Chen, 1997). This is constituted by the acknowledgement of the expectations from different departments related to the new system. The technology choice is, therefore, a product of the expected benefits, involved factors and the quality of the organisational preparation and support for the technology (Small and Yasin, 1997a). Figure 4.1 represents the preliminary framework, based on the review of relevant literature. Interviews with academics, industrialists and consultants were used to develop further the initial framework. Section 4.2 briefly describes the structure and the objectives associated with the interviews with academics and practitioners.

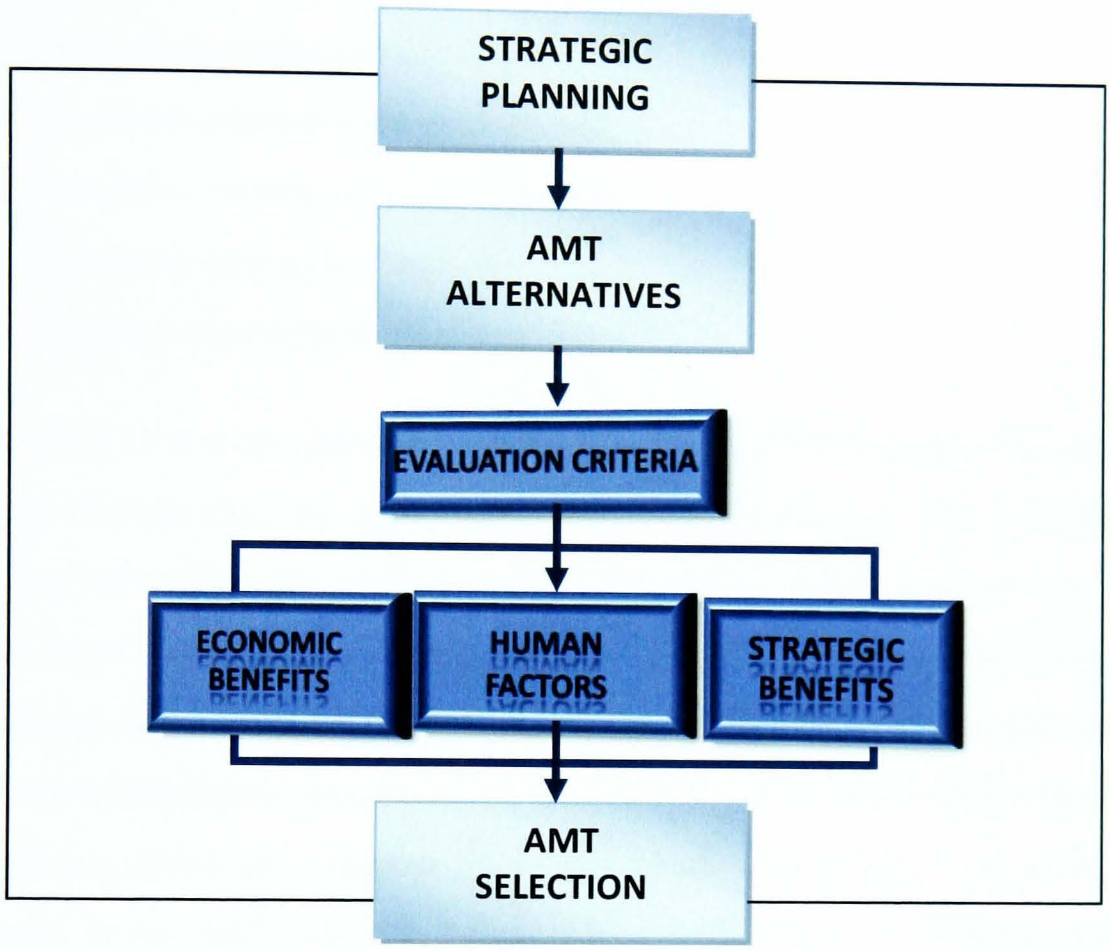


Figure 4.1 - The preliminary framework

4.2 INTERVIEWS: STRUCTURE AND OBJECTIVES

As previously stated, ten semi-structured interviews were conducted in the theory building phase of the research. Three members of the faculty of the University of Nottingham and three academics from the University of Cambridge and its Institute for Manufacturing were interviewed. Moreover, two industrialists (senior managers of two companies) and two consultants of technology management were approached and provided feedback on the preliminary framework. A guide for the interviews was sent in advance to focus the discussions and use the time available for the meetings more efficiently (Appendix B). The interviews covered 8 (eight) main themes:

1) Background information and expertise;
2) Current research projects/identified gap in research;
3) Literature review;
4) Research question and aims;
5) Questions related to the framework;
6) Questions related to the contribution;
7) Questions related to the scope;
8) Suggestions and further comments.

Questions 1 to 8 were posed to academics. The questions aimed to challenge the research process and the logic used in the development of the framework. It is important to assess the relevance of its content and the value of the proposed contributions. Questions related to 'framework', 'contribution', 'scope' and 'suggestions and further comments' were posed to the industrialists and consultants. Issues more specifically related to the proposed approach were explored with those practitioners, since the research aims to develop a practical framework to assist managers in the AMT selection decision. A PowerPoint presentation preceded the interviews to support their understanding and facilitate the grasp of the concepts discussed in the research. The contribution was evaluated in terms of relevance to the current state of knowledge and practical utility for managers. The scope of the research was explored according to the time available for the study, research objectives, and proposed contributions. The feedback provided by the interviewees and the modifications applied to the initial framework are discussed in Section 4.3.

4.3 FEEDBACK FROM THE INTERVIEWS

The interviews with academics demonstrated that the research is relevant to the study of the AMT selection process. According to the researchers, the identification of the criteria to evaluate competing AMT alternatives is a troublesome task. The interviewees highlighted that there are difficulties to assess more intangible factors such as the strategic benefits and the human factors involved in the selection decision. In this sense, it was suggested that the research should focus on the human factors. In the opinion of the researchers, strategic and economic benefits have been extensively covered by literature; whereas, human factors influencing the AMT selection have been overlooked. Hence, the study could provide a more relevant contribution by assessing the human factors involved in the acquisition decision.

Moreover, the limited time of the PhD studies requires the focus to be narrowed down. The strategic planning should be out of the scope of the study, since it takes place before the selection decision-making process. The academics pondered that objectives for the acquisition are devised from the planning. A number of technology alternatives are then gathered through market perusal and benchmarking based on these objectives. The assessment of human factors, therefore, depends on the acquisition objectives and the perception of their achievement through the available AMT. Two main processes should be part of the framework, the identification and the evaluation of human factors. The researchers indicated that the assessment of human factors depends on a structured identification process. Examples collected from literature could trigger this process. After the identification, managers should be able to quantify these factors to incorporate them into the decision. A robust method should be proposed for this quantification. It should be easy to use and understand. The use of a simple scoring method and an analytic approach to the evaluation of human factors were suggested as means to compare the AMT options.

The interviews with industrialists and consultants reinforced the relevance of the study for the decision practice. According to the industrialists, evaluation methods tend to address strategic and economic benefits, but frequently ignore human factors. Therefore, a framework to assess these factors is considered useful for managers given their importance. Regarding the evaluation of AMT alternatives, the complexity of methods constitutes another hurdle. The proposed approach should be translated into a decision aid easy to use. Two consultants specialised in technology management were also interviewed. For these practitioners, the involvement of key stakeholders should be associated with the approach. Usually, the decisions are made by the top management and boards of directors without the participation of other interested parties. This tends to interfere negatively in the implementation of new manufacturing technologies, affecting the commitment to the change. The ease of use was also mentioned as a desirable characteristic for the framework.

Table 4.1 - Feedback from interviews and changes applied to the framework

Learning points	Feedback from interviews	Modifications applied to the framework
Input for the framework	- The strategic planning should be assumed; - Acquisition objectives are used to select the technologies; - A number of AMT alternatives are usually available.	**AMT alternatives constitute the initial input and the acquisition objectives 'guide' the selection**
Evaluation criteria	- Strategic and economic benefits have been extensively researched; - The study should focus on the human factors.	**The assessment of human factors represents the research focus and the evaluation criteria explored in the framework**
Required processes	- The assessment of human factors depends on their identification and evaluation.	**The identification and the evaluation of human factors constitute the main processes in the framework**
Identification of human factors	- The identification should be structured and examples could be used to trigger the process.	**Examples of human factors collected from literature are used to trigger the identification**
Evaluation of human factors	- A robust method for quantification should be used; - Simple scoring methods and analytical approaches were suggested.	**A simple scoring method is being employed for the evaluation of human factors**
Suggestions and further comments	- The approach should be easy to use and understand; - It should involve key stakeholders and seek consensus; - A process should be used to apply the framework.	**These points are regarded as desirable characteristics for the framework application**

Finally, the interviewees suggested that a process should be used to apply the framework. It should conduct the application and seek consensus on the selection decision. Similarly, the existence of a process could improve the practical relevance of the study. The 'process approach' developed by Platts (1993) that had been adopted to operationalise the study was suggested for this purpose. Two of the academic interviewees remarked that it encompasses elements suitable to operationalise the framework. At the same time, the approach provides criteria to evaluate its practical performance. The feedback from the interviews generated a list of learning points used to develop the approach. These points and the associated modifications applied to the framework are listed in Table 4.1. A summarised version of the feedback from the interviewees can be found in Appendix H (academics) and Appendix I (consultants and industrialists). The framework modified according to the obtained feedback is represented in Figure 4.2. Following the interviews with experts, the approach was tested through a pilot case study. Section 4.4 describes the application of the framework in a manufacturing industry in Brazil. The case learning and the implications for the development of the approach are discussed.

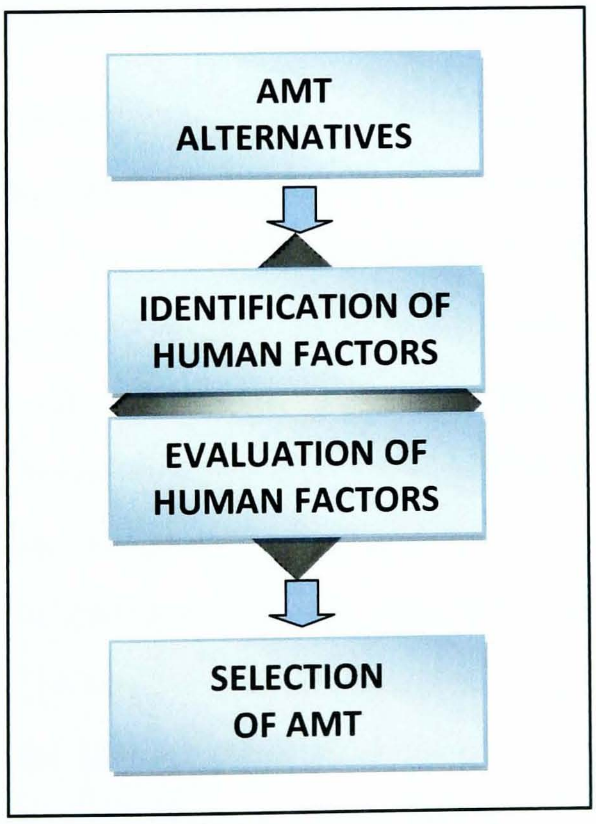


Figure 4.2 - The framework modified after the interviews with experts

4.4 THE PILOT CASE STUDY

Further to the feedback provided by the interviews, a pilot case study was conducted to verify the applicability of the framework. Case A corresponds to a Brazilian manufacturing company in the metal-mechanic sector; it was founded in 1946. The industry operates in three distinctive business units: assembly, exportation, and replacement parts. Spare parts for heavy trucks constitute the main product manufactured by the company and clients include Caterpillar, Perkins, Volvo, and Scania. Recently, the company experienced an increased demand for its products; leading to a general growth rate of 30% in 2007 (the market expected rate was 8%). Such unexpected demand and its strategic expansion plan led to the search for a new melting and milling unit, which was acquired in 2007. The researcher initiated the contact with the Engineering Manager and the company's CEO. A meeting was held with the Engineering Manager and an 'assessment interview' conducted in order to a) understand the company's decision-making practices; b) collect some general information on recent AMT selection decisions and adopted evaluation methods; and c) present the framework and convince the executives of its value. The feedback from the interview was positive and the company agreed to test the approach.

After two weeks, the researcher was back to trial the framework (Case Study A). The company was keen to experience an alternative perspective related to its technology selection. The stakeholders were interested in being able to identify implementation factors that could have been overlooked when the previous evaluation processes took place. In addition, the fact that the firm was eager to test current academic work related to new decision-making techniques and management improvements contributed to its commitment and participation. A group composed by the Engineering Manager, the Internal Consultant for Planning associated with the Board of Directors, and the Expansion Project Manager analysed the approach. The framework was used for the selection of a new melting and milling unit. The researcher acted as facilitator and made a short initial presentation on the study.

4.4.1 The Identification of Human Factors

The proposed framework and the rationale behind it, including the meaning of human factors in the study and their importance for the AMT selection, were described. This initial presentation was helpful in defining key concepts that the company had superficially approached in previous selection decisions. After that, a discussion was carried out to gather further information about the selection process, and the objectives for the AMT acquisition. A more comprehensive way of looking at the AMT adoption decision-making was proposed. The human factors associated with the acquisition should be assessed for the AMT selection. A brainstorming session was promoted to assist the members of the group in identifying the objectives for the AMT acquisition. Five objectives were listed by the decision makers:

1. Adjust the manufacturing capacity to the current and the planned demand;
2. Better qualify the labour force;
3. Update the technology related to the melting manufacturing process;
4. Improve the conditions of the work environment to retain labour; and
5. Maintain the company's position in its market.

However, from the five listed, one objective was chosen as the most important and the main driver for the evaluation and the selection of technologies. The objective selected was the 'Technology Update' to cope with the growing demand and keep the good positioning the firm has acquired through the years. The abbreviation 'TU' was used to designate this acquisition objective. Having identified the key objective, managers were asked to describe the human factors related to the decision. The group listed some factors and attributed points to them. A simple scoring method was proposed to evaluate the human factors associated with the selection decision. One (1) point was attributed to the human factors that affect the achievement of objectives in the short term and two (2) points were attributed to the factors, which provide a long term impact. Some of the factors were designed as having both a short and a long term nature, thus receiving both scores. Figure 4.3 presents the human factors identified by the members of the group and correspondent scores.

Objective: Technological Update (TU)			
Description of human factors	**Short term**	**Long term**	**Total**
Improvement of working conditions	*	-	1
Keeping market flexibility	*	**	3
Lower exposure to labour unrest	*	-	1
Better manufacturing management	*	**	3
New opportunities for professional qualification	-	**	2
Learning related to environment safety	*	**	3
New opportunities for design development	*	**	3
Improvement of the collaborators' satisfaction	*	**	3
Improved strategic management	*	**	3
Total Score	**8**	**14**	**22**
Key: * = 1 point; ** = 2 points; - = no points			

Figure 4.3 - TU objective and associated human factors

4.4.2 The Evaluation of Human Factors

Following the identification of human factors, the technology alternatives were evaluated according to their ability to address them. The group members designated the technologies as alternatives A, B, C, and D, corresponding to the four types of AMT collected through benchmarking and market perusal. The ultimate goal of this evaluation was to check the correspondence between the human factors involved in the decision and their perception of achievement through the available alternatives. Hence, the score associated with a particular human factor was attributed to the technology the decision makers perceived was capable to address that human factor.

Alternative A obtained the highest assessment score and it was regarded as the best alternative. Figure 4.4 shows the score assigned to each AMT alternative.

Objective: Technological Update (TU)				
Description of human factors	**A**	**B**	**C**	**D**
Improvement in working conditions	*	*	*	-
Keeping market flexibility	*	-	-	*
Lower exposure to labour unrest	*	*	*	-
Better manufacturing management	*	*	*	*
New opportunities for professional qualification	*	*	*	*
Learning related to environment safety	*	-	-	-
New opportunities for design development	*	*	*	*
Improvement of the collaborators' satisfaction	*	*	*	*
Improved strategic management	*	*	*	*
Total Score	**22**	**16**	**16**	**17**
Key: * = 1 point; ** = 2 points; - = no points				

Figure 4.4 - The evaluation of human factors and AMT alternatives

After the evaluation of alternatives based on the human factors, the group revisited the identification and the assignment of scores to confirm or correct the findings. The consensus was sought for that matter. The company had based its decision on a few relevant items, i.e., economic benefits that included increased productivity, reduced labour force costs, reduced scrap rate, and reduced operational costs. The results showed that the four AMT alternatives provided similar economic benefits in terms of revenue increment. However, Alternative A could better collaborate to the achievement of objectives by addressing the identified human factors. Considering the assessment of human factors, Alternative A was confirmed as the most adequate. The results from the case were recorded and made available to the stakeholders. The list of human factors and the evaluation process associated with the 'winning' option and the competing alternatives was provided through a report of the findings.

4.5 LESSONS LEARNT FROM THE PILOT CASE STUDY

After the case, an evaluation worksheet was distributed to the group members to seek their feedback on the framework (Appendix C). The approach was evaluated in terms of feasibility, usability, and utility (see Chapter 3). A high score was obtained, indicating the framework as quite easy to understand and clearly defined. The collaborators remarked that it improved their confidence in strategic decision-making. The participants felt enabled to include new aspects not usually considered in the AMT selection process. In addition, the framework demonstrated that it was possible to identify and quantify more intangible attributes involved in the decision. The degree of confidence in the approach, according to the participants, provided a strong encouragement towards the development of the approach (82% in a scale from 0 to 100%). Nevertheless, some shortcomings were indicated regarding the identification and the evaluation of human factors, and the framework application.

The identification of human factors correspondent to the acquisition objectives was a particular up-hill task. The participants suggested that categories of human factors should be proposed. These categories could clarify the definition of human factors and facilitate this step. Moreover, a database of human factors could be made available for future decisions. Greater effort, therefore, will be employed to present categories of human factors for future applications. Although the evaluation of technologies based on the human factors was considered consistent with a broader view of the AMT adoption, the 'measurement' of factors still needs considerable work and improvement. The practical performance of the framework is associated with a reliable way of assessing the technologies' potential. A simple scoring model was regarded as excessively simplistic to evaluate these intangible factors. In order to address this issue, the prospective use of analytical approaches identified in literature was mentioned to participants. Methods such as Taguchi's Loss Functions were discussed with the decision makers, especially those with an Engineering background and familiar with the tool as a quality control procedure. Positive feedback was attained, indicating a possible alternative to compose a more robust approach.

Finally, the participants indicated that some activities could be performed simultaneously, making the assessment of human factors more appealing. A process is needed to apply the framework and facilitate the participation of decision makers. A consistent series of activities could improve the level of discussions by involving appropriate decision makers to perform them. An easy and coherent process should be developed to apply the framework. This point relates to the feedback provided by the interviews with experts under the heading 'suggestions and further comments' presented in Table 4.1. Thus, the 'process approach' used in the research operationalisation and suggested by interviewees is also employed to apply the framework. The developed process is described in detail in Chapter 5. The next chapter initiates with a summary of the findings associated with the review of literature, the interviews with experts, and the pilot case study. Although no changes were made in the framework as a result of the pilot case, the lessons learnt in the study constitute part of the input from the empirical studies. The framework after the initial empirical studies is reproduced and briefly discussed in Chapter 5.

4.6 CONCLUSION

A preliminary framework for the identification and the evaluation of human factors was presented through Chapter 4. Interviews with experts were used to develop further the approach. The feedback from the interviews generated a list of key learning points, which led to the first refinement applied to the framework. In consequence, a modified framework was proposed. Following the interviews, a pilot case study was conducted and the learning from the case discussed. Chapter 5 describes the development of a process to apply the proposed framework. The actions to refine the approach based on the learning from the findings of the theory building phase are highlighted. The process is described in detail within the chapter.

CHAPTER 5

THE PROPOSED FRAMEWORK AND PROCESS

Chapter 4 introduced the theoretical assumptions that underpin the proposed framework. In addition, the input provided by the interviews and a pilot case study were discussed. The initial empirical studies provided the first refinement applied to the preliminary framework. Chapter 5 explains and represents the modified framework and elaborates on the process developed for the field applications. The learning from the empirical studies and the process approach adopted for its development defined stages and activities. The process is described in detail in terms of input, activities and expected outcomes. Furthermore, the time necessary for its application, the procedures, and the required team of participants are explained.

5.1 THE PROPOSED FRAMEWORK

The literature review revealed that an approach containing specific characteristics is necessary to assist managers in assessing human factors. A framework should be developed to identify and evaluate human factors involved in the AMT selection decision. Secondly, it should establish a common measure to compare different technologies. Third, key stakeholders should be involved in the decision and, fourth, it should provide consensus in the prioritisation of AMT alternatives. Based on these features, a preliminary framework was devised. Initial empirical studies represented by interviews with experts and a pilot case study (Case Study A) were used to further develop the proposed framework. The interviews indicated that the AMT selection decision is guided by objectives established by a firm's strategic planning. This process usually takes place before the identification of a set of technology options. The planning generates the acquisition objectives. Considering these objectives, AMT alternatives are initially pre-selected through market perusal or benchmarking. Thus, acquisition objectives should represent the main driver for the identification of human factors. Available AMT should be evaluated according to their potential to address relevant human factors. A structured identification and a robust evaluation stage are deemed essential to produce meaningful guidance for managers.

Additional desirable characteristics for the approach were indicated by interviewees. It should be easy to use and key stakeholders should participate in the selection decision. A process is considered necessary for the application of the framework. The 'process approach' (Platts, 1993) was suggested for this operationalisation. Alongside the interviews with experts, a pilot case study assisted in the development of the framework. A brainstorming session was conducted to list the AMT acquisition objectives and the involved human factors. Participants of the case study suggested the existence of categories of human factors as means to facilitate the identification and turn the task into a more structured process. According to the group, this would trigger the identification effort and contribute to the understanding of concepts.

Table 5.1 - Input from the literature review, interviews and pilot case study

Topics	Literature Review	Interviews with Experts	Pilot case study (Case A)
Driver for the assessment of human factors	Strategic planning	Acquisition Objectives	Acquisition objectives
Initial input	Strategic planning and AMT alternatives	AMT alternatives	AMT alternatives
Evaluation criteria	Strategic benefits Economic benefits Human Factors	Focus on human factors	Focus on human factors
Required Stages	Identification Evaluation Prioritisation	Identification Evaluation	Identification Evaluation
Identification	The identification is vital, a structured framework is necessary	Structured identification step	Categories of human factors should trigger the identification
Evaluation	Analytical approaches seem suitable; Establish a common measure for comparison	A robust method for quantification is needed; It should be easy to use and understand	A robust method is required for meaningful quantification
Additional Characteristics			
Participation	Involvement of key stakeholders	Involvement of key stakeholders	Involvement of key stakeholders
Expected outcome	Consensus on the prioritisation of AMT alternatives	Consensus on the selection of AMT	Consensus on the selection of AMT
Application	A practical framework to assist managers should be proposed	A process is needed to apply the framework; The 'process approach' was suggested	A process is needed to apply the framework and be useful for managers

Table 5.1 summarises the input obtained from the literature review, interviews and pilot case study. As for the evaluation of identified factors, a simple scoring method was proposed. However, the method was regarded as rather simplistic and a more

robust approach was deemed necessary. Analytical approaches were discussed with the group and highlighted as a potential alternative to evaluate human factors and technology options. Specifically, the Taguchi Loss Function was explored as a viable method, since its principles relate to the definition of a common magnitude used in the comparison of options. In addition, the tool showed to be appropriate for the 'quantification' of intangible aspects in previous studies (Pi and Low, 2005; Attavale, Bland and Kethley, 2008, Ordoobadi, 2009a). Given the positive feedback obtained from academics, practitioners, and participants of the pilot case study, the evaluation method will be further explored in the initial testing of the approach. Finally, after this assessment, the AMT prioritisation and the selection decision would be made possible. The need for a process to apply the framework was reinforced by Case A. The study demonstrated that the usefulness of the framework for decision makers is linked with providing a practical decision aid built on consensus. The robustness of the approach and its performance in the field were especially valued by companies. Figure 5.1 represents the framework after the input of the initial empirical studies. The process developed to apply the framework is described in detail next.

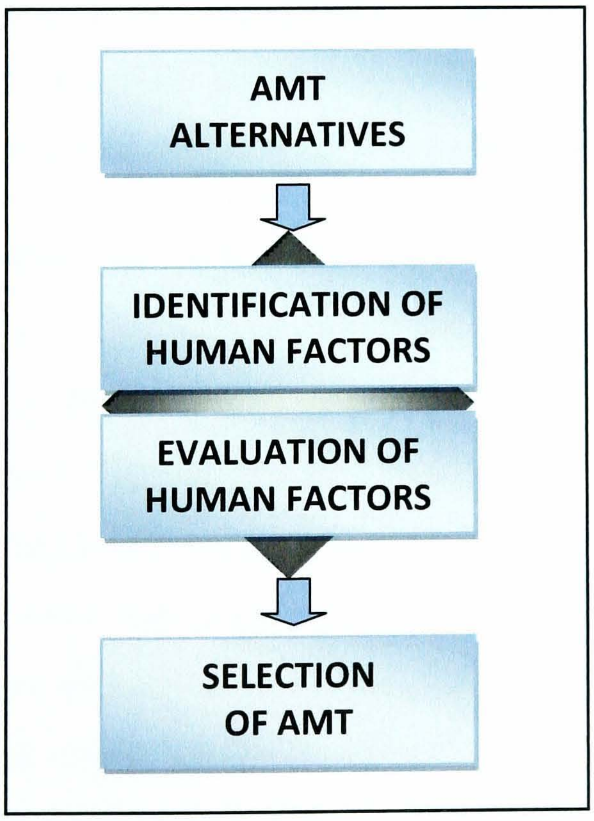


Figure 5.1 - The proposed framework after the initial empirical studies

5.2 THE PROPOSED PROCESS

The 'process approach' developed by Platts (1993) is used to operationalise the framework (see Chapter 3). As suggested in the initial empirical studies, its elements are considered suitable to apply the framework. The approach is defined by 5Ps (Platts *et al.*, 1998): Purpose, Procedure, Project Management, Participation, and Point of Entry. The purpose sets the objectives behind each stage, expected outcome and importance within the scope of the overall process. The procedure relates to the specification of logical steps for information gathering and analysing, and the identification of improvement opportunities. Tools and techniques corresponding to the procedures should be simple and easy to understand whilst maintaining reliable written records of the results of each stage. Project management aims to warrant the resources required for the process and the adequate time to perform the activities, according to plan. Three types of resourcing are suggested by Platts (1994), a management, a supporting and an operating group. The management group ascertains the project progresses while the supporting group addresses the necessary expertise. The latter is usually represented by one person, the facilitator. The operating group is concerned with the actual performance of activities. The Point of Entry is necessary to introduce the process, its objectives and assumptions. It seeks to publicise it and obtain the commitment of the management and operating groups.

Apart from these elements, the 'process approach' encompasses strategies used in the manufacturing audit (Platts and Gregory, 1990). Activities prescribed in the process are performed during workshops (WH) using a seminar format and worksheets (WS) to record the collected information. Interviews with key actors are also employed in the data gathering. The process is evaluated by participants after each stage in terms of feasibility, usability and utility. In this case, the approach is adjusted to the research objectives and the proposed framework. The developed process comprises three stages. The first stage corresponds to the identification of human factors. The evaluation of human factors represents the second stage, that is, the quantification of these factors to be incorporated into the decision. Finally, the third stage involves the prioritisation of technology alternatives after the assessment of human factors. Two hours are estimated for the completion of each stage. One hour is reserved to provide feedback on the results to the company and gather impressions and suggestions related to the approach. Thus, the process requires a business day of 7 (seven) hours, from 9AM until 5PM, with one hour break between 1PM and 2PM. Seven worksheets are used to record each of the activities prescribed in the process. Four workshops are realised, one workshop in each stage and a final session for the feedback on the results and the process evaluation. Figure 5.2 represents the proposed process, its schedule, stages, activities and worksheets. A detailed description of the each stage and correspondent activities is found next.

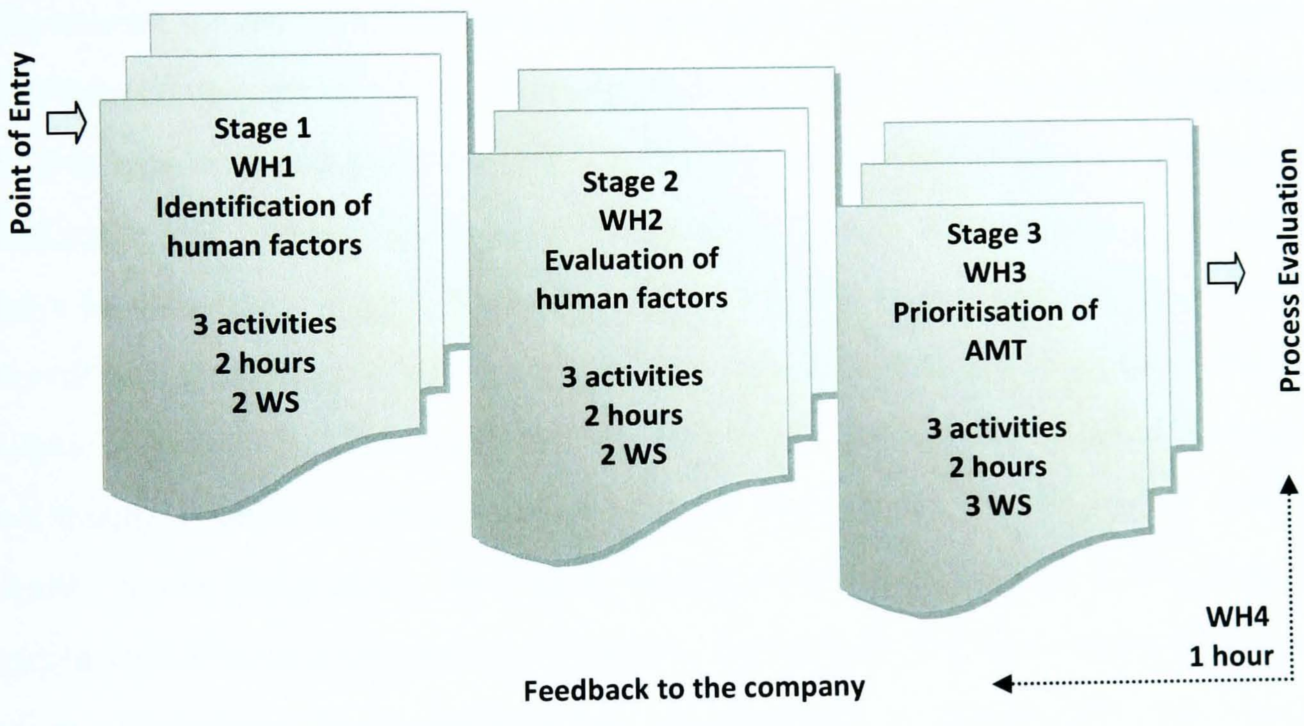


Figure 5.2 - The proposed process

5.2.1 Point of Entry (Stage 0)

The point of entry or Stage 0 constitutes the communication to stakeholders of the process objectives, expected benefits for the company, inputs and outputs, different stages and activities to be performed. A workshop takes place with the involvement of the facilitator (represented by the researcher), the top management, and key stakeholders. It is necessary to publicise the process to achieve understanding, commitment, and participation. As established through the literature review and reinforced by the interviews, key stakeholders should be involved in the decision. At this point, a multidisciplinary team of key participants is selected to represent the operational group, which performs the activities of the process. In the study, this group is also responsible for the project management, ensuring inputs and outputs of the process are obtained, and activities are executed according to plan. This new group was named 'co-ordination group'. The supporting group is represented by the researcher, who acted as facilitator in the process application. The activities are recorded through worksheets as recommended by Platts and Gregory (1990).

Similarly, the consensus on the decision was regarded as a specific characteristic the framework for the identification and the evaluation of human factors should seek. A multidisciplinary group serves this purpose. Platts (1994) indicates that the existence of this type of group performing the activities in workshops provides a medium for discussions of different opinions. This contributes to the achievement of consensus prior to subsequent stages. Moreover, the seminars represent an open forum for the correction of eventual mistakes in the data collection. The group gathers different types of knowledge from participants, which can benefit the decision. Finally, it attributes a sense of process ownership and commitment to the results. A team leader is also designated. This figure, usually a senior manager or a firm director, guarantees the attendance of participants, making sure the time required for each stage is reserved. Four professionals are proposed as participants: the Human Resources Manager, the Production Manager, the Production Supervisor, and the Team Leader. Evaluation forms are distributed after each stage to assess the feasibility, usability, and utility of the process (see Chapter 3).

5.2.2 Stage 1: Identification of Human Factors

Participants of the pilot case study suggested that the existence of categories could facilitate the identification of human factors. From the reviewed literature, three main categories of human factors were found: the labour flexibility, the individual capabilities and the employee relations factors. The presentation of these categories aims to assist in the identification of human factors, since it facilitates the assignment of a new item to an existing category (Fryer and Jackson, 2003). At the same time, it attributes structure to the identification step by composing a definition for human factors. The labour flexibility refers to human factors mainly associated with the manufacturing process affected by the AMT adoption. While the individual capabilities relate to the skills and attitudes that employees acquire or develop through the acquisition of new technologies. Finally, the employee relations factors define the relationship between a company and its workers, which influence the adoption of advanced technologies. At least, three examples of each category are presented to participants in the identification stage. Table 5.2 summarises items associated with each category that are used to trigger the identification effort.

Table 5.2 - Examples of human factors per category

CATEGORIES OF HUMAN FACTORS		
Labour Flexibility	**Individual Capabilities**	**Employee Relations**
Job enlargement	Development of managerial, technical and basic skills	Better working conditions
Delegation of tasks	Empowerment of employees	Job security, welfare, incentives, reward systems
Involvement in the decision-making	New skills from training on the new technologies	Influence of unions
Enhanced knowledge of the manufacturing process	Pro-active attitude towards the solution of issues	Improvement in ergonomic conditions
Process ownership	Skill breadth	Quality of work life
Employee co-operation	Developed expertise	Decreased safety hazards
Manpower planning	Increased ability to learn	Employee morale

Stage 1 aims to identify the human factors based on the AMT acquisition objectives. Four activities are performed in Stage 1. Activity 1 corresponds to the familiarisation of the group with concepts such as human factors, acquisition objectives, etc. Participants are once again presented with the general objectives related to the process and the expected outcomes. The consensus established through this activity is vital to the commitment and participation of key stakeholders. A brief seminar takes place, discussing the concepts and the activities involved in the stage. Within Activity 2, the group lists the objectives the firm intends to achieve with the AMT adoption. The list is composed from the strategic planning the company previously defined. Activity 3 relates to the identification of human factors. Participants are asked to list the human factors, which should be considered for the achievement of the objectives. The categories of human factors are introduced to the group members to trigger the identification. The worksheets used to perform the activities and record the stage can be found in Appendix J. It is estimated that this stage will take up to 2 (two) hours (9-11AM). Figure 5.3 represents the activities within Stage 1.

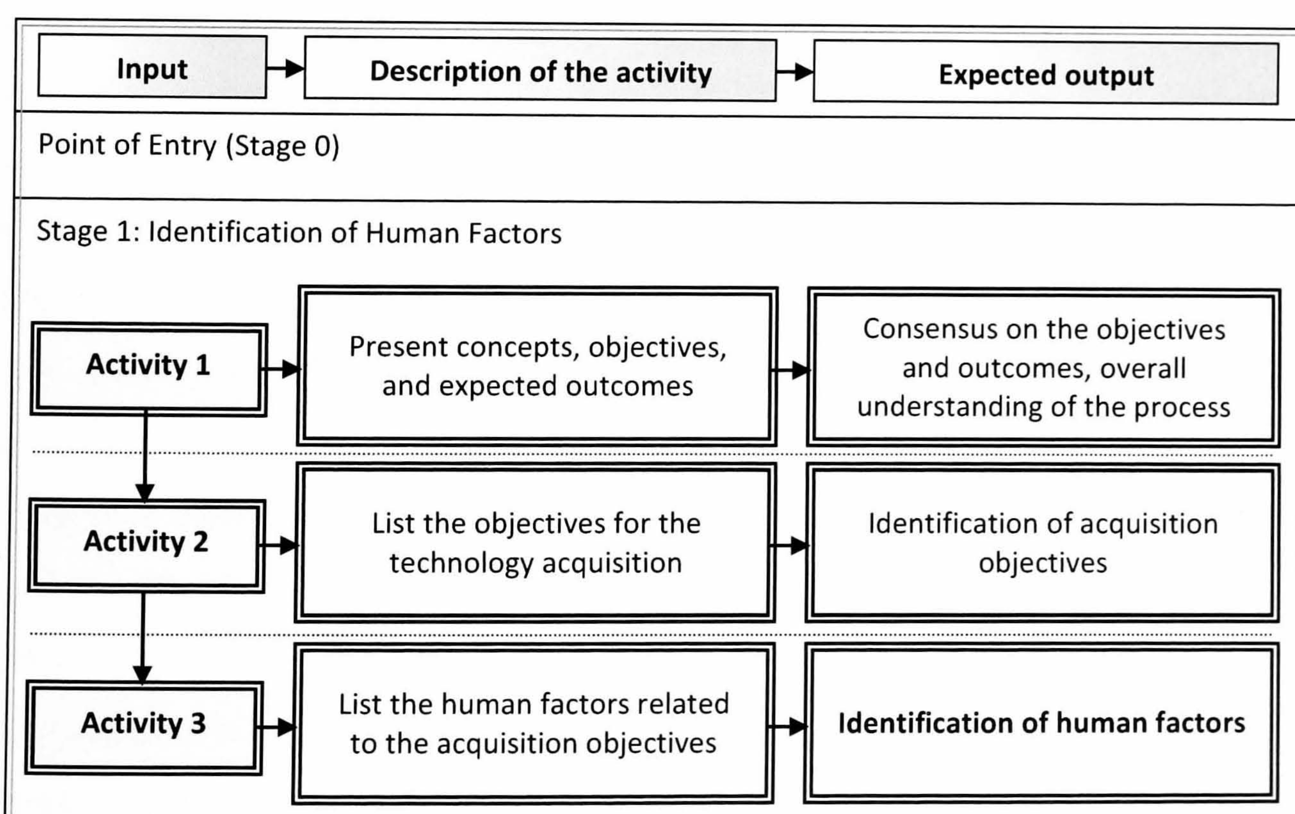


Figure 5.3 - Stage 1: Identification of human factors

5.2.3 Stage 2: Evaluation of Human Factors

Stage 2 aims to evaluate the identified human factors. The preliminary empirical studies indicated that the simple scoring used to assess these factors was inappropriate. According to the interviewees, human factors represent intangible attributes, which need a more robust approach for quantification, since they are harder to measure. In the literature review, the use of Taguchi's loss functions was briefly explored in its application to the quantification of intangible factors. The method allows the achievement of a common measure, the loss score, related to a set target. A penalty for the deviation from a desired target is imposed. This allows the comparison of different options based on the loss scores. The most appropriate option corresponds to the highest in the ranking based on the minimum loss score. This satisfies another of the characteristics of the framework for the assessment of human factors identified during the literature review and reinforced by the pilot case.

The Taguchi Loss Function (TLF) 'larger is better' is being used for the evaluation of human factors. A target value of 100% is assigned. The rationale behind this assignment is that, considering the identified factors, technology alternatives should facilitate the achievement of acquisition objectives. Therefore, the AMT alternatives should be closer to the target of 100%. Based on previous applications of the Taguchi Loss Functions (Pi and Low, 2005; Attavale, Bland and Kethley, 2008; Ordoobadi, 2009b), the second stage of the process is adjusted to serve the research purposes. The ranking of human factors and the minimum required level of each factor to obtain the target of 100% is established by decision makers. A ranking is defined; since it is unlikely that different human factors present the same impact on the decision. Moreover, the specification limits are assigned, i.e., the maximum deviation allowed from the target value (Ordoobadi, 2009a). The target of 100% and the specification limit represent the range allowed for a set factor to vary. The loss function can be formulated as $L(X) = k(1/X^2)$. $L(X)$ corresponds to the loss of the specific value of X. X is a vector that represents desired specification limits set by the decision makers for the identified factors. The loss coefficient is represented by k

that depends on the specification limits assigned by participants. For example, a decision maker may set the lowest desirable limit of a factor as 80 percent compared to not adopting the AMT. Taguchi's loss is 100% for the technology that performs at this level. The value of the loss coefficient k is then calculated as 100 X $(0.80)^2$ = 64 and the loss function for this factor can be calculated as $L(X) = 64(1/X^2)$. The loss score for each technology alternative can now be calculated by using this function.

Stage 2 encompasses three activities. Activity 4 involves the initial ranking of human factors identified in the previous stage. In addition, the decision makers establish the minimum required level for each human factor. As the target value is set in 100 percent, the range the factor can vary is between 100 and the assigned value. In an example, if the decision makers set the minimum required level as 80, the range of variance will be 100-80. Activity 5 addresses the calculation of the loss score k for each of the factors. In Activity 6, the list of human factors and loss scores are examined by the group to forge consensus and verify eventual distortions. The expected output is the evaluation of the human factors. Two hours are scheduled for this stage (11-1PM). The worksheets used in the stage can be found in Appendix J. Figure 5.4 represents the activities required for the completion of Stage 2.

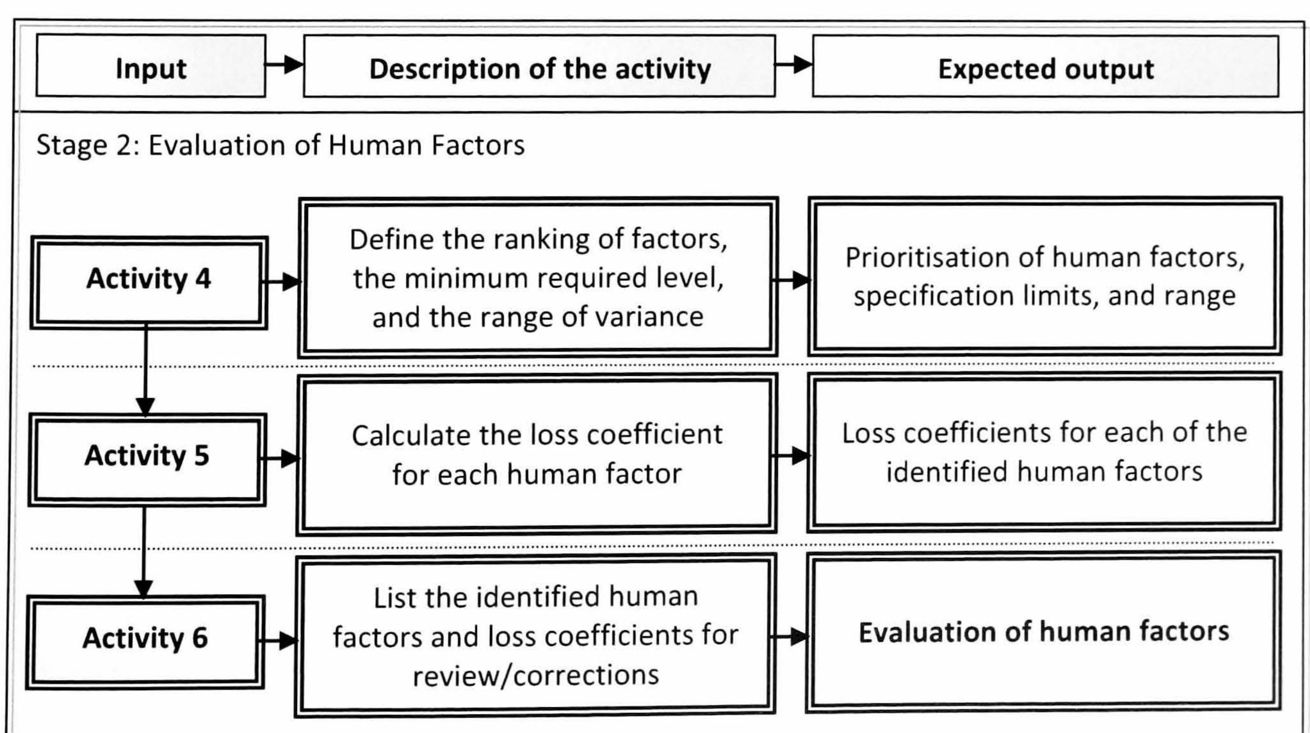


Figure 5.4 - Stage 2: Evaluation of Human Factors

5.2.4 Stage 3: Prioritisation of AMT

Stage 3 corresponds to the prioritisation of technology alternatives. Although the use of the loss function aims to achieve a common measure, Ordoobadi (2009a) remarked that different technologies have several loss scores. Seeking to obtain a common measure for the comparison of options, a weighted loss score for all the identified factors is calculated for each AMT. Different weights are assigned by decision makers and used in the calculation. The technology that obtains the lowest weighted loss score is regarded as the most adequate alternative ('the best option'). Three activities compose the stage. During Activity 7, the decision makers assign their perceptions of performance to each of the technology alternatives. The participants judge the AMT in a scale between 0 and 100 percent in terms of their capacity to address (deliver) the identified human factors. In the following activity (Activity 8), individual loss scores are calculated by applying the loss function: $L(X) = k(1/X^2)$. For example, the decision makers may set the perception of performance for alternative A and the human factor 'delegation of tasks' as 90 percent. The loss score k calculated in the previous stage (64) is combined with the perception assignment:

$$L(x_{11}) = 64\left(\frac{1}{x^2}\right) = \left(\frac{64}{0.90}\right)^2 = 79.01$$

In the formula x_{11} represents the perception of the decision makers related to the human factor 'delegation of tasks' with the adoption of technology alternative A. The weight of the factor is based on the ranking of importance set by the participants. Hence, suppose the 'delegation of tasks' is number 4 (four) in priority amongst 6 (six) other identified human factors. The weight for the human factor will be $4/21 = 0.19$. Finally, within Activity 9 the weights for each of the factors and calculated loss scores are listed. The weighted score for each of the technologies is composed by the multiplication of the weights and the loss scores calculated for the human factors. The sum of these values represents the weighted loss score for each AMT. The AMT with the lowest weighted loss score constitutes the 'best option' for selection. The rationale behind this assessment is that the technology with the lowest weighted loss score deviates less from the target of 100% while addressing the involved human factors. Worksheets for the activities in Stage 3 can be found in Appendix J. Two hours are estimated for this stage (2-4PM). Figure 5.5 represents the activities to be performed during Stage 3, for the prioritisation of the available AMT alternatives.

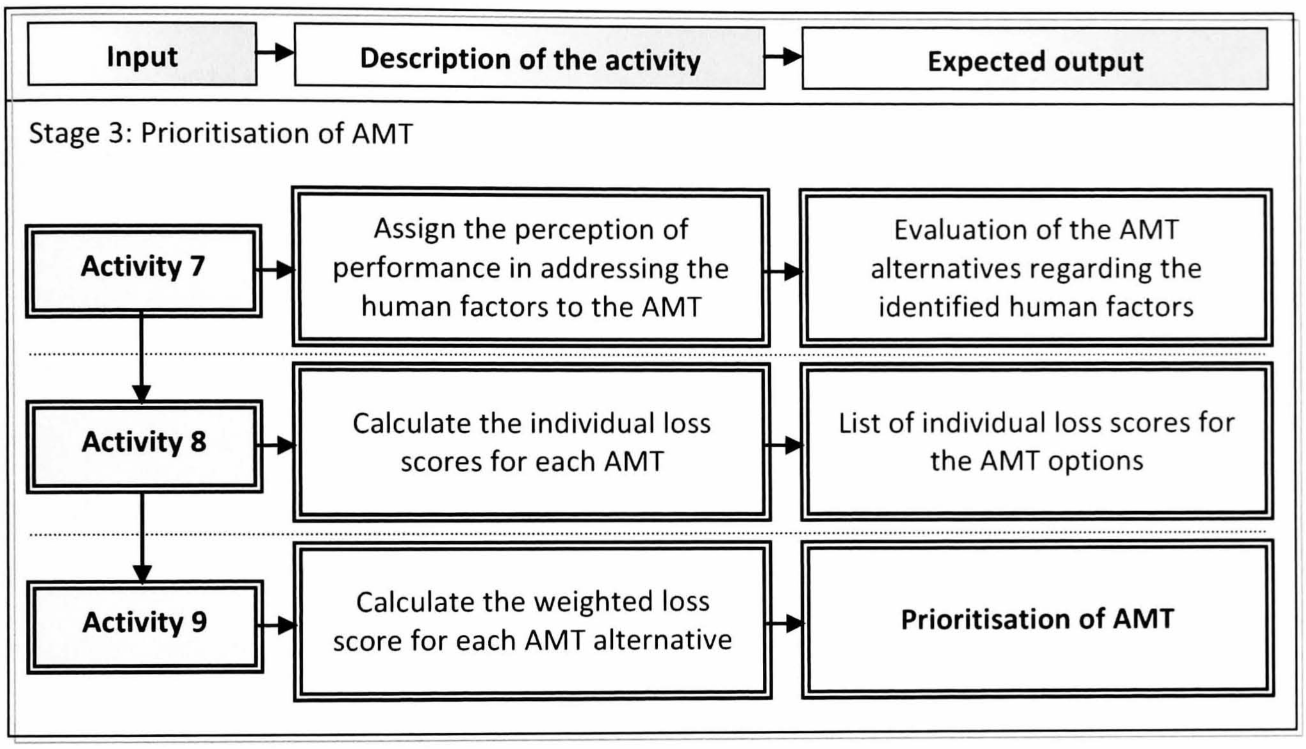


Figure 5.5 - Stage 3: Prioritisation of AMT

5.2.5 Feedback and Process Evaluation

After the process completion, a brief seminar is organised to discuss the outcomes. The facilitator presents the results and the worksheets that recorded the decision-making. The main objective is to provide feedback to the stakeholders and assess the impact of the approach on the company. It is important to highlight that the process is evaluated by participants after each of the stages. Evaluation forms are distributed and filled in by the group members assessing the feasibility, usability, and utility of the process. At this point, the general impressions of the group are also recorded. Any difficulties in performing the activities and suggestions for improvement are discussed with the participants. This aims to contribute to the refinement of the approach and its practical relevance. One hour is scheduled for this process (4-5PM).

5.3 CONCLUSION

Chapter 5 started by presenting the framework refined through interviews with academics, industrialists and consultants and the conduction of a pilot case study. The process developed for its application and defined by the input of the literature review and the initial empirical studies was described in detail. Three stages compose the process. The expected output from Stage 1 is the identification of human factors. Categories of human factors found in the review of literature are used to trigger the identification effort. The second stage (Stage 2) aims to evaluate the human factors. The Taguchi Loss Function 'larger is better' is used to assess the human factors. The rationale behind its use is to provide a common measure for the comparison of different technologies, the loss score, related to the identified human factors. In Stage 3, the technology alternatives are prioritised according to the assessment of human factors and their loss scores. The result is a list of AMT; the 'best option' is represented by the technology with the lowest weighted loss score. Chapter 6 describes the testing of the approach in four companies. In addition, lessons learnt and implications for the refinement of the framework and process are discussed.

CHAPTER 6

DEVELOPMENT OF THE FRAMEWORK AND THE PROCESS

Chapter 5 elaborated on the modifications of the preliminary framework after the initial empirical studies and the process developed for its application. Chapter 6 describes the initial testing of the process in four companies in Brazil. Section 6.1 briefly discusses the profile of companies and background to their participation in the testing. Participants evaluated the feasibility, usability and utility of each stage and the overall process, along with its general utility. Improvement opportunities were indicated, leading to the refinement of the framework and the process. Section 6.2 elaborates on the evaluation feedback provided by participants. In Section 6.3, the report on the process findings is briefly analysed in terms of the achievement of the companies' objectives for applying the approach. Section 6.4 introduces the refined framework based on the feedback from case participants. Section 6.5 presents the revised process. Appendix K contains a more detailed description of the case studies.

6.1 PROFILE AND BACKGROUND TO THE CASE STUDIES

Four companies were approached to test the process. The case studies conducted through action research were designated as Cases B, C, D and E, following the pilot case study designated as Case A. The information on the companies' profile is constituted by: a) years of operation; b) sector and main product (s); c) annual turnover; d) type of ownership (national, transnational, family-owned); and e) number of employees. The background to the studies relates to currently used decision-making practices for the acquisition of new manufacturing technologies. Moreover, the people and criteria involved in the process, and the motivation of the firm's participation in the testing are described. The information related to the profile and the background was collected through an 'assessment interview' conducted before the actual process application (Appendix D). This interview aimed to:

- Establish the profile of the company;
- Understand the company's decision-making practices;
- Collect some general information on recent AMT selection decisions and evaluation methods used by the firm;
- Present the framework/process and convince the company of its value.

Case B is a national company. The initial contact was made with the company's CEO who is also the Industrial Director. The firm is in the meatpacking business and agro-industry, selling its products to butcher shops and supermarkets. The family-owned company has operated in Brazil since 1948 (62 years) and exported since 1995. Currently, 1600 workers are employed in its two plants. The annual turnover is £90M. The acquisition of new equipments is usually proposed by the manufacturing function through its Industrial Manager and discussed with the Industrial Director. The technology alternatives are prospected by the Industrial Director. The options are evaluated through the Return on Investment (ROI) and Payback (PB) methods and the acquisition made with the Industrial Director's approval. Recently, the main concern for the executive has been the modernisation of the manufacturing process.

Due to new contracts with China and Saudi Arabia, the firm has been looking for new technologies to enhance its capacity. The CEO attended several fairs and conventions in Brazil and abroad seeking a new packing system. In addition to enhancing the capacity, the risk of contamination associated with the manual handling and packing of products has been a concern for the manufacturing. The Industrial Manager decided to automate the meatpacking process and an alternative was sought.

Some national options were evaluated for the acquisition, but the technical analysis demonstrated that there was no adequate technology produced in Brazil. A potential supplier from Spain was contacted through its Brazilian representative. The economic assessment of the packing systems PV-350 and PV-550 indicated that an investment of £126,000 was necessary to buy 4 (four) machines. The payback was calculated in 2.5 years. According to the Industrial Manager, the acquisition was associated with a reduction of 1/3 (one-third) of the employees involved directly in the production line. The prospect of job losses could considerably affect the quality and the success of the implementation of the equipment. The company was also interested in structuring skills of workers to retain new knowledge related to safety conditions and manufacturing versatility. The impact of human factors was deemed significant and a framework to assess these intangible factors was considered necessary. According to the Industrial Director, no decision aid tool was found to assess the human factors and their impact on the installation of the AMT. Furthermore, the executive was interested in testing new decision-making tools available through academic research. This made the framework testing appealing to the company. The CEO agreed on the firm's participation based on the proposed usefulness of the approach to evaluate the human factors involved in the selection of advanced technologies.

Case C has been in Brazil since 1954 (56 years of operation). It is the leading supplier for the local market of automotive parts with four industrial units in the country. It is a transnational company of the automotive sector and constitutes the main subsidiary in Latin America of its head office in Germany. The research was conducted in Curitiba, located in the Southern Region of Brazil; the local plant employs 4600 people. The industry produces diesel systems for automobiles. The initial contact was made through a researcher's former student, who is a Quality Engineer in the plant. Through him, the Engineering Manager was contacted and the assessment interview scheduled. The firm's turnover is £1.2B per year. The Curitiba plant acts as development lead and non-lead in the acquisition of technologies, depending on the global planning of the company. Two main drivers lead the decision on the acquisition of technologies: local plant requirements if in its development role and worldwide policies from the Head Office whilst in the non-lead development position. Technologies are developed or acquired to support strategies. AMT used by other branches are initially analysed in the decision-making and, in almost all cases, adopted by the company. In total, 90% of manufacturing equipments are imported.

In this case, however, the plant was working on the development of a technology. The department intended to update the CRIN durability test bench to develop a new workbench, maintaining the same quality of its products. According to the Engineering Manager, mainly intangible factors are considered for the development. The project aimed to deal with a recent demand fluctuation. Being flexible was a major concern, especially in terms of skills of the labour force. For this particular decision, the company lacked a formalised process to address these factors. Intangible factors are considered vital to the acquisition and development of AMT. "There is a specific danger in not including them [the intangible factors]: to be disconnected from reality", as the interviewee elaborated. Furthermore, in the past, the Engineering Team faced a number of problems due to the lack of consideration of safety hazard issues involved in a key technology development project. The project came close to its failure due to the non-existence of a suitable method for the assessment of human factors such as working conditions. Moreover, concerns on the level of informal education to absorb training on the new AMT and technical expertise of workers were raised. Because of this background, the proposed approach became attractive to the firm for testing and appraisal of human factors.

Case D is a joint venture of a Brazilian company (85% of ownership) and an Italian firm (15% of ownership). Three hundred and twenty employees work in the plant. Its annual turnover is approximately £14M. The company produces components and parts for bicycles. The need to acquire new technologies comes, usually, from the sales department to enhance market participation. However, the firm also utilises 5-year macro strategic planning, revised yearly. The Commercial Director (Marketing Department) approaches the Operational Manager to evaluate the best alternative for the capacity enhancement. The Operational Manager makes the case and presents his recommendation to the Administrative Manager for analysis. Both recommendations are presented to the top direction for evaluation and final decision. Mostly tangible aspects are relevant to the decision, especially sales growth and enhancement of capacity. Increased productivity is the final goal for the process. ROI and Payback are used as methods to evaluate the manufacturing technologies. T he initial contact was made with the Financial Manager, who deals with the actual acquisition. The executive was interested in methods to evaluate the aspects that affect the decision while attributing some structure to the process.

Tangible aspects regarding cost reduction and increased capacity are, in general, the main items appraised in the decision-making. Some human factors such as working conditions are considered in automation projects. Even though the firm understands the importance of including those aspects, it lacks a structured approach to assess them. Reportedly, AMT implementation processes have not reached their full potential because of this issue. The Commercial and the Administrative director decided to test the proposed framework in order to deal with the human factors. The company was interested in comparing three different options, two Chinese brands and one Brazilian alternative to replace a moulding machine. The selected equipment should be compatible with an Italian machine currently in use in the production line and imported from its foreign counterpart. In addition, it should enhance productivity and reduce setup. The decision makers were interested in assessing specific human factors such as improvement in working conditions, development of the employees' skills through training, mitigation of stress related to the manual tasks, improvement of 'on the spot' quality inspections, and others. The approach was used to evaluate the different options and appraise the human factors involved in the decision.

Case E was founded 14 years ago and it is a national company with two main partners and directors. It has 101 employees. Two major businesses direct the strategic efforts of the company. The automotive business includes products such as elevators for automobiles, ramps for the alignment of vehicles and automotive balancing devices. The second business is related to steam equipments, especially boilers for other manufacturing companies. Around 90% of the sales are destined to the national market and 10% dedicated to exportation to the Mercosur and Latin America. In the latter demand market, the company is the main supplier of automotive equipments such as the described. The firm faced a restructuring process and the directors have played multiple roles in the company's management. The investments were cancelled due to this process and a 2005 project for a new unit has been examined in more detail, leaving the investments in technology in standby. Due to external market conditions, the restructuring process, and the new plant project under analysis, the turnover of the company has been reduced. Although the company is prepared for a turnover of £13M, it has reached only half of it, £7M lately. Nonetheless, the company has recently restarted its acquisitions. Three potential options for a new CNC machine were undergoing an evaluation process.

Usually, the acquisition of a new technology is associated with the sales department needs. Sales reports the needs, the Plant Manager prepares a case and presents to the Directors. The decision-making involves both executives. The first to analyse the project is the Executive Director who also takes the role of Financial Manager, verifying the economic and financial viability of the project (ROI, Payback, and NPV). The second director occupies two positions, Industrial Director and Quality Manager. Both Directors require an evaluation analysis from the Planning and Control Manager and the Purchasing Officer. This analysis is based on market needs versus the technology performance and the general cost of the equipment, respectively. To select the equipment, the suppliers and associated after-sale services such as technical assistance, access to parts and pieces are appraised. The alternative with the best price and conditions, according to the Purchasing Department, is selected. Human factors are rarely considered; the intent is to solve specific problems and immediate needs. At the same time, the executive feels that addressing human factors becomes increasingly difficult when the emphasis is placed on short term outcomes. By using this approach, several opportunities have been lost to competitors and implementation problems related to human factors have arisen. Furthermore, the company executives questioned the adjustment of employees with a weaker formal education to the adoption of advanced technologies. Considering these difficulties, the firm decided to participate in the testing. According to the Supply Chain Manager, the AMT options were similar in scope. Thus, the framework was used to compare the different alternatives and select the most appropriate AMT while incorporating human factors into the decision. Table 6.1 summarises the background on the companies' participation in the initial testing.

Table 6.1 - Background on the companies used in the initial testing of the process

CASE STUDY	INDUSTRY	ANALYSED DECISION	MAIN CONCERNS ON HUMAN FACTORS	CO-ORDINATION GROUP
Case B	Agro-industry	Packing System	- Resistance to change; - Structuring skills to retain new knowledge.	Industrial Director* Industrial Manager Production Supervisor HR Manager
Case C	Automotive	Workbench for quality testing	- Labour flexibility; - Working conditions; - Technical expertise; - Informal education.	Engineering Manager* Product Development Manager Production Supervisor
Case D	Metal-mechanic	Moulding Equipment	- Working conditions related to stress level; - Skill development; - Quality of inspections.	Financial Manager* Industrial Manager Production Supervisor HR Supervisor
Case E	Metal-mechanic	CNC Machine	- Level of education of employees vs. new technologies.	Financial Director* Supply Chain Manager Production Manager HR Manager

*** It indicates the team leader**

The detailed description of the application of the process in the cases can be found in Appendix K. The following section describes the process evaluation provided by participants. The main objective for the initial testing cases was to obtain feedback on the feasibility, usability and utility criteria, leading to the development (refinement) of the framework and the process.

6.2 THE EVALUATION OF THE PROCESS

After the process application in Cases B, C, D, and E, evaluation forms were filled in by participants. The evaluation is represented by the assessment of three criteria: feasibility (can the process be followed?); usability (can the process be easily followed?) and, utility (are the results useful for managers?). Each criterion is also composed by a set of sub-criteria. The feasibility relates to the availability of information, the appropriateness of the time scheduled for the activities and the required mix of participants. Usability is composed by the clarity of concepts and activities, the ease of use and the appropriateness of the activity or stage to desired outputs. Relevance, usefulness, facilitation and level of confidence compose the utility criterion. The relevance and usefulness relate to the achievement of the stage or overall process objectives through the performed activities. The facilitation refers to the facilitator's ability to assist in the realisation of activities and the communication of concepts and expected outcomes. The level of confidence represents the confidence in the results on a percentage scale (0 to 100%).

Finally, through a separate evaluation form, the general utility of formal and informal outcomes and quality of analysis and operationalisation of the process were further analysed. The objective behind the employed assessment criteria is twofold. First, to address the issues of validity and reliability related to the research methods adopted in the study. Second, the evaluation criteria relates to the contribution the research aims to provide, presenting practical usefulness for managers to assess human factors during the AMT selection decision (see Chapter 3, Subsection 3.4.5). A high rating was obtained in the criteria. Nonetheless, some points for improvement were indicated, leading to the refinement of the framework and the process and described in Sections 6.4 and 6.5. The evaluation forms covered:

- The first stage for the identification of human factors;
- The second stage for the evaluation of human factors;
- The third stage for the prioritisation of AMT;
- The general utility of the process;
- The overall process.

Additionally, the evaluation forms contained two open-ended questions exploring the main difficulties encountered during the process and suggestions to improve the framework and the way concepts are approached in it. Platts (1994) recommends three groups for the process application and evaluation: an operating, a management and a supporting group. The latter is usually represented by a facilitator. In this case, the role of facilitator was undertaken by the researcher. The operating and the management groups were combined to form a group named 'co-ordination'. This group is composed by the participants that possess the expertise required in the process and perform the activities contained in it. A team leader, represented by a senior manager or firm director, was also appointed to guarantee the attendance of participants and the time required for each stage as established in the process.

6.2.1 Stage 1: Identification of Human Factors

The feasibility of Stage 1 was evaluated by participants after its completion. In Case B, 'the identification of human factors' was initially described as 'somewhat clear' in terms of availability of information. The participants found dealing with more intangible factors difficult at first. As a family-owned business without more formalised strategic planning, the identification of acquisition objectives represented an issue. Moreover, as human factors tended to be overlooked in the assessment of new technologies, greater effort was employed to clarify the concept. However, after the activities became clearer to the participants, the criterion assumed a 'quite feasible' rating. In Cases C and D, the participants also revealed that they felt some initial intimidation related to the concepts present in the process. Once this initial reaction was overcome, the participants regarded the stage as 'quite clearly' defined.

Timing and participation were rated as 'somewhat adequate' in Case C. According to the participants, more time should be put into the first stage. "It represents the input for the process and sets the pace for the following stages. Therefore, more time should be spent in the identification of acquisition objectives and human factors", highlighted the Engineering Manager. Furthermore, due to internal time pressures, the co-ordination group could not be formed with the mix of professionals defined in the process. Because of this difficulty, the group felt that different viewpoints were missed. The team was composed of three engineers: the Engineering Manager, the Product Development Manager, the Production Supervisor; no representative from the Human Resources sector took part in the process. "Team members from different areas should be involved, since different opinions could enrich the process and facilitate the identification of human factors, especially in the case of the human resources department", remarked one of the executives. In Cases B, D and E, timing and participation were rated as 'quite adequate'. In these companies, it was possible to compose an appropriate team for the application, thus timing and participation did not become an issue. Overall, the stage was regarded as 'quite feasible'.

In terms of usability, the stage was regarded as 'quite usable' in all cases. According to the participants of Case B, different professionals were enabled to present multiple ideas and experiences. The format of seminars was considered particularly adequate by the team members of Case C. "Being a subsidiary of a global company, we are not always involved in the decision-making. Thus, our local needs and specific human factors are not considered in the process", the Production Supervisor remarked. Moreover, for the Product Development Manager, "by gathering different collaborators, you gain important insights in terms of pros and cons associated with the decision". The stage was regarded as 'quite usable' and 'very easy' to understand in Case C. In Cases D and E, it facilitated the identification of important factors related to the decision that could have been ignored, according to the groups.

The concept of human factors proposed in the process was rated as 'quite appropriate' to be used by companies. The comprehensiveness of the concept created by the three categories of human factors was highlighted by the four groups. Furthermore, in Cases B, D and E, the stage was regarded as clearly defined; and the sequence of activities was considered adequate for the general purpose of the stage. However, participants of Cases C, D and E remarked that the stage objectives are achieved only when the required mix of professionals is guaranteed. A properly assembled co-ordination group was considered to be crucial. The stage was regarded as 'easy to follow' and 'quite clear' in terms of the communication of the concept of human factors through the proposition of categorised examples. The groups of Cases D and E pondered that examples attributed a 'sense of reality', more closely connected with their routine. "This made the identification of human factors easier, since they are harder to recognise", according to the Financial Manager in Case D.

The utility of the stage was also evaluated by participants. In Cases B and C, the stage was regarded as 'quite useful' to consider important factors that otherwise could have been overlooked. According to the Industrial Manager in Case B, "the cost reduction is almost always the objective for the acquisition; but, apart from that, not much is incorporated into the decision. The task of identifying involved factors, especially those related to the human element, seems to be very relevant to the acquisition". Similarly, the time scheduled for the effort was considered 'quite adequate' in terms of the relevance of the stage for the final selection. The general appraisal of the stage provided a high level of confidence in the decision (85%). Nonetheless, participants of Case C highlighted that their level of confidence could have been improved through a proper mix of professionals/decision makers. Moreover, "the possibility of errors could have been reduced and a higher level of certainty could have been achieved", remarked the Product Development Manager.

In general, the stage was regarded as 'quite useful' to identify the human factors that were to be quantified in the second stage. In Case E, the stage was regarded as 'very relevant' to fulfil the objectives behind the process and 'very useful' for managers regarding the identification of factors involved in the decision. In Case D, the participants highlighted that being the first stage, the process was initially challenging, but with the assistance of the facilitator, it became increasingly easier to understand. It was also suggested that the identification categories should be presented in the proposed framework, when the approach is introduced to the company stakeholders. The main difficulty in the stage, according to team members of Cases D and E, was to place the emphasis away from a short term assessment of options. As the Supply Chain Manager reported in Case E, "99% of acquisitions of new technologies are related to enhancing capacity, and seeking improved profits. It is, therefore, difficult to overcome a natural tendency to fall into the trap of the short term. You 'become blind' to the impact these technologies promote on our workers". Overall, the stage was regarded as 'very useful' and 'quite useful' to identify involved human factors and grasp new concepts introduced by the process.

However, participants of Case C reported a difficulty in the identification of factors. Although, the categories of human factors (labour flexibility, individual capabilities, and employee relations) assisted in the task, the team members suggested that the list should be expanded; more examples of human factors were deemed necessary. In addition, a separate exercise at the beginning of the session was proposed to assist in the understanding of the concept of human factors. The time put into the stage was well rated in Case E. The participants remarked that the identification was a very important step toward the evaluation of human factors. The level of confidence in Cases D and E reached 90%, indicating the high utility associated with the stage. The proposition of categories for the human factors was especially valued by participants. Table 6.2 presents the results of the evaluation of the first stage. The discussion on the evaluation of the second stage and the ratings obtained are presented next.

Table 6.2 - Stage 1: Evaluation summary

Criteria	***Sub-criteria***	***Case B***		***Case C***		***Case D***		***Case E***		***Overall Sub-criteria***	***Overall Criteria***
	Information availability	3.0		2.0		2.0		2.0		**2.3**	
Feasibility	Timing	2.0	2.0	3.0	2.7	2.0	2.0	2.0	2.0	**2.3**	**2.2**
	Participation	1.0		3.0		2.0		2.0		**2.0**	
	Clarity	2.0		2.0		2.0		2.0		**2.0**	
Usability	Ease of Use	2.0	1.7	1.0	1.7	2.0	1.7	2.0	1.7	**1.8**	**1.7**
	Appropriateness	1.0		2.0		1.0		1.0		**1.3**	
	Relevance	2.0		2.0		3.0		1.0		**2.0**	
	Usefulness	2.0	2.0	2.0	2.0	2.0	2.3	1.0	1.3	**1.8**	**1.9**
Utility	Facilitation	2.0		2.0		2.0		2.0		**2.0**	
	Confidence	80%		80%		90%		90%		**85%**	

Scale of the evaluation: (1) very, (2) quite, (3) somewhat, (4) not at all.

6.2.2 Stage 2: Evaluation of Human Factors

In Cases B and E, the stage was rated as 'quite feasible' and 'quite clearly defined'. The time spent on the stage was regarded as 'quite appropriate'. However, once again the participation was an issue in Case C. The participants felt that the existence of different opinions discussed in an open forum could have been beneficial to the process. "By putting together different people with divergent contributions, the discussion that leads to consensus is an advantage in itself", elaborated the Engineering Manager. The use of the Taguchi Loss Function was considered 'quite adequate' and 'quite useful'. The participants, who are engineers, were familiar with the method due to its use in the verification of the quality of products. The Product Development Manager remarked that some type of measurement of more intangible factors is always part of the technology evaluation (even if not formalised). According to the group members, the internal procedures the department currently adopts are somewhat similar to the process. Hence, the stage was rated as 'quite appropriate' for the evaluation. The Product Development Manager remarked that the "process is quite clearly defined and allows extensive participation". The participation was well rated in Case B, obtaining a 'very appropriate' rating. The team of Case D recognised the method as a useful tool, commonly used in the engineering department. In consequence, it can be more easily understood and accessible to most collaborators.

In general, the stage was regarded as 'quite usable' in all four cases. The stage was considered 'quite easy' to follow and communicate to company members. Especially, when it comes to calculating the loss scores of the involved human factors, the evaluation was regarded as usable to compose a more informed decision. The focus on a specific set of factors leads to a better understanding on their impact, according to Case B participants. Nonetheless, in Cases C and D, where participants were familiar with the use of the Taguchi Loss Function as a quality control procedure, the method became an issue. The engineers in both companies remarked that it was difficult to apply the method to the evaluation of technologies instead of its 'usual' role. The participants were concerned with the prioritisation of human factors, especially in Case C. In this case, as mentioned, the mix of professionals for the co-ordination group was not obtained. Therefore, the group felt that an important discussion on the ranking of human factors and perceptions on their achievement with the technology alternatives was being missed. "It is easy for us to impose what we think is appropriate; but what if this perspective is misleading? ", the Engineering Manager argued. The participation of different stakeholders as prescribed in the process was deemed essential. Similarly, for the participants in Case E, the presence of interested parties is beneficial to the stage and the overall process. The method was rated as 'quite clear' and 'quite easy to use' by different decision makers, and even 'very appropriate' for the evaluation of human factors. In Case B, the stage was regarded as 'quite usable'. According to the participants, the concepts were clearly defined and the method showed to be 'quite easy to follow and understand'.

In terms of utility, in Case B, the participants remarked that the time deployed for the stage was 'very appropriate' for the achievement of the final objective, the evaluation of human factors. The use of the Taguchi Loss Function also allowed the decision makers to visualise the impact of human factors. Nonetheless, a graph or equivalent visual aid comparing the human factors was suggested. It could be a useful tool to promote the accomplishment of activities, according to the groups. In addition, the visual representation of the application of the method and related outcomes was proposed for the initial presentation of the framework. According to participants, this could improve the understanding of the method and its application to the evaluation of AMT options. In Case C, the dynamic amongst team members was once again mentioned as crucial to a more informed decision-making process.

Finally, a high level of confidence was obtained (90% as average). This may be explained by the proposed quantification method and the structured involvement of different stakeholders. As highlighted by participants of Cases C and D, being able to quantify intangible factors has been a concern for managers in the selection decision. The use of a method known to team members, although provoking some resistance at first, ended up becoming an advantage. Second, the prescribed format of seminars and workshops with participants from distinct areas to define the scores of the human factors improved the reliability related to the process. In the decision-making practices of Company B, for instance, there is some involvement of operators and maintenance personnel in a very informal way. However, by applying the participation procedures contained in the process, some structure was created. Participants pondered that their voice was heard in the decision. Overall, the stage was rated as 'quite useful', especially due to the attribution of "a quantitative dimension to subjective criteria" as remarked by the Financial Director in Case D. The stage supports a better understanding of the involved factors by comparing the criteria with the acquisition objectives. It also made evident crucial factors related to the implementation of technologies. The process assisted in the quantification of important concerns on human factors such level of formal and informal education of workers as highlighted by executives of Cases B, C and D. The evaluation summary of Stage 2 is shown in Table 6.3. The evaluation of the third stage is examined next.

6.2.3 Stage 3: Prioritisation of AMT

The stage was rated as 'quite feasible' in all cases. According to the group members of Case B, the stage allows the company stakeholders to evaluate the technologies in a more structured way. The time was regarded as 'quite adequate'. Similarly, the participation was also cited as vital to the stage and the objectives associated with it. Referring to the participation, in Case C, the group composed by engineers remarked that, the lack of involvement from different professionals was somewhat detrimental to the activities. A full participation could have improved the appropriateness related to the stage. However, the criteria for the prioritisation of alternatives were considered 'quite adequate' and the time 'adequate'. In Case D and E, team members remarked that the activities within the stage were easy to follow and understand. After getting used to Taguchi's Loss Function as means to evaluate human factors and AMT, it became reportedly easier to participants to perform the activities. The familiarity with the method, in this case, became an asset for the prioritisation stage.

Table 6.3 - Stage 2: Evaluation summary

Criteria	***Sub-criteria***	***Case B***		***Case C***		***Case D***		***Case E***		***Overall Sub-criteria***	***Overall Criteria***
Feasibility	Information availability	2.0	1.7	2.0	2.0	2.0	2.0	2.0	2.0	**2.0**	**1.9**
	Timing	2.0		2.0		2.0		2.0		**2.0**	
	Participation	1.0		2.0		2.0		2.0		**1.7**	
Usability	Clarity	2.0	2.0	2.0	2.0	2.0	2.3	2.0	1.7	**2.0**	**2.0**
	Ease of Use	2.0		3.0		3.0		2.0		**2.5**	
	Appropriateness	2.0		1.0		2.0		1.0		**1.5**	
Utility	Relevance	1.0	1.3	2.0	2.0	2.0	1.7	1.0	1.3	**1.5**	**1.6**
	Usefulness	1.0		2.0		2.0		1.0		**1.5**	
	Facilitation	2.0		2.0		1.0		2.0		**1.7**	
	Confidence	90%		85%		95%		90%		**90%**	

Scale of the evaluation: (1) very, (2) quite, (3) somewhat, (4) not at all.

Overall, the stage was considered 'quite usable'. In Case B, assigning the perception to the technologies was regarded as 'quite appropriate' for the comparison of options. The criteria and the time used were rated as 'quite adequate'. Nonetheless, in Case C, the participants felt the criteria remained somewhat subject. This issue, added to the lack of participation, concerned the Product Development Manager. The team remarked that the participation must be guaranteed if reliable results are to be obtained. Nonetheless, the clarity of employed terms and the logical sequence of steps were highlighted as 'quite usable', according to participants of Cases D and E.

In Case B, the utility of the stage was rated as 'quite useful' to "obtain a better quality decision", pondered the Industrial Director. The time put into the stage was rated as 'quite adequate', especially because of the discussions inside the group. The dynamic of the duo seminars/workshops was considered 'quite appropriate' to obtain a prioritised list of AMT. The co-ordination group of Case B indicated the importance of the stage to evaluate the impact of the employees' resistance to the technical change. In Case C, a particular high level of confidence was achieved (95%). The team members highlighted the importance of the participation as proposed by the approach. According to the group, the participation is crucial to more informed decisions and trustworthy results. The level of confidence, even though very high (95%), was mostly related to the method of evaluation. The lack of participation was still nominated as an important issue that became a difficulty. Case D executives managed to identify, evaluate and incorporate important concerns into the decision-making, according to the team members. The influence of working conditions and development of operational and technical skills, for instance, was quantified and played a significant part in the technology choice. In Case E, the Supply Chain Manager remarked that, "the focus on tangible factors and measures such as ROI and PayBack period do not express the fluidity of the criteria that should be involved in the evaluation of technologies. The use of the Taguchi Loss Function showed to be suitable for the quantification of relevant human factors". Table 6.4 represents a summary of the evaluation of Stage 3 correspondent to the prioritisation of AMT.

Table 6.4 - Stage 3: Evaluation summary

Criteria	***Sub-criteria***	***Case B***		***Case C***		***Case D***		***Case E***		***Overall Sub-criteria***	***Overall Criteria***
Feasibility	Information availability	2.0	2.0	2.0	2.3	2.0	2.0	2.0	2.0	**2.0**	**2.1**
	Timing	2.0		2.0		2.0		2.0		**2.0**	
	Participation	2.0		3.0		2.0		2.0		**2.3**	
Usability	Clarity	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	**2.0**	**2.0**
	Ease of Use	2.0		2.0		2.0		2.0		**2.0**	
	Appropriateness	2.0		2.0		2.0		2.0		**2.0**	
Utility	Relevance	2.0	1.7	2.0	2.0	2.0	2.0	2.0	2.0	**2.0**	**1.9**
	Usefulness	1.0		2.0		2.0		2.0		**1.8**	
	Facilitation	2.0		2.0		2.0		2.0		**2.0**	
	Confidence	80%		95%		80%		90%		**86%**	

Scale of the evaluation: (1) very, (2) quite, (3) somewhat, (4) not at all.

In addition to the evaluation of the feasibility, usability and utility of each stage, the general utility of the process was analysed. Participants rated the value of the produced outcomes and the quality of the analysis and the operationalisation of the process application. The value of formal and informal outcomes was assessed. The formal outcomes were evaluated per stage and in terms of the overall process. Group discussion and communication, sense of team building, learning related to the concepts of the process and related to the proposed quantification of human factors constituted the informal outcomes evaluated by the participants. The quality of analysis was represented by the strategies used in each stage and the overall approach of the process. The quality of the operationalisation was rated according to the utilisation of the participation, its breadth and depth, the project management, the adopted procedures (worksheets, workshops, and seminars), and the communication of the purpose behind the process. These criteria were evaluated in a 4-point rating scale: very good (1), quite good (2), somewhat good (3), not at all (4).

6.2.4 General Utility of the Process

In terms of the utility of formal outcomes, the rating remained between 'very good' and 'quite good' for all cases. In Case B, the participants felt that the proposed process became an important record of discussions and a valid source of information for future decisions. Moreover, the existence of three logical stages and the sequence of activities attributed structure to the companies' decision-making. Case C participants confirmed that the identification of human factors was an uphill task in which the participation of a mix of professionals is needed. According to the co-ordination group, an attempt to expand the list of human factors should be made. Furthermore, the communication of concepts should be conducted through a separate exercise prior to the first stage. For team members, since the process deals with intangible factors, greater effort should be employed to improve the general understanding of crucial terms. In Case D, the group indicated that the pace set in the application was appreciated. As the HR Manager elaborated, "considering the limited time we have, it is more useful to have a decision process that can be concluded over just one day". The Supply Chain Manager (Case E) stated that the robustness of the outcomes depends directly on the full participation of team members. The mix of professionals, according to the executive, is essential to obtain reliable results.

Quality of analysis	***Scores***				***Quality of operationalisation***	***Scores***			
	1	***2***	***3***	***4***		***1***	***2***	***3***	***4***
1) Overall outcomes	BC				1) Group discussion and communication		B	C	
2) Identification of human factors	C	B			2) Team building		B	C	
3) Evaluation of human factors	C	B			3) Learning related to the concepts in the process		B	C	
4) Prioritisation of AMT	BC				4) Learning related to the 'quantification' of human factors	B	C		
Quality of analysis	***Scores***				***Quality of operationalisation***	***Scores***			
	1	***2***	***3***	***4***		***1***	***2***	***3***	***4***
1) Overall process	B	C			1) Participation - utilisation	BC			
2) Identification of human factors		BC			2) Participation - breadth and depth	BC			
3) Categories of human factors	C	B			3) Project management	B	C		
4) Taguchi's loss function	BC				4) Procedures - seminars worksheets workshops	BC			
5) Quantification of intangible factors	C	B			5) Communication of purpose	BC			
Scores:	1 very good 2 quite good 3 somewhat good 4 not at all				Keys:	——— CASE B .... CASE C			

Figure 6.1 - Utility evaluation summary (Cases B and C)

Quality of analysis	***Scores 1***	***2***	***3***	***4***	***Quality of operationalisation***	***Scores 1***	***2***	***3***	***4***
1) Overall outcomes		DE			1) Group discussion and communication		DE		
2) Identification of human factors		DE			2) Team building		DE		
3) Evaluation of human factors	DE				3) Learning related to the concepts in the process	D	E		
4) Prioritisation of AMT	DE				4) Learning related to the 'quantification' of human factors	D	E		

Quality of analysis	***Scores 1***	***2***	***3***	***4***	***Quality of operationalisation***	***Scores 1***	***2***	***3***	***4***
1) Overall process	DE				1) Participation - utilisation	D	E		
2) Identification of human factors	DE				2) Participation - breadth and depth	DE			
3) Categories of human factors		DE			3) Project management	D	E		
4) Taguchi's loss function		DE			4) Procedures - seminars worksheets workshops	DE			
5) Quantification of intangible factors	DE				5) Communication of purpose	DE			

Scores: 1 very good; 2 quite good; 3 somewhat good; 4 not at all

Keys: solid line — CASE D; dotted line (..........) — CASE E

Figure 6.2 - Utility evaluation summary (Cases D and E)

The evaluation of the general utility of the process is represented through Figure 6.1 and Figure 6.2. The evaluation provided by participants is presented in pairs for a better visualisation of the ratings. In terms of utility of informal outcomes, the rating 'somewhat good' can be explained in Case C. For this company, the co-ordination group did not include a decision maker from the human resources department. One of the participants highlighted that the lack of participation in the process affected the quality of the discussions and the feedback on the utility of the process. Although the process facilitated the team building as remarked by participants, this issue was reflected by the rating. Similarly, one of the group members remarked that, "if we have had full participation we could have improved our learning related to the concepts contained in the process". In Cases D and E, the communication of the value of the process was rated as 'very good'. The participants of Case B felt that the process contributed to their awareness of the importance of incorporating human factors into the selection of advanced manufacturing technologies.

The quality of the analysis represented by the methods used for the identification and evaluation of human factors was rated as 'very good' and 'quite good'. Participants of Case B, for example, highlighted that the strategies were clear and well defined. The criteria utilised in the process were also evaluated as easy to use and communicate. Especially, the use of the Taguchi Loss Function was considered quite effective to achieve a decision of better quality, according to participants of Cases C, D, and E. Even though the groups reported an initial difficulty in dealing with the proposed concepts, the quality of analysis was regarded as 'quite appropriate'. In time, according to the Production Manager in Case E, the experience in the assessment of human factors using the TLF could improve the reliability of results. In consequence, the group felt it could enhance even greatly the quality of the analysis.

Finally, the operationalisation of the framework was mostly rated as 'very good'. The participation of group members was emphasized as a very important component of the process. In the opinion of the group of Case B, the process facilitates the participation of individuals. The co-ordination group in Case C felt enabled to participate fully in the process. The adopted procedures were regarded as 'very good' to coordinate efforts and perform the process activities. Although the project management was rated as 'quite good', participants remarked that the process was affected by the lack of participation from a decision maker of the Human Resources Department. The purpose behind the process application was well understood as justified by the Financial Director in Case E. According to the executive, the process was adequately defined and can be used for other decisions. At the time of the process application, the researcher was approached by the firm to adjust the process to the assessment of human factors in the case of the installation of a new plant.

Two main advantages were identified by participants of Case D: time and procedures. Regarding the time, the Financial Manager considered it to be 'quite adequate' for the application of a decision-making process: "Decisions should be rapid and facilitated by information availability", as stated by the participant. "The process proposed adequate time for discussions, leading to consensus on the AMT selection. Furthermore, the procedures adopted in the process, the use of worksheets and the logical set of steps created a record of the decision for future reference," declared the executive. In Cases B and E, the approach was considered 'very useful' to formalise related strategies and attribute structure to the assessment of human factors. The process was also regarded as a comprehensive tool for evaluation of manufacturing technologies as indicated by the Industrial Director in Case B.

6.2.5 The Overall Process

In terms of feasibility, the process was regarded as 'quite feasible'. The participants of Cases B and E remarked that the information was 'very available' and they were able to follow the process and activities with no difficulty. In Cases C and D, the team members remarked that, "the structure of the process goes straight to the point". They felt enabled to understand what the desired outputs for each stage and the overall process were. However, the participation and timing were rated as 'somewhat adequate' in Case C. This can be explained by the fact that the mix of professionals was not provided by the company due to time and resource limitations. The members of the co-ordination group, composed by three industrial engineers, highlighted that the limited participation became an issue. According to the Product

Development Manager, "an opportunity was missed in our company". As the executive elaborated, "collaborators from different departments should be present to enhance the reliability of the decision and enrich the process". It is important to indicate that the Human Resources function was not represented in the group. Therefore, the approach addressing human factors could not be applied as proposed. The group felt that the discussions leading to consensus were as important as the final decision, especially while testing the proposed framework. This issue also explains the 'somewhat adequate' rating associated with the timing. For the group, the time for the process should have been extended to allow such participation. In Case C, however, there were no guarantees on an upcoming date suitable for the participation of the human resources decision maker. Thus, it was decided that this would be reported as an issue, but the schedule for the process application was to be maintained. In the remaining cases, the time was regarded as 'quite adequate'. Participants performed the activities according to plan and desired outcomes.

The usability was also evaluated by participants. The process was considered 'very clear' and 'quite clear'. The seminar format was well rated and, according to the groups, contributed to the ease of use; the sub-criterion was rated as 'very easy' in three of the four cases. The information provided was regarded as 'quite adequate' and the concepts approached by the process 'quite clearly defined'. The easiness of the interpretation of results was especially highlighted by participants. In terms of utility, the process was rated as 'quite relevant' to achieve the expected results. The outcomes were worth the time spent in the application, remarked the decision makers of Case B. In Case C, the process was regarded as 'very useful' to incorporate into the decision important aspects, the human factors, that could have been otherwise overlooked. The facilitation promoted by the researcher in all four case studies was considered 'quite adequate'. Team members of Case B admitted initially feeling overwhelmed by the process and dynamic of the discussions among decision makers. However, with the facilitation provided by the researcher, they became increasingly confident in performing activities, following the logic of the approach.

Table 6.5 - Overall process evaluation summary

Criteria	***Sub-criteria***	***Case B***		***Case C***		***Case D***		***Case E***		***Overall Sub-criteria***	***Overall Criteria***
	Information availability	1.0		2.0		2.0		1.0		**1.5**	
Feasibility	Timing	2.0	1.7	3.0	2.7	2.0	2.0	2.0	1.7	**2.3**	**2.0**
	Participation	2.0		3.0		2.0		2.0		**2.3**	
	Clarity	1.0		2.0		2.0		2.0		**1.8**	
Usability	Ease of Use	1.0	1.3	1.0	1.7	2.0	2.0	1.0	1.7	**1.3**	**1.7**
	Appropriateness	2.0		2.0		2.0		2.0		**2.0**	
	Relevance	2.0		2.0		2.0		2.0		**2.0**	
Utility	Usefulness	2.0	2.0	1.0	1.3	2.0	2.0	2.0	2.0	**1.8**	**1.8**
	Facilitation	2.0		1.0		2.0		2.0		**1.8**	
	Confidence	80%		85%		90%		95%		**88%**	

Scale of the evaluation: (1) very, (2) quite, (3) somewhat, (4) not at all.

Open-ended questions related to the main difficulties faced in the process and suggestions and comments were included in the utility criterion. For participants of Case C, for example, the experience of participants was regarded as crucial to the process application. Moreover, the level of experience should be similar. Team members felt that only senior executives should be chosen as team members. While in Cases B, D, and E, regardless the experience of participants, the group indicated that the process is associated with a learning curve. Every new application leads to enhanced experience in terms of the concepts and stages of the process. Participants of Cases B, D and E suggested that a software tool should be developed to apply the process. In their opinion, this would accelerate the process application as long as associated with the same format of seminars, workshops and face-to-face discussions. The group of Case C indicated that the identification of human factors was the main issue in the process application. For the group, the understanding of the concept of human factors should be the focus of a separate exercise at the beginning of the first stage. Furthermore, the list of human factors should be expanded. Even though the categories assisted in the identification, human factors still constitute a new concept to most companies, especially regarding their role in the selection and the implementation of advanced manufacturing technologies.

In Cases D and E, group members described the prioritisation of human factors as quite challenging. This point was explored with the groups and some indications of causes and solutions were debated. According to team members of Case D, this issue arose due to the novelty related to the approach, by including aspects not usually considered in the selection decision. For participants of Case E, this difficulty relates to the method used for the evaluation. It became clear from their comments that the use of the Taguchi Loss Function became somewhat problematic. Decision makers presented some resistance to using the technique for the quantification of human factors instead of its usual utilisation as a quality tool. It was suggested that the method should be more clearly represented in the framework, not only in the process. Similarly, participants of Case B remarked that the prioritisation of AMT should be represented. Graphs or charts were proposed as an important visual aid for the second and third stages. Participants felt that it could facilitate the understanding of the impact of human factors and the importance of expected outcomes.

Furthermore, intermediate review sessions were suggested as means to ascertain the reliability of findings. Finally, group members remarked that the limits of the framework should be more clearly defined. Particularly in Cases C and D, the participants were unsure on the contribution provided by the approach at first glance. It was suggested that the 'AMT alternatives' and the 'Selection of AMT' boxes should be deleted. For the participants, the proposed approach should be the focus of the representation of the framework. Table 6.5 contains the evaluation summary for the overall process. The evaluation took place during a one-hour session at the end of the process. Simultaneously, the feedback on the results was provided to participants. The feedback session represented an opportunity for decision makers to evaluate the achievement of the objectives behind the testing of the approach.

6.3 THE FEEDBACK SESSIONS: REPORT ON THE PROCESS FINDINGS

In **Case B**, the application of the process aimed to assess the impact of human factors related to the acquisition of a new packing system. With the installation of the advanced technology, 1/3 (one-third) of the operators involved in the manufacturing were to be eliminated. The fear of job losses and the associated resistance to the technical change represented a concern for the company executives. According to the firm's CEO, the proposed approach managed to identify crucial human factors that should be addressed before the actual installation of the AMT. The firm members indicated further availability for other studies to develop the approach. "The process produced significant insights on the impact of the human factors related to the AMT implementation", indicated the Industrial Manager. Even though, in this case, there was only one technology alternative, the firm saw great potential associated with the approach. The Industrial Director who is also the company's CEO remarked that, "we could use this type of approach in our company. It was easy to understand and follow and, at same time, it structured our decision-making process".

Participants of **Case C** felt enabled to express their views and discuss openly crucial factors involved in the decision-making. The company is a branch of a very large German corporation and, as such, not always perceived specific human factors relevant to the Brazilian plant were considered in acquisition decisions. The use of the approach allowed the identification of items specific to its internal context and the development project at hand, according to the executives. Furthermore, the Engineering Manager felt that "the process collaborated to compose an organised identification effort while, in the past, it was just about very subjective perceptions on the impact of some intangible aspects". Because of this emphasis on the structure of logical steps and procedures present in the process, the decision makers indicated that they would be able to use the approach to justify their choices to the Head Office. The quantification method proposed in the approach was seen as a step forward toward a robust assessment of intangible aspects such as the human factors.

The Industrial Manager and the Financial Manager of **Case D** were quite satisfied with the results. "The process allowed not only the identification of relevant factors, but also quantified this information, so we could use it in the acquisition decision", remarked the Financial Manager. The approach showed to be feasible for the company due to clear definitions and procedures for the assessment of human factors. For this decision, the participants had a very clear idea on the human factors they intended to evaluate. Nonetheless, "other important human factors emerged from the process; the discussions provided a very useful means to identify and quantify these aspects", elaborated the Industrial Manager. The informal outcomes provided by the approach were especially valued by the firm executives. Both managers (Industrial and Financial Managers) remarked that the process was essential to establish a closer relationship between the finance and the production function. "The approach indicated that it was possible to quantify these aspects whereas, in previous acquisitions, the company chose to ignore them".

In **Case E**, the approach assisted in the comparison of the available options. It was felt that the process was even more useful when technology alternatives presented similar conditions. The Supply Chain Manager remarked that, "aspects relevant to the implementation of the available AMT were identified and quantified in the process; something we deemed difficult in the past". The company directors were quite pleased with the results. The decision makers believed that, "thanks to the process; we have a structured and more reliable way of comparing different options based on the identification of important factors". A meeting with the Financial Director occurred after the process application. The executive was interested in using the approach to evaluate the human factors involved in the strategic planning of a new plant. Participants felt that the approach had a strong enough potential to be used for other decisions to assess relevant human factors. Alongside the positive results provided by the process, the feedback sessions indicated that further refinement was required for the framework and the process. The discussion on the development of the framework and the process is present in Sections 6.4 and 6.5, respectively.

6.4 THE REFINED FRAMEWORK

Based on the feedback provided by participants, opportunities for improvement were indicated. These points refer to the framework and the process and contribute to the development of the approach. It was suggested that each of the process stages should be represented in the framework. This would reportedly communicate the purpose of the approach more clearly to company stakeholders. Participants also remarked that the strategy or the evaluation method adopted in each stage should be visually represented in the framework. This representation, according to the groups, would assist in their understanding on the concepts and the expected outcomes associated with the process. The framework was modified to address this issue. In the first stage, the acquisition objectives are represented as the input for the process. The use of the categories of human factors is indicated. Similarly, the graphic representation of Taguchi's Loss Function (TLF) is shown as the evaluation method utilised. The third stage of the process, the AMT prioritisation, was added to the framework. The utilisation of the weighted loss scores to compare AMT options was highlighted. Boxes related to the 'AMT alternatives' and the 'Selection of AMT' were removed. The latter changes aim to define the limits of the contribution provided by the approach. Figure 6.3 represents the framework before the testing cases. Figure 6.4 shows its revised version after the feedback from participants of the initial cases.

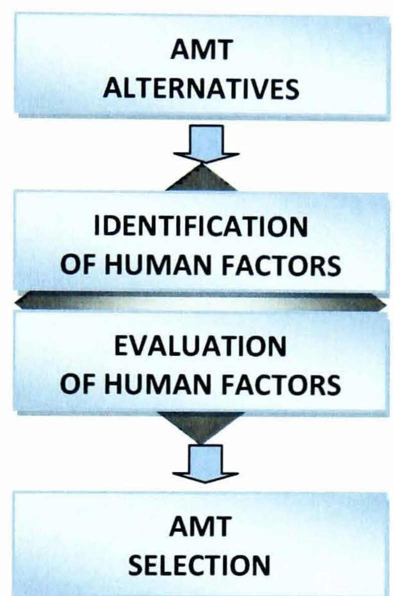


Figure 6.3 - The framework before the initial testing cases

6.5 THE REVISED PROCESS

Improvement opportunities for the process were indicated in the four testing cases. Although no activities were suppressed, additional sessions were proposed. It became clear that the co-ordination group composed by the mix of professionals defined in the process was crucial to the achievement of objectives. It was suggested that more time should be spent in the team creation. Furthermore, the experience of decision makers was regarded as necessary for the accomplishment of tasks. Senior managers or equivalent executives were considered ideal participants. According to group members, extensive knowledge on the company decision practices and AMT acquisition objectives is necessary. Thus, in the Point of Entry, more time will be directed at the negotiation of required participants corresponding to this profile.

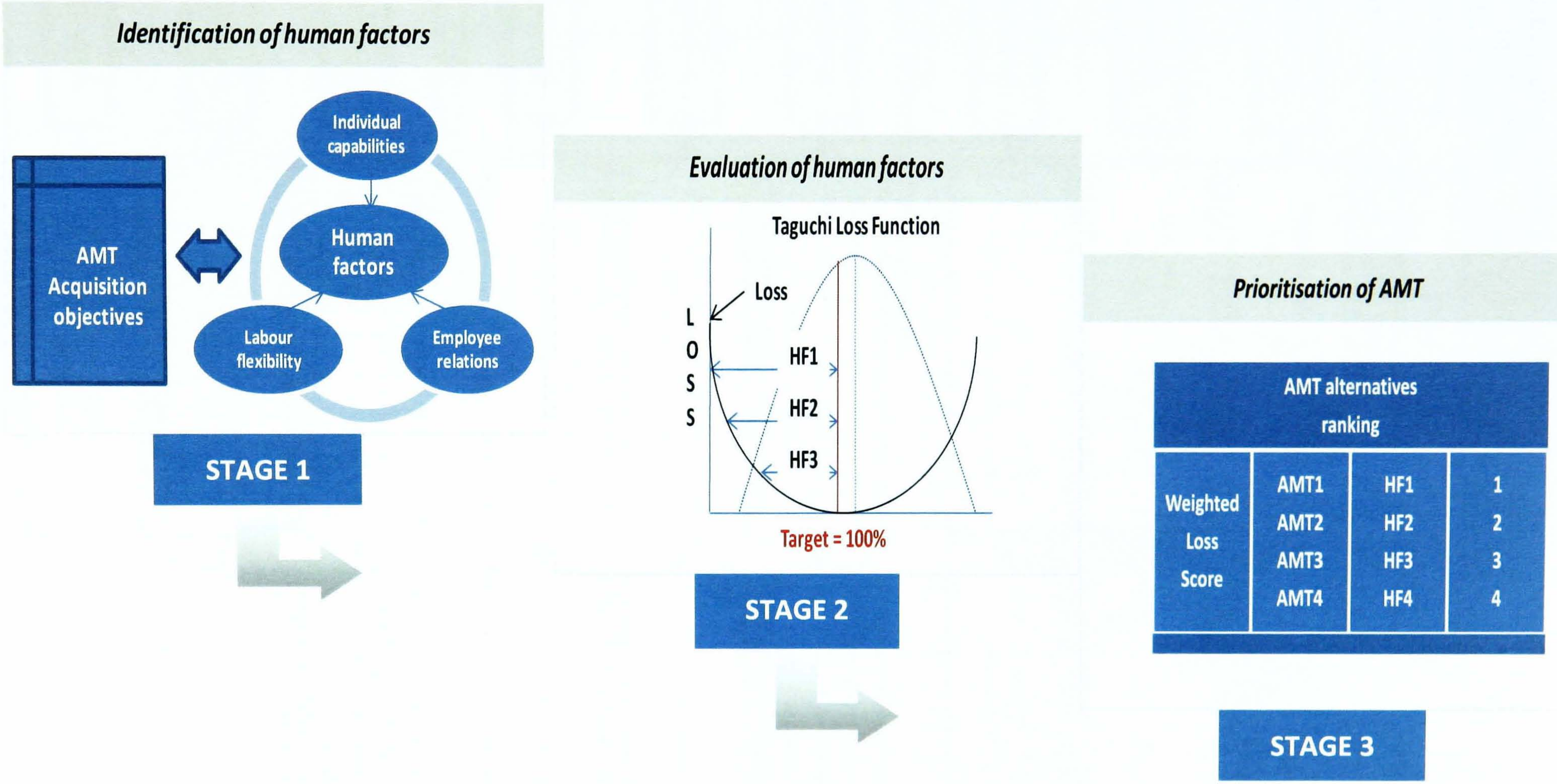


Figure 6.4 - The refined framework

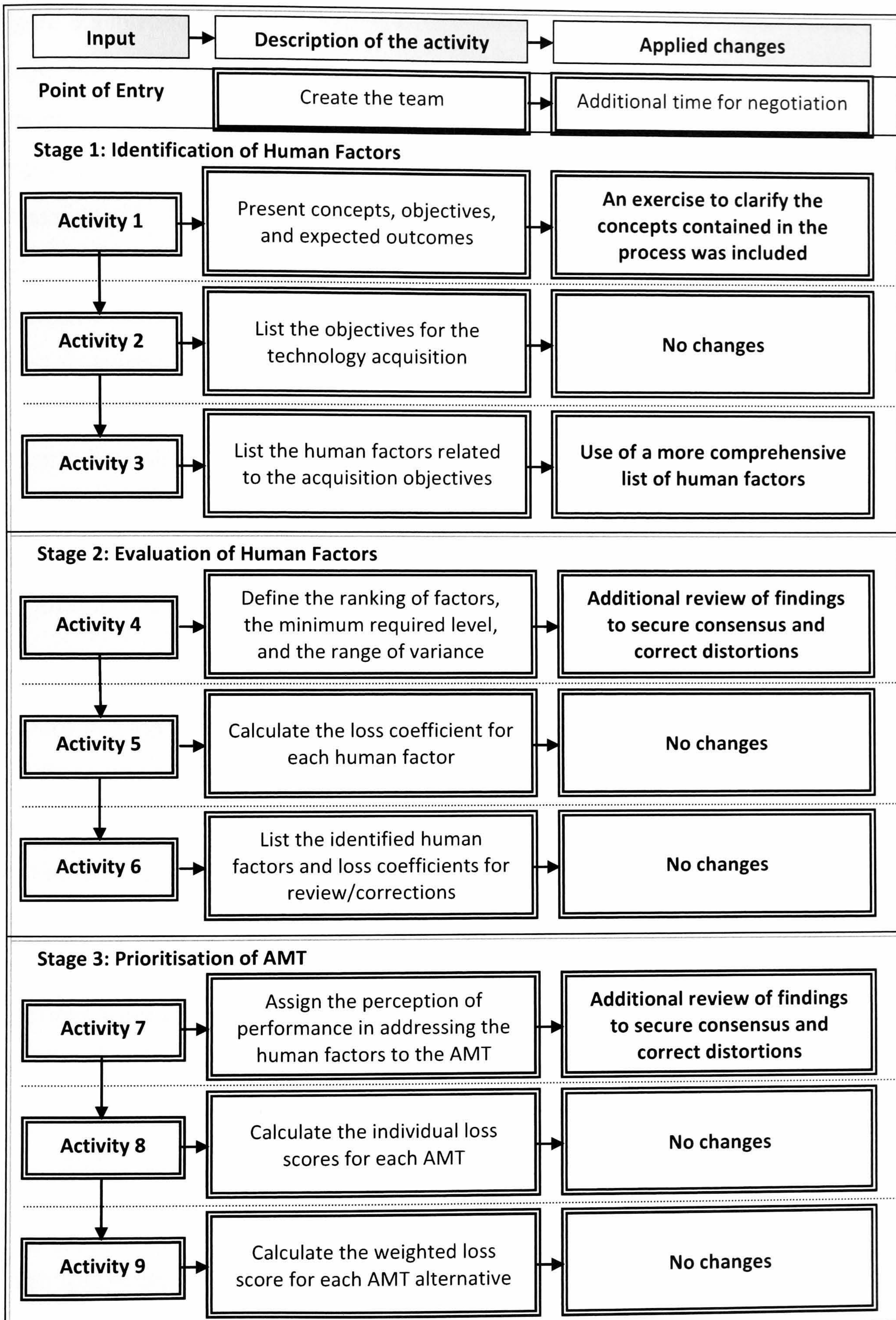


Figure 6.5 - The revised process

Figure 6.5 introduces the revised process, indicating the applied changes. In the first stage, the understanding of the concept of human factors showed to be somewhat troublesome. A session to explain the concept of human factors and their related impact on the implementation of advanced manufacturing technologies was planned (Appendix L). This exercise takes place before the beginning of Activity 1. It introduces the concepts approached in the process and represents a forum for questions and discussions. A summarised list of human factors found in literature was used to trigger the identification in the testing case studies (Activity 3). However, according to group members, the list should be expanded. Further examples would reportedly assist in the general comprehension of the process and identification of factors involved in the acquisition. To address this issue, a more comprehensive list of human factors collected from literature will be used for future applications (see Chapter 5, Table 5.2). The examples are presented at the beginning of Activity 3.

The main difficulty encountered in the second stage, according to the co-ordination groups of Case C, D and E, was the confidence in the ranking of the human factors attributed by participants. In Case C, this issue was related by team members to the lack of participation of required decision makers. The group of Case D felt somewhat challenged by the process and associated this initial difficulty to the novelty of the approach. Case D participants reported some resistance to the use of the method for the quantification of human factors. Regardless the potential cause, additional review sessions were proposed to correct distortions and confirm results. A session for the review of the ranking of human factors, minimum required levels, and the range of variances was proposed. This session takes place at the end of Activity 4.

Similarly, in the third stage, the assignment of the perceptions of decision makers related to the technology options was considered slightly challenging. In order to deal with this issue, another review session was forecasted for the end of Activity 7. The sessions for review proposed for Stages 2 and 3 seek to improve the general level of confidence in the performance of activities. Moreover, they represent an opportunity for decision makers to debate their choices, correct mistakes and reach consensus on the decision. Charts used as visual aids were also suggested by the groups; thus, they will be used to report the results of the activities. Finally, the participants suggested that the process should be applied through a computational tool. From their point of view, this would facilitate the application of the approach. As this recommendation does not address directly the content of the process (still under development), it was decided this point would be evaluated at a later stage of the study.

6.6 CONCLUSION

Chapter 6 elaborated on the evaluation feedback from four case studies conducted to test the process. A detailed description of the case studies can be found in Appendix K. The proposed approach was evaluated as quite feasible, usable and useful. Nonetheless, points for improvement were indicated. Furthermore, suggestions and comments from case participants were used to develop the framework and the associated process. Chapter 7 contains the testing of the refined versions of the framework and the process in four companies in Brazil. Amongst the case studies, three are represented by new companies. One of the firms used in the initial testing was approached to test the revised approach and evaluate the changes.

CHAPTER 7

TESTING THE FRAMEWORK AND THE PROCESS

Chapter 6 discussed the development of the framework and the process. Four case studies were conducted. Improvement points were indicated by the feedback of participants, leading to refined versions of the framework and the process. Chapter 7 elaborates on the final testing of the developed versions. The evaluation feedback provided by participants of the four additional case studies is discussed within the chapter. Three companies represented new studies whilst a firm used in the initial testing was approached to apply the refined process and evaluate the modifications. Section 7.1 establishes the background to the studies and clarifies the profile of the companies. Section 7.2 discusses the evaluation of the process realised by participants. In Section 7.3, the report on the findings from the application of the approach and the achievement of the firms' objectives for testing the proposed process are discussed. Appendix M presents a more detailed account of the cases.

7.1 PROFILE AND BACKGROUND TO THE CASE STUDIES

Four companies were used to test the framework and the process. Cases F, G, and H were represented by new companies. Case I referred to a company used in the initial testing. The cases were preceded by assessment interviews to establish the company's profile, time of operation, sector and main product (s), annual turnover, ownership type, and number of employees. Additionally, decision-making practices for technology investments, people and criteria involved for the evaluation were explored, including the most recent AMT acquisition the interviewees could recall. Finally, the reasons for testing the process were discussed with the decision makers.

Case F is represented by a national family-owned firm that was founded in 1946. It manufactures steam generators and boilers. Currently, 152 employees work in the plant; 104 in the manufacturing process. The company works by project and its turnover varies according to the orders delivered and in operation. Each project is worth £1M approximately and 12 (twelve) projects are taken per year, on average. Investments in technology are considered by the top management of the Manufacturing Department. If above US$ 120.000,00 (£80,000.00), the acquisitions are analysed by the Board of Directors, using technical and economic benefits as criteria for their evaluation. The company initiated a modernization process in 2008. Although this process involved AMT acquisitions, the substitution of equipments was still reduced. According to the Administrative Manager, the production of steam generators involves considerable concern on safety issues in the manufacturing process. Thus, a more technical evaluation of equipments is prioritised, especially maintenance and technical assistance requirements. As the executive pondered, "a marginal consideration of intangible factors takes place because of the technical emphasis. Related human factors are often overlooked in the decision process".

Nonetheless, these factors greatly influenced the acquisition of technologies in the past. During a recent acquisition of a CNC machine (£200,000.00), for instance, the selection of the AMT was primarily based on its easiness of use for workers. Even though, the technology was the most expensive option, it was selected because of softer issues related to the human element. "The lack of figures demonstrating it was the right decision generated a dispute between the Manufacturing Function and the Board of Directors". In addition, the concern on the safety of employees had great impact on the implementation of the technology, which was not considered during the decision-making. In this case, the company decision makers were interested in the acquisition of a CNC lathe and a CNC turret-type drilling machine. Three international brands were identified. Due to the recent emphasis on the need to identify and quantify human factors, the company became interested in employing the approach. The sets of skills of employees represented a recurring concern for decision makers given the complexity of advanced technologies. Associated with the skilling issues, the motivation of workers related to the technical change was being evaluated. The initial contact was made through the Administrative Manager who consulted the Board of Directors and agreed to apply the process. The co-ordination group had three main participants: the Administrative Manager who acted as the team leader, the Production Manager, and the Human Resources Manager.

Case G corresponds to a national company created in 1990. It is one of the main world players in the manufacturing sector of hydraulic jacks. The company has been ranked for the past five years as the national leader in the production of hydraulic jacks for vehicle assemblers. Its clients include brands such as Mercedes-Benz, Ford, Volkswagen, Mitsubishi, IVECO, and others. The industry is certified by several quality appraisal entities. It is the only producer in Brazil, which follows the international quality regulations to supply equipments to large vehicle assemblers. The company is certified by the ISO 14001:2004, the ISO TS 16949:2002, the ISO 9002, EN 1494:2000, QS 9000, and the Venezuelan Regulation COVENIN. The firm generates an average of £1M in profits per month. Its production is divided amongst three major markets: 50% of the production for assembly, 35% is reserved for reposition and 15% for exportation. Although its products are sent to the "four corners of the globe" as stated by the Industrial Director, the internal market is still the industry's priority.

Usually, the demand for new technologies is identified by the Industrial Director from the feedback of manufacturing supervisors. The decision involves the Industrial Director and the Purchasing Officer. The firm has tried to keep up with market changes by automating the manufacturing process. Furthermore, the company has recently sought in the market techniques or methods suitable for AMT selections. According to the Industrial Director, one of the most critical issues in the AMT selection is the human factors. The executive recalled the significant resistance of senior machine operators when a new moulding technology was installed two years ago. As a result, the company was forced to hire two new operators in their 20s. After the effectiveness of the technology was demonstrated, the same senior employees, who resisted at first, came forward seeking the opportunity to work with the equipment. A new foundry centre and a pipe cutter were being sought by the company and two options were identified. The industry was keen to test the approach to assess human factors involved in the decision. "We need more information on which technologies better suit the company and its characteristics related to the human element", remarked the Industrial Director. The resistance to change and the consideration of employee morale represented vital issues. The company was interested in uncovering problems with the process application. The co-ordination group was composed by the Industrial Director (team leader), the Human Resources Manager, the Purchasing Officer, and the Production Supervisor.

Case H refers to a national company. The firm was founded in 1961 to manufacture radios, the most powerful mass medium in Brazil at the time. Following the process of modernization of its industry, the company started to produce sound systems for cars and trucks, micro systems and radios for personal entertainment, amplifiers and acoustic products for musicians. It counts on 380 collaborators, 300 in the operations, mainly women. According to the Industrial Director, female workers tend to be better suited for the handcraft work particular to its assembly line. Two brands are commercialised. The first brand comprises the multi-use musical equipments for musicians and residential entertainment (55% of the production). The second brand is destined to the reposition goods for the automotive industry (45% of the volume produced). The firm's revenues reach £2M per month and the turnover of employees tends to be very high (around 4% per month). The company sells its products to the internal market (95%) and exports a small percentage of the volume produced (5%).

The industry embarked on an automation process initiated in 2005 when the production of furniture changed from manual to CNC. Several problems arose from this process. The investment was not economically justified, which generated some disagreements among top management executives. In addition, the workers presented significant resistance to the change, fearing the loss of jobs. However, since then, the company's profitability increased about 50% and the investment was repaid, which motivated a new acquisition of AMT. Furthermore, the Brazilian labour regulations were ready to change in 2009 and the working hours were being reduced from 44 to 40 hours per week. Although an improvement in the autonomy of workers to recognise problems and propose solutions was being sought, issues related to the existing technical expertise were also being questioned. The firm felt that the continuous modernization of its manufacturing processes, maintaining quality and reducing labour needs was necessary. A new SMD machine was being sought through market perusal to accomplish this objective. Five technology alternatives were being studied. Three failed to meet technical criteria established by the Industrial Manager, the Research and Development Manager and the Engineering Design Expert and were eliminated. The two remaining presented similar costs and conditions. Due to the significant influence of human factors in past decisions and the required evaluation of options, the testing became appealing to the company.

Finally, **Case I** refers to a firm used in the initial testing of the framework. The company executives indicated availability for the testing of the revised approach. As reported in Chapter 6, it is a family-owned firm operating 62 years in Brazil with 1600 employees and £90M as turnover. The industry is in the agro-industry. The automation sought by the company referred to a new packing system for *'in natura'* meat. The company aimed to enhance capacity, reduce the risk of contamination of the food and reduce the workforce. No national options were deemed adequate for the established goal. The acquisition of a machine imported from Spain was being studied by the company. Concerned with the resistance of employees due to the job losses, the firm executives felt that it was important to evaluate the human factors involved in the decision. Table 7.1 summarises the information on the companies' background. A more detailed description of the cases can be found in Appendix M.

Table 7.1 - Background on the companies for the final testing of the process

CASE STUDY	INDUSTRY	ANALYSED DECISION	MAIN CONCERNS ON HUMAN FACTORS	CO-ORDINATION GROUP
Case F	Industrial Equipments	CNC lathe CNC turret-type drilling machine	- Workers' skill set; - Employee motivation.	Administrative Manager* HR Manager Production Manager
Case G	Hydraulic jacks	Foundry centre/pipe cutter	- Resistance to change; - Employee morale.	Industrial Director* HR Manager Purchasing Officer Production Supervisor
Case H	Sound Equipments	SMD Machine	- Resistance to change; - Technical expertise.	Industrial Director* HR Supervisor Research and Development Manager
Case I	Agro-industry	Packing system	- Resistance to change; - Structuring skills to retain new knowledge.	Industrial Director* Industrial Manager Production Supervisor HR Manager
*** It indicates the team leader**				

7.2 THE EVALUATION OF THE PROCESS

As in Chapter 6, the participants of the cases studies evaluated the overall process in terms of its feasibility, usability and utility (Platts, 1993). The evaluation forms were distributed and completed after each stage. The utility of the provided outcomes and the quality of the operationalisation and analysis were also appraised (Cáñez, 2000; Tan, 2002). The evaluation and the report on the process results took place during the same one-hour feedback session at the end of the application. It is important to remark that Case I corresponded to a company that had tested the previous version of the approach (designated as Case B in the theory development phase). Thus, some of the feedback provided by the co-ordination group related to the changes applied to the process and the assessment of the impact of its modified version on the firm.

7.2.1 Stage 1: Identification of Human Factors

Stage 1, which corresponded to the identification of human factors, was rated as 'quite feasible'. The information on the stage activities was regarded as clearly and well defined in all four cases. In Case I, the stage was regarded as 'very feasible'. The company tested the previous version of the approach. Participants felt that the modified framework was very effective in communicating the purpose behind the stage. Similarly, according to group members in Cases G and H, the visualisation of the strategy used in each stage facilitated their grasp of concepts and focused the efforts. The time was also regarded as 'quite adequate' for the discussion of vital issues. Nonetheless, the participation represented an issue in Case F. The decision makers pondered that a professional from the Purchasing Department should have been present. This explains the rating 'somewhat adequate' related to the appropriateness of the mix of professionals. The difficulty was also associated by participants with the difference in the seniority of the individuals within the co-ordination group. In Company F, the team was composed by the Production Manager, the Administrative Manager and the Human Resources Manager. The Administrative Manager who acted as team leader was a new employee. The same referred to the Human Resources Manager. Both professionals had been with the firm for less than a year while the Production Manager started as machine operator in 1989. Due to the lack of experience of participants, the Production Manager felt that it was important to count on a senior representative from the Purchasing Department. This point was discussed with the group. In order to address the issue, the process was paused and one of the senior buyers was contacted via conference call. After collecting the relevant information, the process was restarted and concluded with no further difficulties. The usability of the stage is considered next.

The groups of Companies F and I considered the stage 'quite usable' due to its clear definition of purpose. In Case H, the participants related the usability of the stage with the experience of participants in previous decisions. The Industrial Director had been with the company for 38 years, in this case. The same for the Human Resources Supervisor and the Research and Development Manager, who had been with the firm for more than 10 years each. Hence, not only the decision makers had extensive experience in the company operations, but were also part of previous AMT selection decisions. "The identification of human factors relevant to the decision examined by the group was facilitated because of the knowledge accumulated by participants", remarked the Industrial Director. Thus, the participation in previous acquisitions of technology was deemed desirable to accomplish activities. However, in the same company (Case H), the co-ordination group felt that the process application required a more in-depth consideration of human factors. The group members indicated that the identification of human factors had a technical focus, despite the presence of the Human Resources Supervisor. This was due, according to the Industrial Director, to the emphasis on technical aspects contained in the strategic planning of the company. The participants believed that the proposed approach collaborated to intensify the discussion on intangible aspects, which was very beneficial to the firm.

The stage was rated between 'very useful' and 'quite useful'. The participants of Case G felt enabled to include important issues in the decision. The output provided by the stage, i.e., the identification of human factors, was considered crucial to the prioritisation of AMT. In Case F, the co-ordination group members remarked that the stage was useful to identify aspects, which tended to be overlooked in past decisions. The introduction of categories of human factors was fundamental to the identification. "We managed to compose a concept for human factors based on these categories, which was essential", remarked the HR Manager. Participants saw great potential in the use of the approach. From his 20 years of experience with the firm and 25 years in the sector, the Production Manager highlighted that the identification of human factors had rarely taken place. "Companies still base their AMT acquisition decisions on a few financial and technical criteria", stated the executive. "This partially happens because we do not have good methods to assess human issues", ratified the Administrative Manager. High ratings of confidence in the results of the first stage were obtained (around 88%). Nevertheless, the co-ordination group of Case H indicated that more experience on the utilisation of the approach is necessary to improve confidence levels. The executives believed that the identification of human factors is new to most companies, even though the need to include these factors in the AMT selection has become more evident recently. A routine application of the approach was seen as a way to move forward and meet this demand. Table 7.2 shows the evaluation of the first stage, the identification of human factors.

7.2.2 Stage 2: Evaluation of Human Factors

In all four cases, the participants evaluated the stage as 'quite feasible'. According to group members of Cases G, H, and I, the representation of the evaluation method present in the framework was helpful in that regard. The executives of Case H, for instance, revealed that the framework communicated upfront to participants what the expected output from the stage was. Team members of Case F made a similar indication. "From looking at the framework, we were able to visualise the objective of the stage and the method used to quantify the human factors", as the Human Resources Manager elaborated. In the participant companies, the executives of three of the four groups were unfamiliar with Taguchi's Loss Function. Thus, the researcher was prepared to spend more time to clarify the contents of the method. An additional session was scheduled with this goal. Upon the process application, however, this was deemed unnecessary. The individuals managed to understand the principles behind the method quite clearly. The activities were accomplished with no apparent difficulties. In Case I, where the process had been applied in its former version, the participants remarked that the activities were more easily performed this time around. A learning curve was associated with the process application. The time was considered 'quite adequate' to complete tasks. The participants of Cases F, G, and H also mentioned that they felt comfortable in expressing their points of view.

Table 7.2 - Stage 1: Evaluation summary

Criteria	***Sub-criteria***	***Case F***		***Case G***		***Case H***		***Case I***		***Overall Sub-criteria***	***Overall Criteria***
Feasibility	Information availability	1.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0	**1.5**	**1.8**
	Timing	2.0		2.0		2.0		1.0		**1.8**	
	Participation	3.0		2.0		2.0		1.0		**2.0**	
Usability	Clarity	1.0	2.0	2.0	2.0	2.0	2.3	1.0	1.3	**1.5**	**1.9**
	Ease of Use	2.0		2.0		2.0		2.0		**2.0**	
	Appropriateness	3.0		2.0		3.0		1.0		**2.3**	
Utility	Relevance	1.0	1.7	1.0	1.3	1.0	1.7	1.0	1.3	**1.0**	**1.5**
	Usefulness	2.0		1.0		2.0		1.0		**1.5**	
	Facilitation	2.0		2.0		2.0		2.0		**2.0**	
	Confidence	90%		90%		80%		90%		**88%**	

Scale of the evaluation: (1) very, (2) quite, (3) somewhat, (4) not at all.

The second stage was regarded as 'quite usable'. However, some concern on the ranking of human factors in Cases G and H was raised by the groups. In Case G, the participants remarked that more time would be needed to discuss the importance of the human factors. The discussion amongst group members was highlighted as a very positive element of the stage and the process. The Production Supervisor stated that, "the debate leading to the ranking of human factors allowed the evaluation of the impact of human factors in the implementation efforts". Similarly, the Purchasing Officer highlighted the importance of considering different viewpoints proposed in the stage. For the executive, "it was especially relevant to gather those who know the operation in great detail and those who seek the alternatives in the market". The group agreed that the Taguchi Loss Function (TLF) facilitated this process by requiring reflection on softer issues. However, a degree of subjectivity was related to the method. A more robust application of the TLF was deemed necessary, according to the co-ordination group of Case G. Participants of Case H regarded the ranking of human factors as a challenging task. This was indicated by the rating 'somewhat true' attributed to the ease of use criterion. While evaluating the stage, the group members suggested an alternative to the way the discussion occurred. In their opinion, the decision makers should analyse the human factors in individual sessions before meeting as a group. The Industrial Director believed that this would make the task somewhat easier by involving a more in-depth discussion on the ranking of factors. The individuals would then 'defend' their opinion before reaching consensus.

The difficulty on the ranking of human factors and the decision-making dynamic suggested by the participants of Case G and H were further explored with the groups. The Purchasing Officer of Case G mentioned the use of sensitivity analysis to address the subjectivity related to the ranking. According to the executive, this could challenge the choice of decision makers and improve the robustness of the approach. The Taguchi Loss Function was considered quite promising for the quantification of human factors, thus the sensitivity analysis should be associated with the method for better results. In terms of group decision-making dynamic, the possibility of using the sensitivity analysis was also discussed with the participants of Case H. The members of the co-ordination group felt that employing the sensitivity analysis could represent a potential alternative worth exploring. Moreover, the Research and Development Manager remarked that the sensitivity analysis could meet the suggestion of a different dynamic for the decision-making. The in-depth discussion on the ranking of factors could be carried out through the application of the sensitivity analysis, according to the executive. These possibilities were also explored in the evaluation of the utility of the process with the groups of participants of Cases G, H, and I.

In Cases F and I, executives from both co-ordination groups highlighted the utility of the Taguchi Loss Function for the quantification of human factors. Managers remarked that lack of methods to 'measure' intangible factors has been a major obstacle in the selection of AMT. The method as applied in the stage seemed to be suitable to deal with this hurdle. The activities of the stage were considered 'very useful' for the evaluation of human factors, according to participants of Case F, G, and I. The loss scores were also regarded as a suitable measure for this assessment. The decision makers of these companies related the use of the Taguchi Loss Function with an improved level of confidence in the results of the process and the perception of utility present in the approach. Companies F and G felt enabled to explore issues such as the resistance to the technical change and the level of employee morale.

Nonetheless, as described in the usability assessment, issues regarding the subjectivity of the decision and the procedures for the decision-making were raised by participants of Cases G and H. The application of sensitivity analysis was considered by the groups and questioned in terms of the utility of the process. According to some members of the co-ordination groups, the method's utility is related to the robustness of the quantification method being used. In this regard, the sensitivity analysis would explore the changes in preference. The participants felt that this could enhance the robustness of the approach and, in consequence, improve the utility of the process. It was decided that this would be an alternative worth studying in other applications. In the evaluation of the group of Case I, the additional session to review findings proposed in the stage had a very positive effect. Still, according to the team, the application of the method brought another benefit; errors in the decision were minimised by the approach. The participants attributed this benefit to (1) the additional session to ascertain the reliability of findings and (2) the logic of the steps taken in the stage. The level of confidence, in this case, increased from 80% to 95%. For the group, this was mainly due to the changes applied to the process, which allowed a more detailed discussion on issues and provided further reflection. The group also saw potential in the application of the sensitivity analysis to enhance the robustness of the process, which should be explored further. Table 7.3 summarises the evaluation of participants related to the second stage of the process.

7.2.3 Stage 3: Prioritisation of AMT

Overall, the stage was rated between 'very feasible' and 'quite feasible'. However, in Case F, the participants demonstrated some uneasiness in assigning perceptions to the technology options. The lack of experience of group members was once again associated with this issue. While the Production Manager had no difficulties in evaluating the available AMT, the Administrative Manager and the Human Resources Manager struggled with their choices. Both professionals briefly questioned the Production Manager on his perception. It became patent that the opinion of the executive guided their assignment and prevailed in this case. Co-ordination group members of Cases G and I related the feasibility of the stage with the time spent on the activities. The participants felt comfortable in discussing issues after the completion of the previous stages. Especially, considered the team of Case H, "concepts and objectives became clearer to us; in consequence, no time was wasted and activities were performed more easily". Thus, the time was regarded as 'very appropriate' and worth the efforts of the group. The participation was rated as 'quite adequate'. According to the participants of Case H, the format of the sessions facilitated the discussions and improved their confidence in the decision. Table 7.4 represents a summary of the evaluation of Stage 3, for the prioritisation of AMT.

Table 7.3 - Stage 2: Evaluation summary

Criteria	***Sub-criteria***	***Case F***		***Case G***		***Case H***		***Case I***		***Overall Sub-criteria***	***Overall Criteria***
	Information availability	2.0		2.0		2.0		2.0		**2.0**	
Feasibility	Timing	1.0	1.7	2.0	2.0	2.0	2.0	1.0	1.3	**1.5**	**1.8**
	Participation	2.0		2.0		2.0		1.0		**1.8**	
	Clarity	1.0		2.0		2.0		2.0		**1.8**	
Usability	Ease of Use	1.0	1.3	2.0	2.0	3.0	2.3	2.0	1.7	**2.0**	**1.8**
	Appropriateness	2.0		2.0		2.0		1.0		**1.8**	
	Relevance	1.0		1.0		2.0		1.0		**1.3**	
Utility	Usefulness	1.0	1.3	2.0	1.7	2.0	2.0	2.0	1.7	**1.8**	**1.7**
	Facilitation	2.0		2.0		2.0		2.0		**2.0**	
	Confidence	90%		85%		80%		95%		**88%**	

Scale of the evaluation: (1) very, (2) quite, (3) somewhat, (4) not at all.

Table 7.4 - Stage 3: Evaluation summary

Criteria	***Sub-criteria***	***Case F***		***Case G***		***Case H***		***Case I***		***Overall Sub-criteria***	***Overall Criteria***
	Information availability	2.0		2.0		2.0		1.0		**1.8**	
Feasibility	Timing	1.0	1.7	1.0	1.7	2.0	2.0	1.0	1.3	**1.3**	**1.7**
	Participation	2.0		2.0		2.0		2.0		**2.0**	
	Clarity	2.0		1.0		2.0		1.0		**1.5**	
Usability	Ease of Use	2.0	2.0	1.0	1.3	2.0	2.0	1.0	1.0	**1.5**	**1.6**
	Appropriateness	2.0		2.0		2.0		1.0		**1.8**	
	Relevance	1.0		2.0		2.0		2.0		**1.8**	
	Usefulness	2.0	1.7	1.0	1.7	1.0	1.7	1.0	1.7	**1.3**	**1.7**
Utility	Facilitation	2.0		2.0		2.0		2.0		**2.0**	
	Confidence	90%		90%		90%		95%		**91%**	

Scale of the evaluation: (1) very, (2) quite, (3) somewhat, (4) not at all.

In terms of usability, the stage was considered 'quite clearly defined'. In Cases G and H, the stage activities were performed quite rapidly. The researcher questioned the group about the quick timing. For members of the co-ordination teams, this was due to the familiarity with the activities within the stage. The participants reported feeling more confident due to the learning acquired in the previous stages. The additional session proposed for the beginning of Activity 7, the assignment of the perceptions of the AMT performances, was also crucial to the groups. In Case I, this change was welcome by the co-ordination group. The decision makers guaranteed that the extra time influenced their confidence and benefited the overall process.

The utility of the stage was also well rated. In Case F, the activities were considered 'very relevant' to the achievement of the proposed outcomes. Participants of Cases G, H, and I believed that the stage was 'very useful' to obtain more informed decisions. The time spent in the process was thought worthwhile by all four groups. In Cases F and H, the process allowed the analysis of the technology options, considering important human factors. Technical expertise and operational skills, for instance, were evaluated and regarded in the decision. Team members of Cases G and H stated that the stage presented a logical flow of activities towards the final objective. Reportedly, the structure of steps influenced positively the level of confidence in the obtained results. High ratings were achieved in all four cases, which indicated that the stage was deemed useful for the prioritisation of AMT. As they did in the second stage, participants of Cases G and H suggested that the use of the sensitivity analysis should be explored for the prioritisation. According to the groups, the technique could also address the issues related to the assignment of perceptions reported by participants. In addition to the evaluation of the feasibility, usability and utility of each stage, the general utility of the process was appraised. Participants rated the value of formal and informal outcomes and the quality of the analysis and the operationalisation. A four-point scale of evaluation was employed for the general utility: (1) very good, (2) quite good, (3) somewhat good, and (4) not at all.

7.2.4 General Utility of the Process

The formal outcomes represented by the completion of each of the stages of the process were rated between 'very useful' and 'quite useful' in all four case studies. In Case F, the participants highlighted the importance of the Taguchi Loss Function as means to quantify involved human factors. In fact, the members of the co-ordination groups of the three new companies were not familiar with the method. In these cases, some resistance was being expected by the researcher. The opposite occurred. Participants of Case G, for example, felt motivated by the introduction of the evaluation technique. The Industrial Director remarked that, "the reason important aspects more on the intangible side are ignored has to do with the lack of methods suitable to appraise them". The Human Resources Manager of the same company pondered that some assessment of human factors usually takes place in a rather unstructured way. The executive stated that, "the company tried in the past to assess this type of information, but noticed that it was extremely hard to identify and measure". The TLF used to evaluate the human factors and the AMT alternatives was seen as a way forward to achieve this objective by the groups in Cases F, G, H, and I.

The utility of the informal outcomes was well evaluated by participants. In Case H, the Industrial Director was especially pleased with the results obtained from the process application. The executive indicated that the workshops provided important feedback on the human factors. The participants were able to discuss openly the importance of these aspects and foresee their impact on the implementation of technologies. By being unfamiliar with the Taguchi Loss Function, the members of the co-ordination group of Case G, admitted feeling intimidated initially. However, as the activities were performed, 'team building' emerged from the process. Participants felt that they were learning together, elaborated the Purchasing Officer. Individuals from the team of Case F remarked that the process associated a sense of ownership to the AMT selection decision. Group members became closer as they shared responsibilities and debated important issues. Participants of Case I indicated that the process application was quite useful to improve their communication. The Industrial Director and the Industrial Manager highlighted that the process facilitated the dialogue among decision makers. Moreover, "it helped the firm to face issues that could be overlooked or unaccounted for", reflected the Industrial Director.

In terms of quality of analysis, participants felt motivated by the proposed approach. The co-ordination team of Case G stated that the process indicated that the quantification of human factors was possible. Similarly, the structure associated with the decision-making through the process was regarded as quite useful. Collaborators recalled past AMT acquisitions resulting in failure due to involved human factors, which were not identified or evaluated. Participants of Cases H highlighted the influence of the workers' education level in the AMT adoption. This has constituted an emergent issue for the company in recent years, considering the modernization of its market. The strategies proposed to analyse the human factors were deemed quite useful to handle these issues, during the implementation planning. Nevertheless, in Case I, a suggestion related to the use of the Taguchi Loss Function was made. A member of the co-ordination team proposed that the ranking of human factors should take place before the group session. Each individual decision maker should be heard separately. This would lead to a discussion with the other participants, where different points of view would be discussed and consensus sought. The suggestion was discussed with the remaining participants. It became clear from the debate that some verification on the utility of the change was necessary before proceeding. In addition, group members felt that the change would have a more direct effect on the quality of the operationalisation rather than improving the overall quality of the analysis. From the feedback obtained from this group, it was decided that the impact of the suggestion should be verified through further research, which was outside the scope of the present study. Figure 7.1 shows the utility evaluation in Cases F and G. Figure 7.2 represents the evaluation of the overall utility provided by participants of Cases H and I. The feedback on the evaluation is presented in pairs for a better visualisation of the ratings attributed by the members of the co-ordination groups.

Value of formal outcomes	***Scores***				***Value of informal outcomes***	***Scores***			
	1	***2***	***3***	***4***		***1***	***2***	***3***	***4***
1) Overall outcomes		FG			1) Group discussion and communication	G	F		
2) Identification of human factors		FG			2) Team building		FG		
3) Evaluation of human factors	F	G			3) Learning related to the concepts in the process	F	G		
4) Prioritisation of AMT	F	G			4) Learning related to the 'quantification' of human factors		FG		
Quality of analysis	***Scores***				***Quality of operationalisation***	***Scores***			
	1	***2***	***3***	***4***		***1***	***2***	***3***	***4***
1) Overall process		FG			1) Participation - utilisation	F	G		
2) Identification of human factors		FG			2) Participation - breadth and depth	F	G		
3) Categories of human factors		FG			3) Project management	F	G		
4) Taguchi's loss function	F	G			4) Procedures - seminars worksheets workshops		FG		
5) Quantification of intangible factors	F	G			5) Communication of purpose	F	G		
Scores:	1 very good 2 quite good 3 somewhat good 4 not at all				Keys:	——— CASE F .... CASE G			

Figure 7.1 - Utility evaluation summary (Cases F and G)

Regarding the quality of the operationalisation, the process was related to 'very good' and 'quite good' ratings. The participation was enhanced by the performed activities, reported the co-ordination group of Case G. In Case H, the participants highlighted the shift in focus in the company's decision-making because of the process. Technical aspects usually permeated the selection of technologies, explained the Industrial Director. The process created a wider scope of analysis for the options.

Value of formal outcomes	***Scores***				***Value of informal outcomes***	***Scores***			
	1	***2***	***3***	***4***		***1***	***2***	***3***	***4***
1) Overall outcomes		HI			1) Group discussion and communication	H	I		
2) Identification of human factors	I	H			2) Team building	H	I		
3) Evaluation of human factors	H	I			3) Learning related to the concepts in the process	HI			
4) Prioritisation of AMT	H	I			4) Learning related to the 'quantification' of human factors	H	I		
Quality of analysis	***Scores***				***Quality of operationalisation***	***Scores***			
	1	***2***	***3***	***4***		***1***	***2***	***3***	***4***
1) Overall process	I	H			1) Participation - utilisation	HI			
2) Identification of human factors	I	H			2) Participation - breadth and depth	HI			
3) Categories of human factors		HI			3) Project management	HI			
4) Taguchi's loss function	H	I			4) Procedures - seminars worksheets workshops		HI		
5) Quantification of intangible factors	H	I			5) Communication of purpose	HI			
Scores:	1 very good 2 quite good 3 somewhat good 4 not at all				Keys:	——— CASE H .... CASE I			

Figure 7.2 - Utility evaluation summary (Cases H and I)

The mix of professionals proposed in the process allowed other stakeholders to be included in the decision, sharing the responsibility for the outcomes. Team members of Case F ratified the sense of ownership regarding the selection of AMT, because of the breadth and extent of their participation. The activities proposed by the process collaborated to motivate employees, mentioned the group of Case I. "We felt our opinion mattered and shaped the decision", mentioned the Human Resources Manager. The sequence of activities was regarded as quite coherent with the objectives attached to the approach in all cases. Participants of Cases G and H stated that the purpose of the process was quite well communicated and assisted in the accomplishment of tasks. Overall, the framework was considered quite useful to assess human factors involved in the selection of AMT. Nevertheless, the application of the approach through a software tool was once again suggested by participants of Cases G and H. Mainly, due to the amount of calculations contained in the process and associated with the Taguchi Loss Function. According to the participants, this would enhance the participation of individuals and facilitate the tasks. Some members of the groups indicated that additional time could be invested in a more in-depth discussion of the involved human factors with the existence of this tool.

7.2.5 The Overall Process

The information on the activities was considered 'quite adequate' in Cases F, G, and H. Participants reported that the stages were easy to understand and follow. In Case I, where the previous version of the approach had been applied, the co-ordination group was pleased with the changes. More specifically, the team members valued the modifications expressed in the framework. The process communicated effectively the objectives behind each stage and fixed the importance of the outputs. It is essential to highlight that the sequence of steps contained in the process was also presented to companies. Both framework and process were used to communicate visually the purpose of the research. On a number of occasions throughout the cases, the groups highlighted the appropriateness of the time and the participation required in the process. In Case H, however, decision makers felt that more time should be put into the evaluation of human factors (second stage). Team members pondered that a technical appraisal of options should be present in its scope. The researcher clarified that the approach refers primarily to the assessment of human factors, using these items as evaluation criteria for the prioritisation of alternatives. Including other criteria such as the technical assessment would be outside the scope of the study.

Furthermore, the selection decision requires the consideration of other aspects beside technical issues, which could be neglected in this case. The group was satisfied with this rationale and agreed on its validity. Nonetheless, it was important to realise that the process motivated participants to think beyond its scope and application.

The process was deemed 'very clear' in all cases. The steps were considered logically laid out, which assisted in the achievement of results, according to the groups of Cases F and H. In Case H, the practical nature of the evaluation method, the Taguchi Loss Function, was related to the ease of use criterion. Its applicability to quantify human factors was perceived by the Industrial Director. Nevertheless, the team leader reinforced the need of extensive experience to obtain meaningful results. The knowledge on the company practices and other acquisition decisions is required. The Industrial Director of Company G ratified this need. The executive demonstrated some difficulty in completing tasks due to the lack of experience of participants. This point was also stressed by the Industrial Manager in Case I. Experience, in that case, contributed to the quality of the analysis provided by the use of the approach and influenced the level of confidence of decision makers. Overall, the process was considered 'very and quite appropriate' to rank technology alternatives.

Finally, the overall process was rated between 'very useful' and 'quite useful'. Group members of Case F were particularly interested in the relevance of the approach when different options presented similar conditions. Two main advantages were perceived by the executives: its usefulness to assess human factors and its applicability for comparisons. First, managers from all cases felt that the approach addressed the difficulty of finding methods to identify and quantify human factors. "Companies may know instinctively how some human factors affect the implementation of technologies, but include this information in the decision-making is another matter", remarked the Industrial Director of Case H. The process showed to be efficient in meeting this demand, according to the Human Resources Manager of Case F. Secondly, the approach provided a common measure for the comparison of options. For the executives of Cases G and H, available technologies tend to present similar conditions of price and post-sale. "Even if some concern on human factors is included in the decision, managers have no structured justification for it when facing their Board of Directors", argued the Purchasing Officer in Case G. By using the loss scores as magnitude for the evaluation of technologies, a more structured method to justify the decision was proposed, according to group members of Cases F, G, and H. The Production Supervisor of Case G considered that, "often we have apples and oranges [referring to the criteria for the evaluation of options] and no way to demonstrate that the chosen option is better than the next". The Taguchi Loss Function was deemed useful for this purpose by participants of Cases F and I.

The facilitation provided by the researcher was considered 'quite adequate', which collaborated to the smooth running of the process application and the achievement of established goals. However, the participants of Cases H and I remarked that the process application was somewhat dependent on the knowledge of the researcher, who acted as facilitator. Comparing the two applications (this company had been used in the initial testing as Case B), the co-ordination group members highlighted the importance of the facilitator to organise the workshops and guarantee the focus on the expected outcomes. The Industrial Director of Case I felt that a profile for the facilitator's role should be created. Based on this profile, the companies could identify the most suitable collaborator to fill in this crucial role. All cases were conducted according to the schedule of time and resources. Participants indicated that the existence of an Excel-based tool or computational aid to facilitate the performance of activities should be explored. This type of tool, according to members of the groups, would reduce the level of input required from decision makers. A mitigation of errors and an enhancement of the depth and quality of the discussions were associated with the existence of the suggested tool. High levels of confidence were obtained by the process (around 90%), indicating its usefulness for managers. Table 7.5 shows the evaluation of the overall process as determined by participants. Section 7.3 briefly describes the feedback sessions and the discussion on findings.

Table 7.5 - Overall process evaluation summary

Criteria	***Sub-criteria***	***Case F***		***Case G***		***Case H***		***Case I***		***Overall Sub-criteria***	***Overall Criteria***
	Information availability	2.0		2.0		2.0		1.0		**1.8**	
Feasibility	Timing	1.0	1.7	2.0	2.0	2.0	2.0	1.0	1.3	**1.5**	**1.8**
	Participation	2.0		2.0		2.0		2.0		**2.0**	
	Clarity	1.0		1.0		1.0		1.0		**1.0**	
Usability	Ease of Use	1.0	1.3	2.0	1.3	2.0	1.7	1.0	1.0	**1.5**	**1.3**
	Appropriateness	2.0		1.0		2.0		1.0		**1.5**	
	Relevance	1.0		1.0		2.0		2.0		**1.5**	
Utility	Usefulness	1.0	1.3	2.0	1.7	2.0	2.0	1.0	1.7	**1.5**	**1.7**
	Facilitation	2.0		2.0		2.0		2.0		**2.0**	
	Confidence	90%		90%		85%		95%		**90%**	

Scale of the evaluation: (1) very, (2) quite, (3) somewhat, (4) not at all.

7.3 THE FEEDBACK SESSIONS: REPORT ON THE PROCESS FINDINGS

The results of the process application were reported to participants after its completion. A one-hour feedback session was used for the evaluation and the report. This session also sought to evaluate the achievement of the objectives that motivated the firms to test the approach. In **Case F**, the company was interested in an approach to justify acquisition decisions. In the past, the identification and the quantification of human factors represented an issue for decision makers. Although concerns were raised, no structured ways to present this information to the Board of Directors were found. After the process, participants were satisfied with the results. The practicality of the approach was highlighted by the group members. The Taguchi Loss Function, employed as evaluation method to assess the human factors and the AMT, was regarded as quite useful. The Production Manager and the Administrative Manager remarked that the approach "could certainly be used for future decisions".

The Industrial Director of **Case G** stated that, "the company was able to see that there is a way to approach and measure human factors". The industry, in this case, aimed to assess human factors due to the significant impact they carried in previous AMT implementations. In the application of the process, "the company found a more comprehensive and structured way to evaluate the AMT options", indicated the Purchasing Officer. Apart from assessing the available alternatives, the process was also considered a potential instrument to gather commitment and enhance communication amongst decision makers. The group suggested that the decisions on AMT acquisitions should have a sequence of assessments. First, the technical evaluation of the options to eliminate upfront the alternatives deemed inadequate. Second, the company should assess the AMT in economic and financial terms. Third, the human factors should be appraised through the proposed approach.

In **Case H**, the company had two objectives for testing the approach: identify crucial human factors and compare two similar options. Considering the major influence the human factors have in its manufacturing process, the decision makers were interested in identifying relevant aspects. Furthermore, two similar AMT alternatives were being evaluated by the firm. The assessment of human factors was used to compare the two and find the most suitable option. According to the Industrial Director, the process not only collaborated to the choice, but added new information to the decision-making. The stakeholders were pleased with the findings and interested in applying the approach to other decisions. **Case I** was represented by a company used in the initial testing of the approach. This time around, the participants introduced a new AMT alternative that was not considered in the previous application. The comparison between the available options was conducted for testing purposes. The decision makers remarked that they have utilised the approach informally. The utility of the process to assess crucial human factors was highlighted. Finally, the practical relevance of the framework was considered an important asset. The company was interested in adopting the approach permanently.

7.4 ADVANTAGES AND ISSUES RELATED TO THE PROPOSED APPROACH

No major difficulties were identified by the participants of the final testing cases. Some suggestions were made by group members and addressed through discussions as they were provided. Some changes mentioned in the case studies were regarded as being outside the scope of the study, even though reported and considered by the researcher. Others indicated that further research was necessary to address them. The discussion on the latter is undertaken in Chapter 8. From the final testing cases, it is possible to identify advantages and issues that should be addressed in the proposed approach. Table 7.6 highlights these points and implications for the study. A clear communication of purpose through the visualisation of the strategy adopted in the first stage was highlighted as a positive aspect. The definition of the mix of professionals that participate of the decision-making was also regarded as an advantage. Reportedly, the identification effort intensified the discussion on human factors; items often overlooked within AMT acquisition decisions. This associated the approach with a superior degree of practical relevance and utility for managers.

Table 7.6 - Advantages and issues identified by participants in the final testing

Topic	Advantages	Issues
Purpose	✓Clear and well defined purpose ✓The facilitator guarantees the achievement of objectives	✓A profile for the facilitator's role should be created
Participation	✓Coherent as proposed ✓Produced positive informal outcomes: communication and commitment	✓Senior managers with experience are required to compose the co-ordination group and produce reliable decisions
Procedures	✓Logical sequence of activities ✓Appropriate schedule of time and resources	✓Additional time is necessary for the second stage, the evaluation of human factors
Categories of human factors	✓The proposition of categories composed a concept for human factors and assisted in the identification	
Taguchi's loss function	✓Easy to understand, attributing practical relevance to the approach ✓It structures the decision-making	✓Related to rather subject judgements ✓A computational tool should be used for the application

Nonetheless, senior executives with extensive experience are required to compose the co-ordination group and produce reliable decisions. The categories of human factors (labour flexibility, individual capabilities, and employee relations) were fundamental in the identification step. A definition for human factors was created through the categories, according to the participants. Taguchi's Loss Function, the evaluation method used in the second stage, was considered easy to understand and follow, which contributed to the practical relevance of the approach. However, somewhat subjective judgements present in its application were regarded as an issue. Participants suggested that the method should be associated with a sensitivity analysis to improve robustness. The format of discussions was considered adequate and an advantage, even though a different group dynamic was suggested. In the third stage, the subjectivity of the assignment of performance perceptions to the technology options in terms of the involved human factors was reported as an issue. Sensitivity analysis was suggested to deal with this hurdle. The schedule of time, activities and resources was considered positive, improving feasibility and usability.

In the assessment of the general utility of the process, the results of the use of the Taguchi Loss Function (TLF) in the second and third stages were considered an advantage as formal outcome. The format of the workshops and the face-to-face discussions prescribed in the process enhanced the communication amongst decision makers. This was regarded as a very helpful informal outcome. In terms of the quality of the analysis, the group dynamic was considered suitable for the purposes of the proposed approach. Nonetheless, a different dynamic was suggested for the decision. The operationalisation of the process provided greater participation from key stakeholders and attributed a sense of process ownership indicated by decision makers. In consequence, commitment was enhanced and better communication was promoted. Due to the amount of calculations associated with the TLF, a computational or VBA® Excel-based tool was deemed desirable for the application.

Overall, the procedures established in the process were considered a significant advantage, since the decision-making of intangible factors became more structured. Moreover, the practical nature of the TLF was highlighted by participants. The method produced a common magnitude for the quantification of human factors and the prioritisation of alternatives, allowing the comparison among similar options. Nonetheless, participants felt that more time should put into the second stage, the evaluation of human factors. Finally, given the importance of the facilitator's role to assure that the process objectives are achieved, the creation of a profile for this role was deemed necessary. This would assist companies in finding a suitable facilitator for the applications to guarantee the feasibility, usability and utility of the approach.

7.5 CONCLUSION

Chapter 7 described the testing of the framework and the process in four companies. A more detailed description of the cases can be found in Appendix M. The profile and background to the studies was presented and the evaluation provided by the co-ordination groups discussed. The feedback provided by participants demonstrated that the process was considered quite feasible, usable and useful. No major changes in the framework or the process were required, which indicated the overall achievement of data saturation. Chapter 8 discusses the study findings and conclusions. Limitations of the study are analysed and further research is proposed.

CHAPTER 8

DISCUSSION AND CONCLUSION

Chapter 6 discussed the initial testing of the process. The feedback from participants of four cases collaborated to the development of the approach. Chapter 7 described the testing of the refined versions of the framework and the process in four companies. Advantages and issues associated with the approach were identified in the cases. Chapter 8 presents the discussion of the main outcomes of the research. Findings associated with the study are also presented and discussed. Limitations related to the research are addressed and further work briefly described. Finally, the main question addressed in the study and the proposed contributions are analysed.

8.1 THE RESEARCH PROCESS

Addressing human factors has been considered vital to a successful implementation of advanced manufacturing technologies. Training, employee morale, working conditions and reward systems should be evaluated during the AMT selection, since they greatly affect the outcome of the installation. In particular, for developing countries, the assessment of human factors is considered paramount. First, these economies are still in the critical early stages of AMT adoption. Methods used for the selection are often incompatible with the complexity of these state-of-the-art technologies. Secondly, low rates of secondary education, scarcity of technicians, and problems with labour flexibility reinforce the importance of assessing human factors before the actual AMT acquisition. Although some approaches have been proposed to evaluate intangible aspects such as the human factors, difficulties in identifying and quantifying these items still represent a major obstacle for decision makers.

The research aimed to fill in this gap by providing a theoretical and a practical contribution. The theoretical dimension refers to the development, refinement and testing of a framework to identify, classify and quantify human factors. The practical contribution is associated with the verification of its appropriateness to companies in the context of the 'developing world'. In order to make the proposed contributions, a research process was envisaged. In the first phase, a preliminary framework was developed using the review of literature, interviews with experts represented by academics, industrialists and consultants, and a pilot case study. The output from this phase indicated that the framework required some changes and the development of a process for its application was needed. The initial testing in the field was conducted in four companies located in Brazil (Cases B, C, D, and E), which corresponded to the second phase of the study. The feedback provided by participants led to the refinement of the framework and the process. Finally, in the third phase, the proposed approach was tested in three new firms and one company used in the initial testing (Cases F, G, H, and I). Figure 8.1 reproduces the research process.

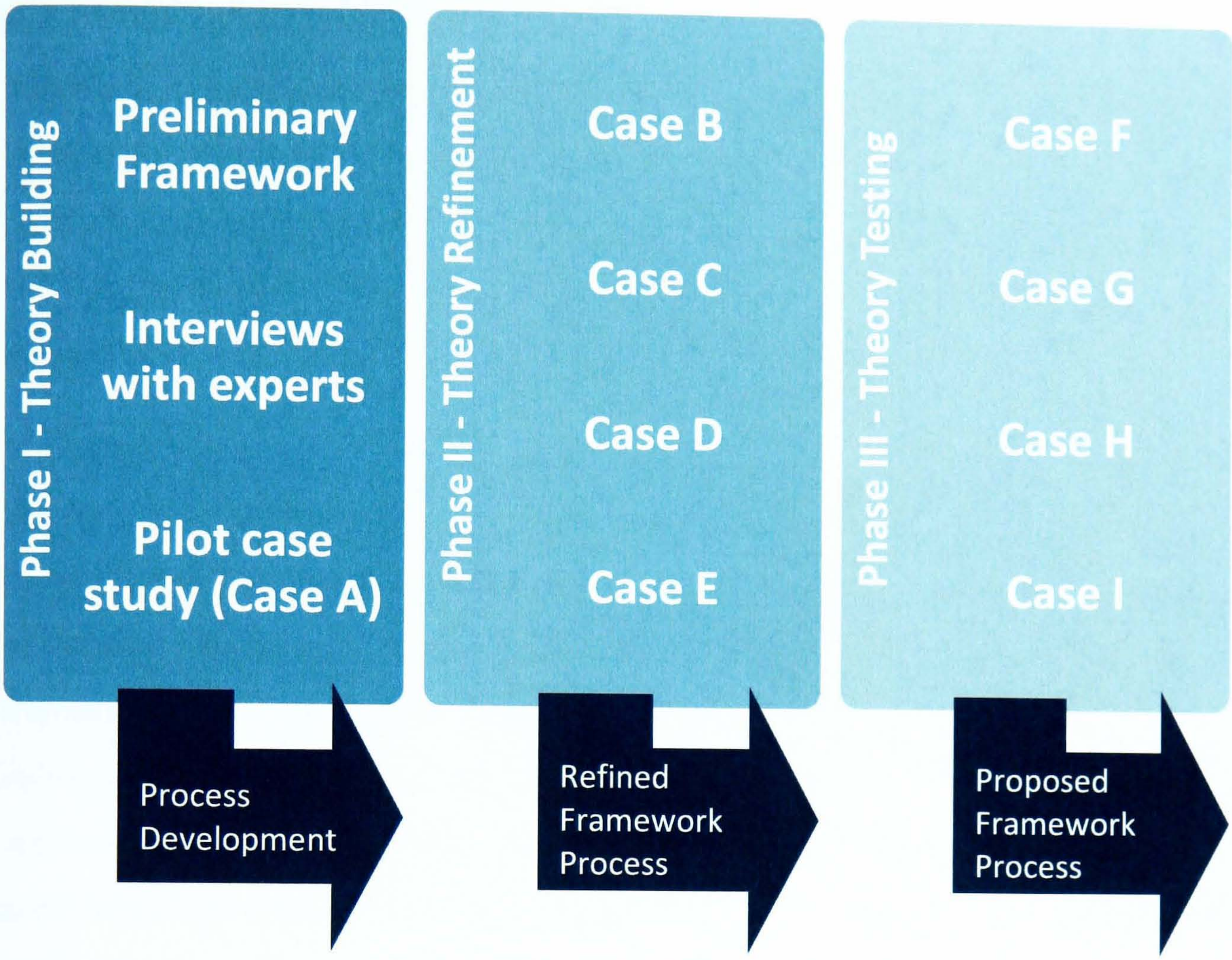


Figure 8.1 - The research process

Four objectives were pursued in the study. First, in the theory building phase, technology selection practices and appraisal techniques currently used by companies were investigated. Second, a framework and a process to identify and evaluate human factors relevant to the AMT selection were developed. Third, the proposed approach was applied in four companies. Its development was based on the input provided by participants. Finally, the applicability of the approach for the assessment of human factors was tested in four companies in Brazil. In the next sections, the main outcomes of research are examined in detail. Associated study findings are also discussed. Limitations attached to the study are considered and further research is briefly envisaged. Concluding Chapter 8, the research question and the proposed contributions are analysed and the achievement of the latter is evaluated.

8.2 MAIN OUTCOMES

This thesis described the development, refinement and testing of an approach to the assessment of human factors involved in the AMT selection. The approach composed by a framework and process addresses the need to incorporate these aspects into the decision-making. The strategies proposed for (1) the identification and (2) the evaluation of human factors represent the main outcomes of the research.

In general, the selection of technologies is based on expected strategic and economic benefits and implementation factors involved in the adoption of advanced technologies. The objectives for the acquisition are constituted by the expectations of decision makers and the concerns on the desirable infrastructure to support the implementation, established during the adoption planning. However, the exam of relevant literature suggested that many of the issues related to the human factors are recognised only after the actual installation of the AMT. Human factors have great impact on the success of the adoption and may contribute to the failure of the implementation. The acquisition objectives, thus, indicate which human factors are relevant to a set decision. A structured identification of human factors should be promoted to list the involved items. The evaluation of human factors should correspond to the quantification of these factors to be considered in the selection decision. In addition, the literature review highlighted the lack of structured approaches for the identification proposed by AMT adoption models. The difficulties encountered by managers because of the complexity of existing AMT justification methods were also emphasized. The need for a common measure for the comparison of options is deemed necessary for a sound selection. The lack of involvement of stakeholders was also indicated in the interviews with academics, consultants and industrialists. Consensus, in this context, was considered crucial to gather commitment related to the acquisition. Thus, the proposed approach to the assessment of human factors should be easy to follow, propose a common measure for the comparison of alternatives, involve key stakeholders, and seek consensus.

In the developed approach, human factors are treated as criteria for the selection of technologies during the AMT adoption pre-installation phase. The objectives for the acquisition of the technologies constitute the initial input for the identification effort. They represent concerns associated with the infrastructure necessary for a successful AMT adoption. The evaluation of human factors is carried out after the identification; it corresponds to the quantification of these aspects. This quantification is considered crucial to incorporate these concerns into decision-making. The strategies devised for the identification and evaluation of human factors are described next.

8.2.1 The Identification of Human Factors

In the framework and the process, a stage for the identification of human factors was proposed. The development of a strategy for this identification has been somewhat neglected by the literature due to the fluidity related to the concept of these intangible factors. Aiming to structure the identification effort, three categories of factors were proposed: a) labour flexibility, b) individual capabilities, and c) employee relations. The labour flexibility category refers to the human factors associated with the manufacturing process affected by the AMT adoption. It can include factors such as job enlargement, delegation of tasks, and involvement in the decision-making. While the individual capabilities factors relate to the skills and attitudes, which employees acquire or develop through the acquisition of new technologies such as development of operational skills, workers' empowerment, and new skills acquired from training initiatives. The employee relations category defines the relationship between a company and its collaborators for the AMT adoption. Some examples can be cited: better working conditions, job welfare and security, and influence of unions. Grouping human factors sought to facilitate the identification and compose a corresponding list of items that should be considered for the selection. The proposition of the categories managed to compose a conceptual definition for human factors. This definition aimed to enable decision makers to accomplish the identification task in a more structured way. The study does not claim, however, the three categories are to be taken as exhaustive. They are proposed as guidance to managers in the identification of human factors pertinent to the decisions and particular to the context of each company. Nonetheless, the categories proposed by the framework were regarded by participants as quite comprehensive and relevant to the context of companies in newly industrialised countries such as Brazil.

8.2.2 The Evaluation of Human Factors

The complexity of existing methods for AMT justification and the wide range of proposed techniques can make the evaluation an overwhelming task for companies. The existence of a sole measure orientated by a target can represent an alternative to address this hurdle. Different magnitudes used as evaluation criteria for the AMT selection decision should be converted into a single measure. As established in the literature review, this common measure is required for the evaluation of technology alternatives. Decision makers require simplicity combined with robustness and focus. Thus, the evaluation should represent meaningful and sound orientation for managers. The quantification of human factors is regarded as vital to incorporate identified human factors into the decision-making. Taguchi's Loss Function (TLF) was defined as the method for the evaluation stage. The method has been employed to appraise factors of an intangible nature with positive results as reported in literature. The TLF attributed a common measure to the comparison of different options, the 'weighted loss score'. The second stage proposed in the framework and the process addresses the difficulties in evaluating human factors as described in literature and practice. The 'weighted loss score' was recognised as a way forward for the quantification effort. The feedback on the adequacy of Taguchi's Loss Function was very positive. Clarity and easiness were related to the application of the method.

The companies evaluated the proposed framework and process as quite adequate for assessing human factors in the selection of AMT. Purpose, procedures, participation, and practical relevance were emphasized as the main advantages of the developed approach. The structure of logical steps leading to the assessment of human factors was easy to understand and follow, according to participants. The time put into the performance of the activities within the process was deemed worthwhile. The mix of professionals required for the application was also considered appropriate. The open discussions conducted in workshops related to a number of informal outcomes that were also considered desirable. The enhancement of communication and the depth of participation achieved through the process application led to a higher level of confidence in the decision. The companies were particularly pleased with this outcome. The decision makers felt that the framework could be applied in their decision practice due to its feasibility, usability and utility. Participants also indicated that the approach could be applied in other decision-making processes to assess human factors. A wider applicability for the framework was envisaged and briefly discussed. Overall, it represented a sound approach for managers in the studied context. However, experience in the companies' operations and in past selection decisions was deemed paramount to obtain meaningful results. Companies faced difficulties when one or more decision makers were new to the firm and correspondent decision-making practices. Senior managers were considered 'ideal' participants due to their extensive and relevant knowledge. The role of the facilitator was also judged essential to guarantee that the objectives of the process are achieved and activities are performed according to plan. The development of a profile for the role was considered necessary by the participants of the case studies.

8.3 ASSOCIATED FINDINGS

In each phase of the research process, relevant findings were identified. Technology selection practices and appraisal techniques currently used by companies were investigated in the literature review. During the assessment interviews conducted to establish the background to the case studies, additional input was obtained on the criteria used for AMT selection and people involved in the decision-making. Even though, the interviews with the company executives were realised in the second and third phases of the research, these points echoed the conclusions drawn from the literature. Thus, such findings are included in the content of the discussion of the theory building phase. The findings related to the theory building, the theory refinement, and the theory testing phases are discussed next.

8.3.1 Theory Building Phase

The human factors should constitute the criteria for the AMT selection. Although decision makers are aware of the importance of human factors, the evaluation of technologies does not include these aspects. Executives tend to overlook issues such as employee morale, ergonomics, and working conditions due to the difficulties in quantifying them. The firms researched in Brazil demonstrated some concern over the human element, but lacked any structured approaches to assess the human factors. The level of education of employees and the lack of technicians to operate the advanced equipments represent a major concern. Similarly, the resistance to the technical change and the skilling level of workers correspond to vital issues reported by decision makers. The selection of technologies is primarily based on technical requirements and, secondly, on economic and financial criteria. A short term view of AMT acquisitions is prevalent. Mostly, decision makers intend to enhance productivity and reduce labour costs. Pressure for short term returns was noticeable in the interviews. Therefore, a framework was deemed necessary to address the assessment of human factors. A set of AMT alternatives are usually available for the selection decision. Market perusal and/or benchmarking of AMT options should take place before the process application. P pre-selection usually involves the evaluation of the technologies according to other criteria such as technical assessment, economic evaluation, etc. While the proposed framework focuses on a defined set of involved factors. Executives should identify and broadly evaluate a number of alternatives prior to the proposed assessment of human factors.

The involvement of key stakeholders should be enhanced. The top management is in charge of the market perusal and the AMT selection. Although some input from stakeholders e.g. machine operators, maintenance personnel may be requested from time to time, the acquisition is usually decided by the high administration. Collaborators have to adjust to the technical changes as they occur. In consequence, the experience of decision makers on AMT selection processes is reduced. Companies in Brazil seem to be in the early stages of adoption of advanced technologies. As discussed in the literature review, this represents a common pattern in developing or newly industrialised countries. Decision makers also have difficulties in articulating the main strategic objectives for the selection. Similarly, the concern on human factors tends to be raised only after the AMT installation, which has caused a number of implementation problems for companies in newly industrialised countries.

A framework for the human factors assessment should be applied using a process. According to interviewees, a coordinated sequence of steps is necessary to apply the framework. The 'Process Approach' (Platts, 1993; 1994; Platts et al., 1998) was suggested for the operationalisation. Upon the process development, the Human Resources Manager, the Production Manager, the Production Supervisor, and a Team Leader were defined as key decision makers to evaluate the available AMT alternatives. Workshops are organised to perform the activities prescribed in the process and worksheets are used for the data recording. A facilitator should assist in the performance of activities and observe the accomplishment of objectives present in each stage and in the overall process. A stage for the prioritisation of AMT was also deemed necessary for the process. With the assessment of human factors and the existence of a common measure, the comparison among alternatives can be conducted. In this stage, the decision makers should evaluate whether the technology options can address the identified human factors and how. Their perception is assigned to each alternative. The prioritisation of AMT based on the assessment of the human factors represents the final output of the process.

8.3.2 Theory Refinement Phase

The 'process approach' elements represent an advantage for the application. Seminars and workshops were organised for the process application. The seminars included the presentation of the objectives for each stage and the workshops corresponded to the actual performance of activities. The participants felt enabled to express their opinion through face-to-face discussions. This format reportedly enhanced the extent of the participation of decision makers and improved the communication among peers. It was also associated with higher levels of confidence in the decisions and a more structured decision-making. The cases highlighted the importance of the participation of the mix of professionals defined in the process. The communication of the objectives related to the approach is also crucial. The process should be publicised to reinforce its importance and guarantee the participation of key stakeholders defined in the schedule. The participants of the case studies found the procedures established in the process quite useful. The proposed sequence of activities and the use of worksheets and evaluation forms were regarded as valuable strategies to record tasks. Moreover, the procedures allowed the focus of the efforts toward the performance of activities. The framework application depends in great measure on the understanding of participants. They should be able to grasp the concepts involved in the approach such as acquisition objectives, human factors, etc. Only after these definitions are apprehended, the process can be applied.

Review sessions are necessary for the second and third stages. The case studies revealed that more time should be put into the review of findings and the correction of eventual distortions. This aimed to improve the level of confidence of participants in the outputs from each stage. While the use of graphs and charts contributed to represent visually the obtained results and facilitate the performance of the tasks present in the process. The existence of a computational tool was also suggested by participants and associated with the facilitation of activities. This type of aid could also reduce the input required from decision makers and mitigate errors. In the study, the researcher played the role of facilitator. It was important to have an individual fully aware of the concepts contained in the approach. It was crucial to observe how participants perceived the process and assist them along the way to perform the activities, explaining the content of the process and creating a good work environment. The feedback sessions were also fundamental to companies, considering the accomplishment of the objectives envisaged when they agreed to participate of the testing of the approach. It represented a valuable opportunity to collect impressions of participants on the utility and impact of the process application on the firms and decision makers that were members of the co-ordination groups.

8.3.3 Theory Testing Phase

The structure of the identification stage was considered quite appropriate. The decision makers found that the brainstorming sessions were an adequate strategy to identify human factors. The categories of human factors, labour flexibility, individual capabilities and employee relations, assisted in the effort and managed to trigger the discussions. Reportedly, focus and structure were attributed with the use of the examples. By categorising these items, a definition for human factors was composed. Participants remarked that the identification of these aspects was facilitated through the recognition of the three proposed groups. Nonetheless, more experience on the use of the approach was deemed important to obtain better results. Furthermore, a database of human factors was suggested by members of the groups. Some of the decision makers remarked that, as the consideration of these intangible aspects rarely takes place in companies, more experience is needed in the identification of human factors involved in the implementation of advanced technologies. The proposed stage was regarded as a significant step forward, considering this context.

The evaluation stage was deemed adequate for the human factors quantification. The utilisation of Taguchi's Loss Function as evaluation method for the human factors was valued by participants. According to the executives, the difficulties of quantification were addressed with the deployment of a technique easy to use and understand. The debate related to the ranking of human factors was especially welcome and enhanced the understanding of decision makers on the impact of the factors. However, the participants felt that the robustness of the approach requires further work. Associating sensitivity analysis with the TLF was suggested as means to address this issue. Moreover, the amount of calculations necessary for the application of the method was considered somewhat intensive. The decision makers felt a computational, software or VBA® Excel-based tool was required to achieve the expected output from the stage. The participants felt comfortable with the use of the method and saw potential in its application to the quantification of human factors. Overall, the application of Taguchi's Loss Function was viewed as an important progress toward a sound evaluation of human factors relevant to the AMT selection.

The AMT prioritisation stage was deemed adequate and of practical relevance.
Participants felt that the prioritised list of AMT options based on the human factors was critical to the selection of technologies. The structure of the stage was particularly well received. The assignment of the perception of decision makers on the performance of the AMT was considered another key feature. Even though, the robustness of the application of Taguchi's Loss Function in the third stage still needs to be addressed, according to the participants of the cases. Sensitivity analysis was mentioned by some of the decision makers to deal with this issue. Through the third stage, the opinion of experts was considered and recorded for future reference, representing an important source of information for the company. The companies highlighted the importance of brief and focused sessions of feedback. This point was also related to the time spent in the application of the framework. The participants added extra value to the fact that the approach could be applied within one working day. Considering the busy routine of executives, the sessions were scheduled not to interfere negatively with their daily activities. The process results were presented after its completion and the achievement of the objectives for testing the approach considered by the companies. The session also meant immediate acknowledgement of the time and work put into the process application by the participants. In Section 8.4, limitations found in the study are explored. Opportunities for further research were also indicated in the study process. Section 8.5 briefly describes these items.

8.4 STUDY LIMITATIONS

A framework and a process for the assessment of human factors involved in the AMT selection were proposed. The approach was regarded as a way forward toward the identification and evaluation of these factors. However, within the research process, some limitations were identified. These limitations refer to the following items:

1) The scope of the research;
2) The number of case studies;
3) The researcher's pre-understanding and process facilitation;
4) The comprehensiveness of the list of human factors;
5) The robustness of the evaluation method;
6) The format of the process application.

Due to time constraints, the focus of the research was narrowed down to address the assessment of human factors involved in the selection of technologies. Because of this focus, other criteria such as technical evaluation, economic and financial analyses were put aside. Even though, the companies were pleased with the results obtained from the approach application, some executives revealed that a more comprehensive decision-making framework was required. Moreover, the way different assessments are interpreted and incorporated into the AMT selection decision-making was not approached by the research. Similarly, the correspondence between the evaluation criteria and performance measures for monitoring purposes was not explored. In this sense, the framework and the process presented a somewhat limited scope in view of the additional needs that were reported by participants of the case studies.

In total nine case studies were conducted, one pilot case study in Phase I, four cases in Phase II and four companies participated in Phase III. According to Eisenhardt (1989), between four and ten cases enable the researcher to justify the influence of the empirical data in the theory. Although, nine cases accommodated this requirement, more cases could have represented richer results. In addition, the companies that participated in the study were located in the same part of Brazil, the South Region. Considering the different patterns of development from region to region (Baer, 2001), it cannot be assumed that the study findings reflect the complexity of the 'developing context' and its specificities. The research depicts a partial portrait of this reality from the input of selected firms and their managers. Furthermore, due to the limited time and resources available for the research, no attempt was made to group companies by sector or size. The study did not seek to engender patterns common to firms with similar profile or industry. Conclusions related to companies with comparable backgrounds were not pursued or drawn. In consequence, the wider applicability of the approach was not explored in the study.

The researcher acted as facilitator for all the cases. The process application, as a result, became rather dependent on the facilitator's pre-understanding of the concepts. As explored by Gummesson (2005), in the action research, the researcher plays two roles. First, he/she is the facilitator of the change introduced while conducting a scholarly investigation. Secondly, the researcher acts as a consultant by proposing a solution to an existing problem. It has been suggested that an independent internal or external facilitator should be used to address this issue (Platts *et al.*, 1998; Cáñez, 2000; Tan, 2002). Due to time and resource limitations, this strategy was not adopted. Stenbacka (2001) indicates the existence of pre-understanding should be acknowledged, especially in qualitative research. In this context, continuous reflection should take place in each phase of the study and participants should feel enabled to speak freely, according to their own knowledge structures. This recommendation was followed. However, further effort should be employed to reduce the possibility of bias and collaborate to the quality of the study.

During Stage 1 of the proposed process, a list of examples of human factors collected from literature was used to trigger the identification effort. As discussed in the review of literature, human factors represent a topic often neglected in theory and practice due to the fluidity of its concept. Additionally, the number of field studies exploring its definition and corresponding examples is still reduced. The companies indicated that a more comprehensive list was necessary. Decision makers felt that the identification of human factors relevant to their context and acquisition decisions would be facilitated, considering a more extensive list of options. The lack of comprehensiveness of the list of human factors presents another limitation identified in the study. On the other hand, the existence of a more comprehensive list or database of human factors collected from other applications could lead firms to identify factors that are not adjusted to their reality or particular sector/industry. This could contribute to creating a significant bias decision. Considering this limitation, the impact of the list on the identification efforts should be assessed as well.

Taguchi's Loss Function was employed as evaluation method. The loss score was used to quantify the human factors and evaluate the available technology options. Although, positive feedback was obtained, the robustness of the approach represented an issue. Participants remarked that the strategy was still perceived as rather subjective, since it depended on the ranking of human factors and the assignment of perceptions to the available options. Sensitivity analysis was suggested as an alternative to deal with this pitfall. The strategy tests the best choice while presenting what-if changes in the criteria priorities (Saaty, 1987) and could address this limitation. Other mechanisms were also mentioned such as iteration with consistency checks, assessment with different individuals, and decomposition (Keeney, 1982). Yet, in this case, the objective was to test the method's applicability without adding excessive complexity to its use. Mechanisms to improve the robustness of the approach may be helpful in that regard for future applications.

Participants suggested that a computational tool or equivalent aid should be used to apply the process. Decision makers even mentioned the appropriateness of a VBA® Excel-based tool to accommodate the procedures to be followed in the proposed approach. The use of worksheets was considered helpful to record the information related to the activities and set an appropriate pace for the process application.

Nonetheless, it was mentioned that a computational aid would be helpful in speeding up the work. Similarly, the findings related to the decision-making could be shared more easily with this format. The tool would also collaborate to a more autonomous decision process. Automatic prompts could assist managers in the performance of activities, according to the sequence and logic prescribed in the proposed approach.

8.5 FURTHER RESEARCH

Considering the limitations associated with the study, the following areas for further research were indicated:

1) Scope: Participants of the case studies indicated that a more comprehensive approach for AMT selection is necessary. Alongside the assessment of human factors, executives suggested that the evaluation of other important criteria such as technical and financial assessments should be present. The possibility of combining assessments without losing the focus established in the study will be investigated. The proposition of performance measures to monitor the human factors will also be explored. Review of relevant literature, interviews with experts and case studies could be used for this investigation.

2) Number of case studies: Applying the process in more cases could represent an opportunity to develop further the framework. Although the saturation of data was achieved, this could enrich the research findings. Conclusions related to particular sectors and/or diverse contexts might be drawn from a larger number of cases; the same for the conduction of case studies in other regions of Brazil. A more complete account of that reality may be provided.

3) Pre-understanding and facilitation: As mentioned in the discussion of limitations, the use of an independent facilitator may be desirable. In this case, specific mechanisms should be associated with the independent testing to assess the impact of the facilitator's role. Furthermore, the profile for the individual that occupies this position in the companies should be defined. Required characteristics should be prescribed within the approach.

4) The comprehensiveness of the list of human factors: A database of human factors was suggested by participants. Further literature will be explored to expand the list. Additionally, the conduction of other cases could assist in the identification of relevant factors. Initially proposed as trigger, managers may become excessively dependent on the existence of examples relevant to other firms and decisions. The objective remains to propose a definition and allow companies to identify the human factors that are relevant to their context. In consequence, the attempt to compose a more comprehensive list will be associated with the evaluation of its influence in the applications.

5) The robustness of the evaluation method: The effective quantification of human factors and the evaluation of the available technologies are considered paramount in the proposed approach. Thus, further effort will be employed to develop the evaluation method proposed in the study, Taguchi's Loss Function. Other techniques such as sensitivity analysis and iteration with consistency checks were proposed to address this issue and contribute to the appropriateness of the framework. The evaluation process should be as robust as possible without representing a hurdle due to its complexity.

6) The format of the process application: Translating the approach into an Excel-based tool will be further explored. The use of VBA® (Visual Basic for Applications), which is a built-in feature of Microsoft Office Excel®, was suggested during the study. Training on VBA was undertaken in the PhD course. This may represent an appropriate format for the process application. Furthermore, a workbook should be associated with the tool. This could be used by the individual chosen to be the facilitator. The proposed approach involves a series of activities for the assessment of human factors in the selection decision. Thus, the existence of a written guide for applications could improve its feasibility, usability and utility. Finally, it could facilitate further in-company applications and disseminate the concepts of the process.

8.6 CONCLUSION

The research addressed the question on how to incorporate human factors into the AMT selection. The approach proposed was the development, refinement and testing of a framework and a process to assess the human factors involved in the decision. It is envisaged that managers will be able to include this assessment to obtain a sounder judgement of technology options. Furthermore, the contextual relevance of the framework was ratified by the positive evaluation provided by participants. The approach was tested in nine companies located in the Southern Region of Brazil. The proposed contributions were also provided. The study enhanced the knowledge on human factors and their impact on AMT implementation initiatives. Labour flexibility, individual capabilities and employee relations were proposed as main categories of human factors. Grouping these items was helpful to compose a definition for human factors and facilitate their identification. Taguchi's Loss Function was employed as evaluation method for the identified factors and the technologies. A framework for the identification and evaluation of human factors involved in the AMT selection acquisition was developed. Considering the assessment of human factors, available technology options were prioritised. The feedback on the application of the approach was quite positive in terms of addressing the identification and the quantification issues reported by researchers and practitioners. An important practical contribution was also made. The in-company applications demonstrated that the approach was deemed feasible, usable and useful for managers and of practical relevance to companies located in the context of a particular developing country, Brazil.

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APPENDICES

APPENDIX A - A COMPREHENSIVE CLASSIFICATION OF AMT

AUTHOR																						
US depart. Of commerce (1989)				✓	✓		✓	✓				✓										
ADLER (1988)				✓	✓						✓											
SOHAL (1997)													✓	✓	✓							
MEREDITH and SURESH (1986)	✓	✓	✓																			
SMALL and YASIN (1997)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓											
BRANDYBERRY *et al.* (1999)																✓	✓	✓				
KOTHA and SWAMIDASS (2000)																			✓	✓	✓	✓
CLASSIFICATION	level of integration			functional application									nature of the apparatus			level of organisational integration			imbedded information processing capabilities			
	stand alone	intermediate	integrated	design and engineering	fabric. / machining & assembly	logistic related	automated material handling	autom. inspection and testing	flexible manufacturing tech.	computer integrated manufac.	manag. / information tech.	communications and control	computer hardware	computer software	plant & equipment	stand alone amt	functionally orientated amt	CIM	product design technologies	inform. exchange and plan. tech.	high-volume automation tech.	low-volume automation tech.
NC – numerically control	✓				✓																	✓
CNC – comput. numerical control	✓				✓										✓	✓						✓
DNC – direct numerical control	✓				✓																	
CAD – computer aided design	✓			✓										✓		✓			✓	✓		
CAE – computer aided engineering				✓															✓	✓		
CAM – computer aided manufac.				✓										✓			✓					✓
CAPP – comp.aided process planning	✓			✓																		
MRP – material requirement planning	✓					✓								✓						✓		
MRP II – manufacturing resources planning		✓	✓								✓			✓						✓		
AGV/AGVS – autom. guided vehicle system							✓								✓	✓						
Robots (general)	✓				✓										✓	✓					✓	
Pick and Place Robots	✓				✓																✓	
AS/RS – autom.storage/retriev.syst.		✓				✓	✓								✓	✓						
AMHS – autom.mat. handling syst.		✓				✓																
FAS – flexible assembly systems					✓										✓							
AITS - Automatic inspection and testing syst.		✓						✓							✓						✓	
Automated shop-floor data collections systems													✓									
FMC – flexible manufacturing cells			✓		✓				✓						✓							
FMS – flexible manuf. systems			✓		✓				✓						✓		✓					✓
CIM – computer int. manufacturing			✓							✓								✓				
PLC – program. logic controllers	✓											✓										
LAN – local area network – digital I/O												✓	✓							✓		
LAN – local area network - messages												✓	✓							✓		
WAN – wide area network													✓							✓		
Data base management system														✓								
TECHNOLOGY																						

Source: Adapted from Gouvêa da Costa, Platts and Fleury (2000)

APPENDIX B - GUIDE FOR THE INTERVIEWS WITH EXPERTS

PART I - BACKGROUND INFORMATION AND EXPERTISE

1. IDENTIFICATION

Academic ☐ **Industrialist** ☐ **Consultant** ☐

Interview nº ________ **Interviewee's name** ______________________________

Affiliation / Company _______________________ **Position** __________________

Date __/__/___ **Location** ___________________ **Duration** _________________

2. RESEARCH INTERESTS / EXPERTISE

a) Could you state your research interest areas / expertise?

____

____

b) How would you qualify your knowledge on AMT* selection?
(*equipments or apparatus, numerical or computational to support manufacturing tasks. e.g.: CAD)

Basic ☐ Average ☐ Advanced ☐

c) Could you elaborate on your existent knowledge?

(in terms of conducted projects, seminars, conferences, etc.)

____

____

d) Please indicate the main correlations you make when the topic 'AMT selection' is mentioned.

Themes	Very weak (-2)	Weak (-1)	Neutral (0)	Strong (+1)	Very strong (+2)
AMT adoption					
Strategic planning					
AMT justification					
Decision-making processes					
Economic benefits					
Strategic benefits					
Implementation factors					
Human resources					
Human factors					

PART II – THE IDENTIFIED GAP IN ACADEMIC RESEARCH

1. CURRENT RESEARCH PROJECTS / GAP IN RESEARCH

The researcher analysed existing research projects conducted by universities and identified a gap in academic studies related to the topic. Some of these projects include:

Institute for Manufacturing (Cambridge University/UK)
Existing evaluation methods include roadmapping and development of software tools for hierarchical solutions. Intangible factors are somewhat ignored.

School of Mechanical, Materials and Manufacturing Engineering (Nottingham University/UK)
Existing evaluation approaches include technology roadmapping. Advancing manufacturing science through new theoretical models, methodologies, and tools covering performance indicators. They lack an in-depth consideration of intangible factors involved in the selection process.

Nottingham University / Institute for Manufacturing (Cooperation)
Studies cover management of strategic investments. Resource allocation and knowledge-based solutions, the project overlooks the consideration of intangible factors.

Produtronica Group (Pontifical Catholic University/Brazil)
The group has focused the economic justification of AMT. The intangibility dimension has been recently explored. However, no structured approaches have been developed.

2. REVIEWED LITERATURE

The researcher reviewed relevant literature with the following objectives:

Subject	Objective
AMT adoption	**Understand different implementation phases and involved variables: pre-installation, commissioning and installation, post-commissioning.**
Selection process	**Understand the steps involved in the process and the associated factors; understand how the different criteria for selection is identified.**
Justification of AMT	**Understand how the selection criteria are assessed: current methods, existing approaches.**
Human Resource Management and Ergonomics	**Understand implementation factors related to the human element.**

PART III – THE PROPOSED APPROACH
1. FRAMEWORK
a) Do you think the strategic planning constitutes the input for the AMT selection process? ____________________________ b) Do you think economic benefits, strategic benefits and human factors are the main evaluation criteria for AMT selection? ____________________________ c) How do you analyse existent methods for the identification of the evaluation criteria? ____________________________ d) How do you analyse existent methods for the assessment of the evaluation criteria? ____________________________ e) Do you consider the framework logically constructed and clearly defined? ____________________________
2. CONTRIBUTION
Research question: How to incorporate the evaluation criteria into the AMT selection? **Research objectives:** Develop a framework to incorporate the evaluation criteria into the AMT selection; Test and refine identification and assessment methods related to the evaluation criteria; Propose an approach to appraise technology alternatives based on the evaluation criteria.
a) What is your view of the level of importance of the mentioned evaluation criteria? ____________________________ b) Do you consider the intended contribution relevant to the subject 'Selection of AMT'? ____________________________ c) What is your evaluation of the framework as means to assist managers in their decisions? ____________________________ d) Does the research question present a coherency of purpose? ____________________________ e) What are the desirable characteristics the framework should encompass to be considered appealing by the top management of companies? ____________________________
3. SCOPE
a) Do you consider the dimensions the study intends to put together sufficient and comprehensive to compose a practical framework for AMT selection? ____________________________ b) How do you evaluate the scope of the study in terms of contribution for the selection of AMT (broad, narrow, neutral)? Please consider the time available for the study. ____________________________ c) What additional or lacking dimensions would you suggest for the study? ____________________________
4. SUGGESTIONS AND FURTHER COMMENTS
a) Whom else do you think should be interviewed for research purposes? ____________________________ b) Do you have any further comments you would like to express at this point? ____________________________

APPENDIX C - EVALUATION FORM: PILOT CASE STUDY (CASE A)

Part 1

1. Was the framework to assess human factors involved in the AMT selection easy to understand?

1. Very easy	*2. Quite easy*	*3. Somewhat easy*	*4. Not at all*
Comments:			

2. Was the framework clearly defined?

1. Very clear	*2. Quite clear*	*3. Somewhat clear*	*4. Not at all*
Comments:			

3. Were you able to participate fully?

1. Very	*2. Quite*	*3. Somewhat*	*4. Not at all*
Comments:			

4. What is your degree of confidence in the results from the framework application in a scale from 0 to 100%?

0---100%

5. Are the results provided by the framework worth the time you put in?

( ) Yes ( ) No

Please justify.

Part 2

Questions 1 and 2 are open to your comments. Please consider any difficulties you have experienced during the case study (1) and make any suggestions you would find useful to improve the process (2). If you need more space, please use the back of the page.

1. **What were the main difficulties faced during the study?**

2. **Do you have any suggestions to improve the process or the way the concepts are approached by the framework?**

Part 3

Please fill in the form according to the level of contribution of the framework to incorporate the assessment of human factors into the AMT selection. The level of contribution is categorised in very good (1), quite (2), somewhat (3) or not at all (4). I would like your opinion on the feasibility, usability and utility of the approach:

1) Feasibility (the framework can be followed)
2) Usability (the framework can be easily followed)
3) Utility (the framework produces useful results)

Feasibility	**1**	**2**	**3**	**4**
Participation				
Information availability				
Timing				
Usability	**1**	**2**	**3**	**4**
Clarity				
Ease of use				
Appropriateness				
Utility	**1**	**2**	**3**	**4**
Relevance				
General utility				
Confidence on the results				

Remember: very good (1), quite (2), somewhat (3), not at all (4)

Thank you very much for your participation!

APPENDIX D - GUIDE FOR THE ASSESSMENT INTERVIEWS

ASSESSMENT INTERVIEW
Page 1/2

1. IDENTIFICATION DETAILS

Date:	**Time:**
Interviewee's name (s):	**Position:**
Duration:	**Other participants:**

2. COMPANY PROFILE

a) Years of operation	b) Sector and main product (s)
c) Annual turnover	d) Type of ownership
e) Number of employees	f) Latest acquisition of AMT / technology

3. CURRENT DECISION-MAKING PRACTICES

How is the current evaluation of investments in advanced manufacturing technologies such as CAD/CAM?

What are the components involved in the process (criteria, tools, people)?

What would you say are the specific problems you face within the decision-making?

What would you say are the characteristics or emphasis an alternative approach could present to improve the decision-making?

How are the intangible factors such as the human factors treated within the current adopted process?

a) The difficulties:	b) The quantification of human factors:
c) The need to include these factors:	d) The process to incorporate human factors:
e) The risks of not including the human factors:	f) Other specific issues:

ASSESSMENT INTERVIEW

Page 2/2

4. PROPOSED APPROACH

Objectives	**Development of the process**
Are the process objectives relevant to your practice? **Are the process objectives clear and well defined? If not, what is needed to improve it?**	Is the process logically expressed? Is it possible to understand and visualise the process, its phases and objectives of its activities?
Process content	**Time and scope**
In your opinion, is it possible to apply the developed process by working with a co-ordination group, a project leader and a facilitator during workshops using worksheets? **How the process could be in terms of application strategy (people, time, resources)?**	Is the process too demanding in terms of time and content? Is it excessively comprehensive or too limited?
Team	**Concepts and themes**
Do you consider the chosen team appropriate for the process? **Do you have any suggestions regarding the people to be involved in the process?**	In your opinion, are any concepts or themes treated superficially or in too much detail in the proposed process?
Evaluation of the process	**Resources**
What do you think about the adopted evaluation criteria (is it possible to follow the process, how easy is the process to be followed, and are the process results useful for you?) **What and/or whom else do you think should be involved in the evaluation process?** **Will you have confidence in the results achieved from the process?**	In your case, are there any restrictions regarding the information collected in the study? Is it possible to guarantee the participation of the mix of professionals defined in the process? Are there time or participation constraints in the case of your company?

5. SUGGESTIONS AND COMMENTS

Do you have any further contributions or suggestions to make regarding the process and the overall proposed approach?

APPENDIX E - EVALUATION FORMS

STAGE 1

Criteria for evaluation

(green)	**Feasibility**
(blue)	**Usability**
(red)	**Utility**
(black)	**Additional Information**

Evaluation Form

Please circle your answers to the following questions.

IDENTIFICATION OF HUMAN FACTORS **Date: __/__/__**

1. Was the stage for the identification of human factors easy to understand and follow?

1. Very easy	*2. Quite easy*	*3. Somewhat easy*	*4. Not at all*
Comments:			

2. The identification stage, which deals with the human factors, was it clearly defined?

1. Very clear	*2. Quite clear*	*3. Somewhat clear*	*4. Not at all*
Comments:			

3. Was the format of the discussions (workshop) appropriate to achieve the stage objectives?

1. Very appropriate	*2. Quite appropriate*	*3. Somewhat appropriate*	*4. Not at all*
Comments:			

4. Was the time sufficient to discuss important issues?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

5. Was the mix of professionals present during the workshop adequate?

1. Very adequate	*2. Quite adequate*	*3. Somewhat adequate*	*4. Not at all*
Comments:			

6. Did the process make possible to identify human factors relevant to the current company's decision-making?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

7. Has the identification process enabled the company to take into account relevant factors that otherwise could have been overlooked?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

8. Was the identification stage vital to the achievement of the final objective related to the process?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

9. What is your degree of confidence in the identification of human factors on a scale from 0 (zero) to 100% (a hundred percent)? Please mark on the scale bellow.

0---100%

10. Main problems encountered during the human factors identification:

11. Are the results provided by the stage worth the time you put in?

( ) Yes ( ) No

Please justify.

STAGE 2

Criteria for evaluation

(green)	**Feasibility**
(blue)	**Usability**
(red)	**Utility**
(black)	**Additional Information**

Evaluation Form

Please circle your answers to the following questions.

EVALUATION OF HUMAN FACTORS **Date: __/__/__**

1. Was the stage for the evaluation of human factors easy to understand and follow?

1. Very easy	*2. Quite easy*	*3. Somewhat easy*	*4. Not at all*
Comments:			

2. The evaluation stage, which addresses the human factors, was it clearly defined?

1. Very clear	*2. Quite clear*	*3. Somewhat clear*	*4. Not at all*
Comments:			

3. Was the Taguchi Loss Function employed for evaluation easy to follow?

1. Very easy	*2. Quite easy*	*3. Somewhat easy*	*4. Not at all*
Comments:			

4. Was the time sufficient to discuss important issues?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

5. Was the use of the Taguchi Loss Function to quantify the human factors in the decision useful?

1. Very useful	*2. Quite useful*	*3. Somewhat useful*	*4. Not at all*
Comments:			

6. Did ranking human factors and establishing minimum required levels seem coherent with the process' final objectives?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

7. Was the evaluation of technologies based on the human factors vital to the achievement of the final objective related to the process?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

8. Was the process of attributing individual rankings by each participant and composing a unique loss score adequate to the process objectives?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

9. What is your degree of confidence in the evaluation of human factors based on the loss scores on a scale from 0 (zero) to 100%? Please mark on the scale bellow.

0--100%

10. Main problems encountered during the human factors evaluation:

11. Are the results provided by the stage worth the time you put in?

( ) Yes   ( ) No

Please justify.

STAGE 3

Criteria for evaluation

	Feasibility
	Usability
	Utility
	Additional Information

Evaluation Form

Please circle your answers to the following questions.

PRIORITISATION OF AMT **Date: __/__/__**

1. Was the process of prioritising manufacturing technologies easy to understand and follow?

1. Very easy	*2. Quite easy*	*3. Somewhat easy*	*4. Not at all*
Comments:			

2. Was the prioritisation stage using the weighted loss scores clearly defined?

1. Very clear	*2. Quite clear*	*3. Somewhat clear*	*4. Not at all*
Comments:			

3. Were the criteria used to prioritise the AMT clearly defined and communicated?

1. Very clear	*2. Quite clear*	*3. Somewhat clear*	*4. Not at all*
Comments:			

4. Was the format of the discussions (workshop) appropriate to address the stage?

1. Very appropriate	*2. Quite appropriate*	*3. Somewhat appropriate*	*4. Not at all*
Comments:			

5. Was the time sufficient to discuss important issues?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

6. Was the mix of professionals present during the workshop adequate?

1. Very adequate	*2. Quite adequate*	*3. Somewhat adequate*	*4. Not at all*
Comments:			

7. Has the prioritisation enabled the company to have a more informed assessment of investments in technology?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

8. Was the prioritisation of AMT vital to the achievement of the final objective related to the approach?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

9. What is your degree of confidence in the prioritisation of AMT on a scale from 0 (zero) to 100%? Please mark on the scale bellow.

0---100%

10. Main problems encountered during the AMT prioritisation:

11. Are the results provided by the stage worth the time you put in?

( ) Yes ( ) No

Please justify.

APPENDIX F - EVALUATION FORM: GENERAL UTILITY OF THE PROCESS

Evaluation of Process Utility

- Please score each criterion as follows:

  (1) very good, (2) quite good, (3) somewhat good, (4) not at all

- Please justify the attributed score.
- Participant: ______________ Position: ______________ Date: __/__/__

Value of formal outcomes	***Scoring***	***Notes***
1) Overall outcomes	1 2 3 4	
2) Identification of human factors	1 2 3 4	
3) Evaluation of human factors	1 2 3 4	
4) AMT Prioritisation	1 2 3 4	
Value of informal outcomes	***Scoring***	***Notes***
1) Group discussion and communication	1 2 3 4	
2) Team building	1 2 3 4	
3) Learning related to the concepts in the process	1 2 3 4	
4) Learning related to the 'quantification' of human factors	1 2 3 4	
Quality of analysis	***Scoring***	***Notes***
1) Overall process	1 2 3 4	
2) Identification of human factors	1 2 3 4	
3) Categories of human factors	1 2 3 4	
4) Taguchi's loss function	1 2 3 4	
5) Quantification of intangible factors	1 2 3 4	
Quality of operationalisation	***Scoring***	***Notes***
1) Participation - utilisation	1 2 3 4	
2) Participation - breadth and depth	1 2 3 4	
3) Project management	1 2 3 4	
4) Procedures (worksheets/workshops)	1 2 3 4	
5) Communication of purpose	1 2 3 4	

APPENDIX G - EVALUATION FORM: OVERALL PROCESS

Criteria for evaluation

	Feasibility
	Usability
	Utility
	Additional Information

Evaluation Form

Please circle your answers to the following questions.

PROCESS FACILITATION **Date: __/__/__**

1. Was the proposed approach easy to understand and follow?

1. Very easy	*2. Quite easy*	*3. Somewhat easy*	*4. Not at all*
Comments:			

2. Was the process clearly defined?

1. Very clear	*2. Quite clear*	*3. Somewhat clear*	*4. Not at all*
Comments:			

3. Were the workshops implemented according to the process?

1. Very true	*2. Quite true*	*3. Somewhat true*	*4. Not at all*
Comments:			

4. Was the information provided by the facilitator clear and easy to understand?

1. Very	*2. Quite*	*3. Somewhat*	*4. Not at all*
Comments:			

5. Did the process facilitate your participation?

1. Very	*2. Quite*	*3. Somewhat*	*4. Not at all*
Comments:			

6. Were the results obtained from the process easy to interpret and understand?

1. Very true	2. Quite true	3. Somewhat true	4. Not at all
Comments:			

7. Was the mix of professionals present during the process adequate?

1. Very adequate	2. Quite adequate	3. Somewhat adequate	4. Not at all
Comments:			

8. What is your degree of confidence in the results from the process in a scale from 0 (zero) to 100% (a hundred percent)?

0---100%

9. Are the results provided by the process worth the time you put in?

( ) Yes ( ) No

Please justify.

10. What were the main difficulties faced during the process?

11. Do you have any suggestions to improve the process or the way the concepts are approached in it?

APPENDIX H - INTERVIEWS WITH ACADEMICS

	Academic A The University of Nottingham	Academic B The University of Nottingham	Academic C The University of Nottingham	Academic D The University of Cambridge (IfM)	Academic E The University of Cambridge (IfM)	Academic F The University of Cambridge (IfM)
Research areas	Innovation, strategic growth, development, and strategic networks.	Decision-making processes, operational performance.	Generative process planning, road-mapping and decision-making	Manufacturing strategy, decision support tools, and innovation	Strategic technology management, technology evaluation	Technology strategy, management processes
Current approaches	Intangible factors are often overlooked, a robust evaluation approach is necessary.	Some intangible assessment is made but human factors are often ignored.	Some operational intangible factors are considered through road-mapping.	Capital budgeting decision tools are inappropriate for intangible factors.	Analytical approaches may represent a useful way to evaluate competing alternatives.	The evaluation of intangible factors requires a suitable approach for quantification.
Proposed framework	Scope is too broad. Through strategic planning, some alternatives are usually proposed.	The identification and evaluation of human factors should represent the research focus.	The focus should be narrowed down to focus on the identification of human factors.	Strategic and economic benefits are heavily researched; human factors are less studied.	A scoring model could be associated with the framework using the evaluation criteria.	A process is necessary to apply the framework. The contribution of the study is important for the AMT selection.
Suggestions for further development	Consider the limitations of time and scope. The strategic planning should be assumed.	A process is needed for the application of the framework. Focus on the assessment of human factors.	Narrow down the focus of the research. The identification of human factors should be sought.	A process is required to assist managers in their decisions and approach human factors.	The evaluation of human factors should be the core contribution. The study is relevant and important.	The use of the 'process approach' developed by Platts (1993) is recommended.

APPENDIX I - INTERVIEWS WITH CONSULTANTS AND INDUSTRIALISTS

	Industrialist A	Industrialist B	Consultant A	Consultant B
Industry or Area (s) of expertise	Aerospace industry Technology Management	Meat packing industry Technology Management	Consultant in technology change and acquisition	Consultant in technology development / production engineering
Current approaches used to approach the AMT selection criteria	Some assessment of economic and strategic benefits is made, but human factors tend to be overlooked.	Although human factors are regarded as important, the assessment is based on economic benefits	The methods to select technologies tend to be very complex in scope. Capital budgeting is not suitable for the evaluation of more intangible aspects.	The decision is made by the top management. The selection lacks the involvement of key stakeholders.
Proposed framework	The scope is too broad to be useful for managers.	If focused on human factors could be a good improvement on the existing methods.	The scope should be re-evaluated to present a more practical application.	The participation of key stakeholders should be present in an alternative approach.
Suggestions for further development	The assessment of human factors should be sought by the approach.	Focus on the human factors involved in the decision. The approach should be easy to use.	The proposed approach should be easy to understand and not excessively time-consuming.	Any approach should involve key stakeholders in the decision. The consensus should be sought.

APPENDIX J - WORKSHEETS

STAGE 1

Activity 2: List the objectives for the technology acquisition

WORKSHEET 1: OBJECTIVES FOR THE TECHNOLOGY ACQUISITION	
OBJECTIVE 1	
OBJECTIVE 2	
OBJECTIVE 3	
OBJECTIVE 4	

Activity 3: List the human factors related to the acquisition objectives

WORKSHEET 2: LIST OF HUMAN FACTORS			
HUMAN FACTORS	LABOUR FLEXIBILITY*	INDIVIDUAL CAPABILITIES**	EMPLOYEE RELATIONS***
HUMAN FACTOR 1			
HUMAN FACTOR 2			
HUMAN FACTOR 3			

Instructions:

* **Labour flexibility factors** refer to human factors associated with the manufacturing process affected by the AMT adoption.

e.g.: Job enlargement, delegation of tasks, and involvement in the decision-making.

** **Individual capabilities factors** relate to the skills and attitudes that employees acquire or develop through the acquisition.

e.g.: Development of managerial, technical skills, and empowerment of employees.

*** **Employee relations factors** relates to the relationship between the company and its workers.

e.g.: Better working practices, job security and welfare, influence of unions.

STAGE 2

Activity 4: Define the ranking of human factors, minimum required level, and the range of variance.

WORKSHEET 3: RANKING OF HUMAN FACTORS, MINIMUM REQUIRED LEVELS, RANGE OF VARIANCES				
HUMAN FACTORS	IMPORTANCE RANKING	TARGET VALUE (PERCENT)	RANGE* (PERCENT)	SPECIFICATION LIMIT (PERCENT)
HUMAN FACTOR 1		100		
HUMAN FACTOR 2		100		
HUMAN FACTOR 3		100		

* Range: 0 to 100% (zero to one hundred percent)

Activity 5: Calculate the loss coefficient for each human factor.

WORKSHEET 4: RANKING OF HUMAN FACTORS, MINIMUM REQUIRED LEVELS, RANGE OF VARIANCES, LOSS COEFFICIENTS				
HUMAN FACTORS	IMPORTANCE RANKING	RANGE (PERCENT)	SPECIFICATION LIMIT (PERCENT)	LOSS COEFFICIENT (k)
HUMAN FACTOR 1				
HUMAN FACTOR 2				
HUMAN FACTOR 3				

STAGE 3

Activity 7: Assign the perception of performance in addressing the human factors to the AMT.

WORKSHEET 5: EVALUATION OF THE AMT ALTERNATIVES VS. THE IDENTIFIED HUMAN FACTORS				
AMT	HUMAN FACTOR 1 (PERCENT*)	HUMAN FACTOR 2 (PERCENT)	HUMAN FACTOR 3 (PERCENT)	HUMAN FACTOR 4 (PERCENT)
ALTERNATIVE A				
ALTERNATIVE B				
ALTERNATIVE C				

* Range: 0 to 100% (zero to one hundred percent)

Activity 8: Calculate the individual loss scores for each AMT.

WORKSHEET 6: LIST OF INDIVIDUAL LOSS SCORES FOR THE AMT OPTIONS								
AMT	HUMAN FACTOR 1		HUMAN FACTOR 2		HUMAN FACTOR 3		HUMAN FACTOR 4	
	k *	L **	k	L	k	L	k	L
ALTERNATIVE A								
ALTERNATIVE B								
ALTERNATIVE C								

*= loss coefficient k (calculated in Activity 5)

** = loss score L

Activity 9: Calculate the weighted loss score for each AMT alternative.

WORKSHEET 7: WEIGHTED LOSS SCORES PER AMT ALTERNATIVE									
AMT	**HUMAN FACTOR 1**		**HUMAN FACTOR 2**		**HUMAN FACTOR 3**		**HUMAN FACTOR 4**		**WEIGHTED LOSS SCORES**
	w*	***L*****	***w***	***L***	***w***	***L***	***w***	***L***	
ALTERNATIVE A									
ALTERNATIVE B									
ALTERNATIVE C									

* = factor weight ***w*** (assigned in Activity 4)
** = loss score ***L*** (calculated in Activity 8)

APPENDIX K - SUMMARY OF THE INITIAL TESTING CASES

CASE B

PROFILE - COMPANY B

Company Profile – Case B	
a) Years of operation 62 years c) Annual turnover £90M e) Number of employees 1200	b) Sector and main product (s) Agro-industry and *in natura* meat and sub-products d) Type of ownership national, family-owned f) Latest acquisition of AMT / technology - a stacking machine (£70,000) - a transport bras (£50,000) - an energy generator (£3.5M)
Examined AMT acquisition	
Investment required: £126,000 for a packing system Alternatives: One machine imported from Spain, through a local representative Co-ordination group: Industrial Director (team leader) Industrial Manager Production Supervisor HR Manager	

PROCESS APPLICATION – COMPANY B

Point of entry (Stage 0):

After the initial contact with the company's CEO and the assessment interview, the framework and process were presented to key stakeholders. The co-ordination group was composed on this particular occasion. Emphasis was placed on the objectives associated with each stage and the overall process. A short break preceded the application, when some questions were responded by the researcher.

Stage 1 – Identification of Human Factors:

In Case B, the participants had some difficulty in listing the acquisition objectives related to this particular decision. As a family-owned business, the strategic planning is somewhat unstructured, according to the collaborators. The group members did not have a clear idea on the main objective related to the acquisition of the packing system. After some discussion, five objectives were listed (Table 1).

Table 1 – Acquisition objectives (Company B)

Acquisition Objectives	Description
#1	Automate the manufacturing process to obtain productivity with quality
#2	Provide qualified working conditions for the human element present in the company
#3	Enhance the acceptance of products by consumers through superior quality
#4	Retain the talent present in the company through growth based on productivity
#5	Obtain superior productivity through the modernisation of the productive process

From the five objectives, 'automate the manufacturing process to obtain productivity with quality' was identified as the main reason behind the current acquisition. According to participants, the process assisted in structuring their understanding of the planning established by the company. "The sequence of logical steps in the process made us ask questions and provide provisory answers. This discussion led to a better understanding of our own planning", remarked the Industrial Director. Based on the main acquisition objective, the human factors involved in the decision were listed (Table 2). The evaluation of the process in terms of feasibility, usability and utility took place immediately after the completion of each stage.

Table 2: List of identified human factors (Company B)

Acquisition objective: Automate the manufacturing process to obtain productivity with quality
Increased flexibility of the labour
Greater versatility in the job skills
Decreased manual handling of products (new attitude toward job)
Decreased risk of product contamination by workers
Superior knowledge on quality
Increased motivation through achievement of better working conditions
Better working relations with the company due to the modernisation
Better working conditions
Enhanced knowledge on safety and contamination issues
Decreased risk of diseases and medical leaves of employees

Stage 2 – Evaluation of Human Factors:

The second stage proved to be a little easier for the participants. The ranking of human factors was considered 'quite easy to understand and follow'. The participants remarked that they felt enabled to visualise the impact of the human factors on the decision. The decreased risk of contamination was regarded as a priority and so was the effect of the modernisation of the production line on the motivation of workers. Nonetheless, the group members highlighted that the use of charts to visualise the comparison of the different human factors could improve their confidence in the results. In addition, the utilisation of visual aids could help in the communication of the decision to collaborators. The dynamic of the group, in this case, demonstrated that the opinion of every participant was deemed important. The Industrial Director participated in the discussion as any other group member and many times enquired the Production Supervisor's opinion on the decisions. For the executive, the professional had a clearer view on the specificities concerning the manufacturing process and, therefore, had a lot to contribute to the process. The consensus was always sought for that matter. The group members were particularly pleased with the structure of steps in the process and the time spent in the activities.

Stage 3 – Prioritisation of AMT:

Considering that, in this case, there was only one option to be evaluated; the participants remarked that they perceived the technology to be quite compatible with the identified human factors. The focus was placed on the human factors and the analysis of the ability of the AMT to address them. The option received a high rating and a very low weighted loss score. Thus, it was confirmed as adequate to fulfil the purpose of the acquisition.

Feedback:

A report on the findings was presented to the group and the evaluation of the overall process conducted. Some discussion occurred after the process application. Suggestions and comments were presented at this point. The Industrial Director and the Industrial Manager were confident in the results and demonstrated their interest in the approach. Finally, the company indicated further availability for the development of the proposed framework and associated process or any other studies of similar nature.

CASE C

PROFILE - COMPANY C

Company Profile – Case C	
a) Years of operation 56 years	b) Sector and main product (s) Automotive / Diesel Systems
c) Annual turnover £1.2B	d) Type of ownership Transnational
e) Number of employees 4600	f) Latest acquisition of AMT / technology - an anti-fire system developed locally (£2M)
Examined AMT acquisition	
Investment required: £40,000 / workbench for quality testing Alternatives: Several of multiple combinations Co-ordination group: Engineering Manager (team leader) Product Development Manager Production Supervisor	

PROCESS APPLICATION – COMPANY C

Point of Entry (Stage 0):

Time constraints and difficulties of access were associated with the application in Case C. The initial negotiation of the firm's participation involved several emails. Since the access was gained through a Quality Engineer, the Engineering Supervisor and the Engineering Manager had to be convinced. This negotiation took several weeks. Finally, the date for the study was set and the assessment interview was to take place before the application. Similarly, the team of collaborators defined in the process represented an issue. By involving a mix of professionals from the manufacturing function and the human resources department, the availability of the group members had to be verified. It was possible to guarantee the participation of the Engineering Manager as team leader, the Product Development Manager and the Production Supervisor to compose the co-ordination group. However, the professional from the Human Resources Department represented a challenge. There was some indication on her / his participation for a future date in a month's time. The group decided to proceed as scheduled without the participation of this professional.

Stage 1 – Identification of Human Factors:

Company C had a clear view of the objective for the examined acquisition. The workbench was to be used for the quality testing of products. The main goal was to update the equipment, developing the technology locally. The participants identified the list of human factors related this objective as shown in Table 1. The format of seminars with the participation of different professionals was considered 'quite adequate' for this type of decision. According to group members, being a part of a larger corporation located in Europe, local needs and specificities are not usually taken into account in acquisition decisions. The process made possible the evaluation of the human factors involved in the local development of a new technology. Nonetheless, the lack of participation of some of the professionals and the timing for the process application were highlighted as an issue. According to group members, different opinions could have improved the level of confidence in the results of the process. In their opinion, the stage should have accommodated that need. Once again, the continuity of the study was discussed. However, participants decided to report the problems in the process evaluation and proceed with the work.

Table 1 – List of Human Factors (Company C)

Acquisition objective: Execute the durability essay for a new generation of products within the required time and quality
Enhanced robustness related to the process and the human element
Improved safety measures and standards for employees
Enhanced ability of workers to identify critical issues and constraints
Improved process delivery to be compatible with demand issues
Increased flexibility of labour
Improved ability to deal with the obsolescence of equipments
Better deployment of resources
Better training preparation for technology recycling and updating
Enhanced readiness through an improved level of automation
Developed expertise through the networking and technologies integration

Stage 2 – Evaluation of Human Factors:

The group was particularly careful with the ranking of human factors. Since the participation of the professional of the Human Resources Department was not obtained, the participants revised twice the activity. Their main objective was to act as closely as possible to previous decisions that involved human factors. The priority for the team members was to update the system to improve delivery and cope with the demand. The flexibility of labour was a major concern for the company, especially the robustness of the process based on the human element. The dynamic amongst the individuals in the group demonstrated a balance in the decision. The participants regarded the activity as fulfilled only after a decision was reached through consensus. Some concerns were also raised regarding the Taguchi Loss Function (TLF) as a method for the evaluation of intangible factors. The three engineers were familiar with the method for quality assurance of products. Thus, some resistance was noted. After the participants performed Activity 5 of the second stage, i.e., the calculation of the loss scores, they became more confident in the method, qualifying its use as 'quite adequate'.

Stage 3 - Prioritisation of AMT:

Three technology alternatives were available to participants. The ROI and Payback for the options were similar. After the evaluation of human factors and the assignment of the perception by decision makers, the AMT designated as alternative A obtained the lowest loss score (48,75). Therefore, this option was selected as the most adequate for the achievement of the acquisition objective.

Feedback:

Each stage and the overall process were evaluated during the application. A report of the findings was discussed with the team members. The results were satisfactory to the stakeholders and the process obtained high ratings. The participants remarked that they felt enabled to communicate their opinion and discuss relevant items in the decision-making.

CASE D

PROFILE – COMPANY D

Company Profile – Case D	
a) Years of operation 30 years Brazilian company 53 years Italian firm	b) Sector and main product (s) Metal-mechanic / parts for bicycles
c) Annual turnover £14M	d) Type of ownership Joint-venture (85/15)
e) Number of employees 320	f) Latest acquisition of AMT / technology - £15,000 for a plastic injection moulding machine

Examined AMT acquisition
Investment required: Moulding Equipment Alternatives: 3 options (3 Chinese brands and 1 Brazilian) Co-ordination group: Financial Manager (team leader) Industrial Manager Production Supervisor HR Supervisor

PROCESS APPLICATION – COMPANY D

Point of Entry (Stage 0):

In Case D, the company was interested in assessing particular human factors related to the decision. Thus, the access was facilitated. The stakeholders were keen on assessing the improvement in working conditions, the development of the employees' skills through training, the mitigation of stress related to the manual tasks, and the improvement of 'on the spot' quality inspections. All the resources necessary for the process application were made available by the team leader. The group presented considerable commitment and appropriate time was reserved for the activities. The co-ordination group was composed by the Financial Manager (team leader), the Industrial Manager, the Production Supervisor and the Human Resources Supervisor.

Stage 1 – Identification of Human Factors:

The team members identified the main acquisition objective as the enhancement of capacity associated with the improvement of quality and flexibility. The identification stage had a very dynamic nature. According to participants, the use of the categories of human factors was particularly helpful to list the involved human factors. Table 1 presents the identified human factors.

Stage 2 – Evaluation of Human Factors:

Although the method became an issue early on, the stage was regarded as 'quite appropriate'. The participants were familiar with the method as a quality assurance procedure. Some resistance was soon overcome due to the usefulness attributed to the evaluation method. The priority for participants was to improve the robustness and the readiness of the process through the 'know-how' of employees. Group members highlighted the importance of the technology inside this context. They indicated that the selected option should be compatible with an Italian machine currently in operation. Therefore, the human factors were ranked according to the characteristics necessary to achieve this compatibility. The consensus was reached quite easily by participants. Their views on the importance of human factors were similar in that regard.

Table 1 – List of Human Factors

Acquisition objective: Enhance capacity associated with improvement of quality and flexibility
Improvement of safety through better ergonomics conditions
Better manufacturing control
Increased ability to introduce new products faster
Faster response to changes in design and market pressure for new products
Better deployment of resources due to the technology update
Improvement of equipment robustness and readiness (maintenance)
Improvement of the response to machinery breakdown
Facilitation of technical assistance support to company and clients
Enhancement of manufacturing robust 'know-how' from a new equipment

Stage 3 - Prioritisation of AMT:

After considering every alternative, the weighted loss scores demonstrate that Brazilian option was the most adequate. The scores were 67.24, 57.89, and 49.22. The participants considered the process 'quite useful' to compare the different AMT. The discussions within the group were also very productive. The group members felt enabled to analyse the decision while assessing the involved human factors.

Feedback:

The Industrial Manager and the Financial Manager were satisfied with the results. Both managers remarked that the process was crucial to establish a straighter relationship between the finance department and the production function. The report was also used by the company to communicate the results to collaborators. The feedback from participants was positive and the process obtained high ratings.

CASE E

PROFILE – COMPANY E

Company Profile – Case E	
a) Years of operation	b) Sector and main product (s)
14 years	Automotive / Metal-mechanic
c) Annual turnover	d) Type of ownership
£7M	National
e) Number of employees	f) Latest acquisition of AMT / technology
101	- Equipments for the new plant (£5M)
Examined AMT acquisition	
Investment required: CNC Machine Alternatives: 4 alternatives were available from Brazilian manufacturers Co-ordination group: Financial Director (team leader) Supply Chain Manager Production Manager HR Manager	

PROCESS APPLICATION – COMPANY E

Point of Entry (Stage 0):

After the initial contact with the company directors, the assessment interview was conducted with the Supply Chain Manager one week before the process application. The professional usually represents the link between the manufacturing needs and the financial department. Hence, the acquisitions of technologies are controlled by the executive. A brief presentation on the process and its objectives was made to key stakeholders. The co-ordination team was composed by the Financial Director (team leader), the Supply Chain Manager, the Production Manager, and the Human Resources Manager.

Stage 1 – Identification of Human Factors:

Company E was interested in reducing the problems with quality. The acquisition of a new CNC machine aimed to address those issues while increasing the manufacturing capacity. The participants had some difficulty in identifying the human factors. According to the group members, mainly tangible aspects are considered in the decision-making. The acquisitions are directed to short term solutions to specific problems. The human element is somehow overlooked within this context. However, as soon as the discussions started and the first activities were performed, the group became increasingly committed to the process. Table 1 shows the identified human factors related to the acquisition objective.

Stage 2 – Evaluation of Human Factors:

The Taguchi Loss Function was known by the engineers that composed the group. Using the assistance of the engineers (Supply Chain Manager and Production Manager), the Human Resources Manager and the Financial Director were able to follow the process application. In this case, the latter participants felt more comfortable in seeking help from their counterparts instead of the facilitator. This dynamic was allowed and observed by the researcher. The group members demonstrated that it improved their confidence in the results. The enhancement of tacit knowledge was very highly ranked. It represented the focus for the acquisition. The participants remarked the new technology would improve the current knowledge of operators and managers.

Table 1 – List of Human Factors

Acquisition objective: Reduce non-conformity and increase manufacturing capacity
Knowledge related to manufacturing process technology update
Enhanced competitiveness by introducing a 'new' technology (multi-skilling)
Increased flexibility of labour
Better control of the manufacturing process
Better working conditions
Enhancement of the company's tacit knowledge basis
Better organisation of work and tasks for employees

Stage 3 - Prioritisation of AMT:

As CNC machines have been used for quite some time in the manufacturing area, the economic and technical benefits were similar amongst the options. The process was useful, according to participants, to compare the four alternatives. The technology designated as alternative B obtained the lowest loss score (39.25) and, therefore, was regarded as the best option.

Feedback:

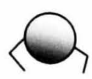
The Directors were very pleased with the results. A meeting with the Financial Director occurred after the process application. The executive was interested in using the approach to evaluate the human factors related to the new plant the company aims to build. However, due to limitations of time, the project was put on hold. The results were presented to the co-ordination group members and very positive feedback was obtained.

APPENDIX L - PLANNED EXERCISE (PRIOR TO THE FIRST STAGE)

1. Room Setting

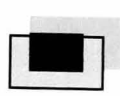
Participants:

Facilitator:

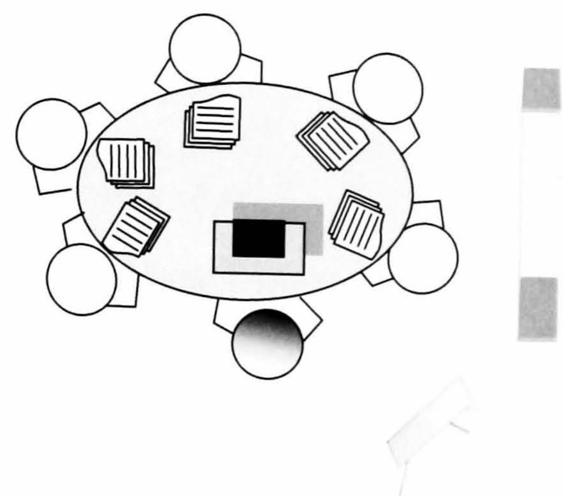


Whiteboard:

Laptop:



Flipchart:



2. Exercise

1. The participants are instructed to write down any questions related to the presentation.

2. The researcher (facilitator) presents the concepts involved in the process and general objectives.

3. After the presentation, an open session for discussions is proposed. Visual aids (flipchart, whiteboard) are used to support this process and answer questions.

4. Following the discussion, the participants are questioned on their confidence in proceeding with the process application. Only when participants are ready to proceed, the process is applied.

APPENDIX M - SUMMARY OF THE FINAL TESTING CASES

CASE F

PROFILE - COMPANY F

Company Profile – Case F	
a) Years of operation 64 years	b) Sector and main product (s) Industrial Equipments / Steam boilers
c) Annual turnover £12M (profits per year)	d) Type of ownership national, family-owned
e) Number of employees 152	f) Latest acquisition of AMT / technology - a CNC Machine (£200,000.00)
Examined AMT acquisition	
Investment required: CNC lathe / CNC turret-type drilling machine Alternatives: Three international brands (Alternatives A, B, and C) Co-ordination group: Administrative Manager (team leader) HR Manager Production Manager	

PROCESS APPLICATION – COMPANY F

Point of entry (Stage 0):

After the assessment interview with the Administrative Manager, the stages of the process and the objectives behind the approach were introduced to company stakeholders. The co-ordination group was formed by the Administrative Manager before the process application. Thus, the participants were defined by the executive based on the mix of professionals prescribed in the approach. An exercise was developed to communicate the concepts contained in the process. All team members had an opportunity to ask questions. Only after participants felt confident in their understanding of definitions and objectives, the process was applied. The exercise showed to be effective in facilitating the apprehension of concepts, according to the co-ordination group of Case F.

Stage 1 – Identification of Human Factors:

In Case F, the group had no difficulties in establishing the objective for the acquisition of a new CNC lathe and a CNC turret-type drilling machine. The Production Manager remarked that the industry established a new plan for modernization two years ago. The main goal was to enhance productivity, improving the general quality of products. The repeatability of tasks was desired and proposed by the Manufacturing Department. According to the Human Resources Manager, the firm implemented a 'job rotation' strategy in the manufacturing line. Thus, the flexibility of the labour force was also paramount. After agreeing on the acquisition objective, the participants identified the involved human factors. Using the three categories of factors proposed in the approach, thirteen items were identified (Figure 1). It is important to point out that, because of the lack of experience of some of the participants, one of the senior buyers was contacted during the process. The executive assisted in the identification of some of the factors listed by the group. Nonetheless, the items were agreed upon by the team.

WORKSHEET 2 – THE HUMAN FACTORS LIST	
Acquisition objective: Enhance productivity, improving the general quality of products.	
Category	***Human Factors***
Labour Flexibility	Improve skills sharing amongst employees
	Increase participation of 'senior' operators
	Motivate employees to participate in the job rotation
	Increase the skills sharing in the manufacturing process
	Enhance the knowledge base of the company
Individual Capabilities	Improve 'job rotation' opportunities
	Development of the labour force skills sets
	Promote specialisation and superior workers qualification
	Improve knowledge on quality and preventive actions
	Update workforce to deal with a complex environment
Employee Relations	Improve chances of promotions / rewards
	Enhance job security based on the new skills
	Improve general motivation of employees

Figure 1 – List of Human Factors

Stage 2 – Evaluation of Human Factors:

Even though participants were not familiar with the Taguchi Loss Function (TLF), used as method for the evaluation of human factors, the stage was completed quite easily. Group members remarked that the visualisation of the method expressed in the proposed framework was helpful in that regard. Moreover, the TLF was considered very adequate for the quantification of human factors, one of the main obstacles found in the selection of AMT, remarked the managers. The decision makers gave priority to the improvement of the knowledge on quality and preventive actions related to the manufacturing process. Table 1 shows the human factors ranked as per their importance in the decision and the calculated loss coefficients. Table 2 represents the calculation of the weight corresponding to the identified factors.

Table 1 - Ranking of human factors, minimum required level, range of variance

WORKSHEET 4 - RANKING OF HUMAN FACTORS, MINIMUM REQUIRED LEVELS, RANGE OF VARIANCES AND LOSS COEFFICIENTS					
Ranking	**Human Factors**	**Target (%)**	**Range (%)**	**Limit (%)**	**Loss Coefficient (*k*)**
1	Improve knowledge on quality and preventive actions	100	100-95	95	90
2	Promote specialisation and superior workers qualification	100	100-80	80	64
3	Improve skills sharing amongst employees	100	100-81	80	64
4	Enhance job safety based on the new skills	100	100-95	95	90
5	Improve general motivation of employees	100	100-80	80	64
6	Update workforce to deal with a complex environment	100	100-60	60	36
7	Enhance the knowledge base of the company	100	100-70	70	49
8	Development of the labour force skills sets	100	100-90	90	81
9	Improve 'job rotation' opportunities	100	100-70	70	49
10	Increase participation of 'senior' operators	100	100-60	60	36
11	Motivate employees to participate in the job rotation	100	100-60	60	36
12	Increase the skills sharing in the manufacturing process	100	100-60	60	36
13	Improve chances of promotions / rewards	100	100-60	60	36

Formula:

$$L(X) = k\,(1/X^2)$$

Table 2 – Calculation of the weight of the factors based on the established ranking

	Ranking	Factors Weights
	1	0.01
	2	0.02
	3	0.03
	4	0.04
	5	0.05
	6	0.07
	7	0.08
	8	0.09
	9	0.10
	10	0.11
	11	0.12
	12	0.13
	13	0.14
Total:	91	1.00
Calc.:	**Number in the ranking / Sum of the factors**	

Stage 3 – Prioritisation of AMT:

Three options were available for consideration. After assigning their perceptions to the technologies (Table 3), Alternative C proved to have the lowest weighted score. Alternative A and B had very similar profiles; both technologies obtained 117.70. Alternative C presented a weighted loss score of 91.95 (Table 3). Thus, it was regarded as the most adequate AMT. Figure 2 represents the comparison amongst the alternatives, based on their weighted loss scores.

Table 2 – Assignment of the perception of performance in addressing the human factors to the AMT

AMT	HF1	HF2	HF3	HF8	HF9	HF10	HF11	HF12	HF13
A	70	85	95	60	60	60	60	60	60
B	70	85	95	60	60	60	60	60	60
C	90	90	90	70	70	70	70	70	70

Table 3 – Calculation of the weighted loss score for each AMT alternative

k	A	B	C	Factors weights	Loss Score A	Loss Score B	Loss Score C	Weighted Loss Score A	Weighted Loss Score B	Weighted Loss Score C
90	70	70	90	0.01	184.18	184.18	111.42	2.02	2.02	1.22
64	85	85	90	0.02	88.58	88.58	79.01	1.95	1.95	1.74
64	95	95	90	0.03	70.91	70.91	79.01	2.34	2.34	2.60
90	80	80	80	0.04	141.02	141.02	141.02	6.20	6.20	6.20
64	90	90	90	0.05	79.01	79.01	79.01	4.34	4.34	4.34
36	60	60	60	0.07	100.00	100.00	100.00	6.59	6.59	6.59
49	60	60	70	0.08	136.11	136.11	100.00	10.47	10.47	7.69
81	60	60	70	0.09	225.00	225.00	165.31	19.78	19.78	14.53
49	60	60	70	0.10	136.11	136.11	100.00	13.46	13.46	9.89
36	60	60	70	0.11	100.00	100.00	73.47	10.99	10.99	8.07
36	60	60	70	0.12	100.00	100.00	73.47	12.09	12.09	8.88
36	60	60	70	0.13	100.00	100.00	73.47	13.19	13.19	9.69
36	60	60	70	0.14	100.00	100.00	73.47	14.29	14.29	10.50
				1.00	1560.93	1560.93	1248.66	**117.70**	**117.70**	**91.95**

Calc. 1	**Loss score: Loss coefficient*(1/(Assigned perception/100))^2**
Calc. 2	**Weighted Loss Score: (Loss score*Factor weight)**

Feedback:

The findings were presented to the co-ordination group for evaluation. Participants were pleased with the results. The practicality of the approach was highlighted by team members. The Taguchi Loss Function and the loss scores used as measure to assess the human factors and technologies were regarded as quite useful. The company demonstrated interest in adopting the framework for future acquisition decisions. Framework and process were considered as quite adequate to assess human factors in AMT selection decisions.

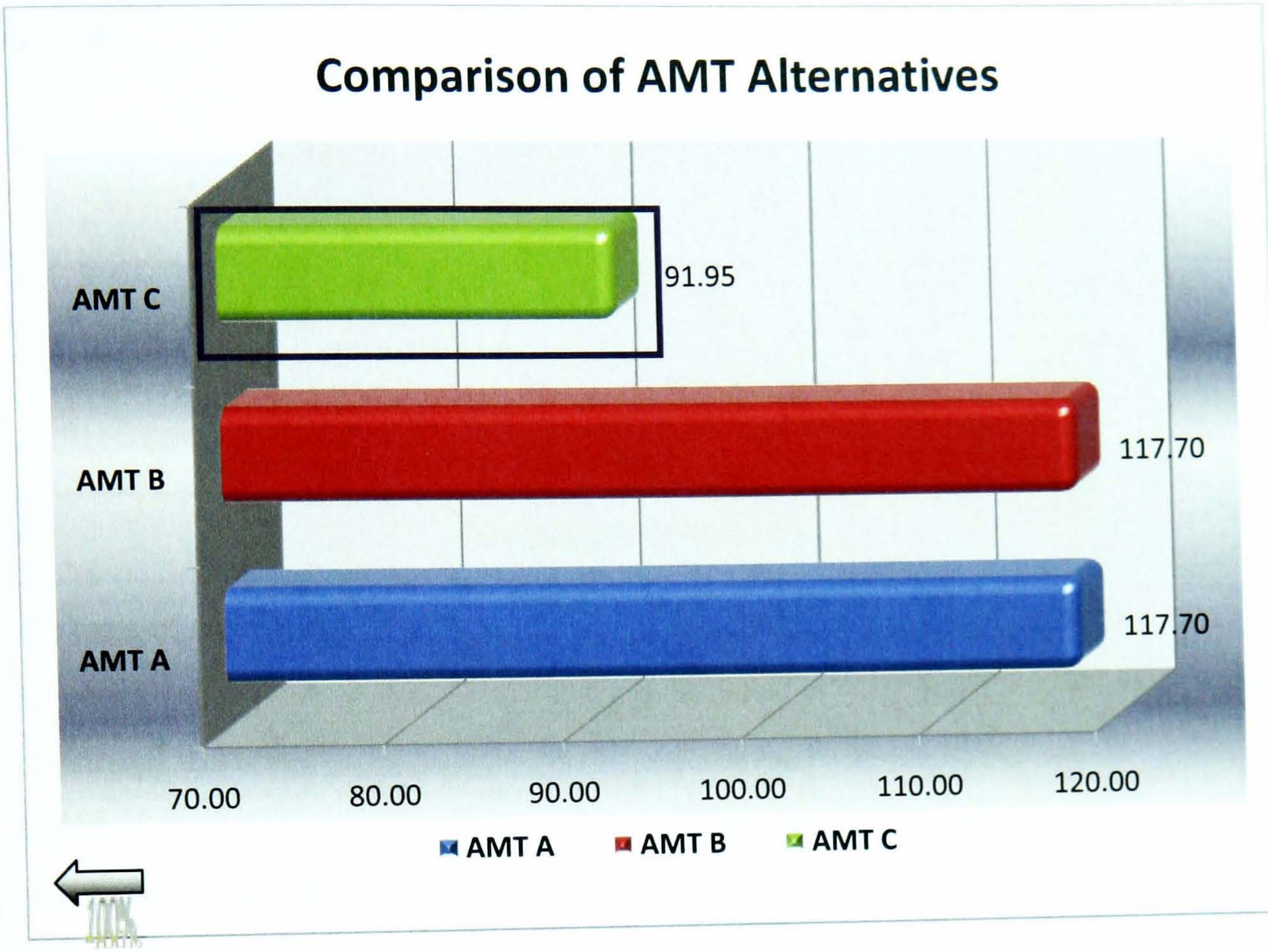


Figure 2 – The comparison among the technology alternatives

CASE G

PROFILE - COMPANY G

Company Profile – Case G	
a) Years of operation 20 years	b) Sector and main product (s) Automotive Industry / Hydraulic Jacks
c) Annual turnover £19M	d) Type of ownership national, family-owned
e) Number of employees 500	f) Latest acquisition of AMT / technology - a CNC machine (£150,000.00)
Examined AMT acquisition	
Investment required: Foundry centre / pipe cutter (£150,000 per equipment) Alternatives: Two Japanese brands (Alternatives A and B) Co-ordination group: Industrial Director (team leader) Human Resources Manager Purchasing Officer Production Supervisor	

PROCESS APPLICATION – COMPANY G

Point of entry (Stage 0):

In Company G, a high degree of commitment was achieved. The co-ordination group was composed during the assessment interview. Although the Industrial Director represented the main interviewee, other members were present during the interview and were asked to contribute at some point. The same mix of professionals became the co-ordination. Human Resources Manager, Purchasing Officer, Production Supervisor joined the Industrial Director in the process application. By being unfamiliar with the Taguchi Loss Function, some extra time to clarify the concept was added to the process. This action, however, was deemed unnecessary since the team members apprehended the principles behind the strategy quite easily.

Stage 1 – Identification of Human Factors:

The team in Company G had a very clear view of the objectives for the examined acquisition of AMT. According to the co-ordination group, the manufacturing process faced several problems in the past due to the outsourcing of core activities. The firm was seeking to regain control over key activities by automating tasks, improving reliability and increasing labour flexibility. A new foundry system and a new pipe cutter operated via CNC were necessary to achieve this objective. Seven options were initially evaluated. However, after considering layout changes required by some of the systems, the level of productivity that could be reached with each option and defined economic criteria (ROI, NPV), five brands were abandoned. The two remaining options presented similar technical conditions and, in both cases, the payback was estimated in 2.5 years. Thus, the executives used the approach to compare the alternatives and assess the involved human factors. From the acquisition objectives, eight human factors were identified. Figure 1 presents the complete list and corresponding categories.

WORKSHEET 2 – THE HUMAN FACTORS LIST	
Acquisition objective: Automate to improve reliability and increase labour flexibility.	
Category	***Human Factors***
Labour Flexibility	Enhanced knowledge to be applied in the manufacturing process automation by workers
	Multi-skilling generating a steadier manufacturing pace
Individual Capabilities	Potential of knowledge transfer and updating acquired through training
	Reduced resistance to change due to technology scope
Employee Relations	Improved working conditions
	Enhanced quality and safety for employees and operators
	Enhanced employee morale to improve productivity
	Well being associated with the facilitation of tasks (especially repeatability due to automation)

Figure 1 – List of Human Factors

Stage 2 – Evaluation of Human Factors:

The co-ordination group of Case G felt that the enhanced knowledge provided by the automation was the most important human factor to be addressed (#1). While the remaining factors followed by association. For the decision makers, the knowledge resultant of the automation led to improved safety and quality conditions (#2). Those meant better working conditions for employees (#3). Improved working conditions generated a general sense of well being among workers (#4). The training on the new technology promoted the update of skills and the transference of knowledge (#5). Table 1 presents the identified human factors, the minimum required level and the range of variance attributed by participants. While Table 2 represents the ranking and weights corresponding to the identified human factors.

Table 1 - Ranking of human factors, minimum required level, range of variance

WORKSHEET 4 - RANKING OF HUMAN FACTORS, MINIMUM REQUIRED LEVELS, RANGE OF VARIANCES AND LOSS COEFFICIENTS					
Ranking	**Human Factors**	**Target (%)**	**Range (%)**	**Limit (%)**	**Loss (*k*)**
1	Enhanced knowledge to be applied in the manufacturing process	100	100-80	80	64
2	Enhanced quality and safety for employees and operators	100	100-90	90	81
3	Improved working conditions	100	100-80	80	64
4	Well being associated with the facilitation of tasks	100	100-80	80	64
5	Potential of knowledge transfer and updating acquired through training	100	100-60	60	36
6	Reduced resistance to change due to technology scope	100	100-60	60	36
7	Multi-skilling generating a steadier manufacturing pace	100	100-50	50	25
8	Enhanced employee morale to improve productivity	100	100-50	50	25

Formula:

$$L(X) = k\,(1/X^2)$$

The trained employees become disseminating 'cells' in the manufacturing, according to the Production Supervisor. In this case, for instance, the training associated with the new equipment is usually directed to specific employees chosen for the task (4 leaders and 1 programmer). Those four leaders have two other operators (1 per shift, 2 shifts a day) learning the job. The programmer has a deputy that is also trained. Every acquisition means initially that 10 people will be trained to operate the acquired equipment. Thus, this group is in charge of transferring the knowledge to the remaining operators. This process can diminish the resistance to the technical change (#6). Moreover, the skills acquired in the process collaborate to a steadier pace of production (#7). All the previous factors can benefit the morale of employees and improve productivity levels (#8).

Table 2 – Calculation of the weight of the factors based on the established ranking

	HF	Weight
	1	0.03
	2	0.06
	3	0.08
	4	0.11
	5	0.14
	6	0.17
	7	0.19
	8	0.22
Total:	36	1.00
Calc.:	**Number in the ranking / Sum of the factors**	

Stage 3 – Prioritisation of AMT:

After the evaluation of human factors, the decision makers analysed the two available options (Table 3). Upon the calculation of their weighted loss scores, it became clear that technology A was a better fit to achieve the acquisition goal (Table 4). Alternative A obtained 41.44 and Alternative B achieved 45.53. Figure 2 represents graphically the comparison among the considered alternatives.

Table 3 - Assignment of the perception of performance in addressing the human factors to the AMT

AMT	HF1	HF2	HF3	HF4	HF5	HF6	HF7	HF8
A	100	100	100	100	100	100	100	90
B	100	100	100	90	90	90	90	100

Table 4 – Calculation of the weighted loss score for each AMT alternative

k	A	B	Factors weights	Loss Score A	Loss Score B	Weighted Loss Score A	Weighted Loss Score B
64	100	100	0.03	64.00	64.00	1.78	1.78
81	100	100	0.06	81.00	81.00	4.50	4.50
64	100	100	0.08	64.00	64.00	5.33	5.33
64	100	90	0.11	64.00	79.01	7.11	8.78
36	100	90	0.14	36.00	44.44	5.00	6.17
36	100	90	0.17	36.00	44.44	6.00	7.41
25	100	90	0.19	25.00	30.86	4.86	6.00
25	90	100	0.22	30.86	25.00	6.86	5.56
			1.00	400.86	432.77	41.44	45.53

Calc. 1	**Loss score: Loss coefficient*(1/(Assigned perception/100))^2**
Calc. 2	**Weighted Loss Score: (Loss score*Factor weight)**

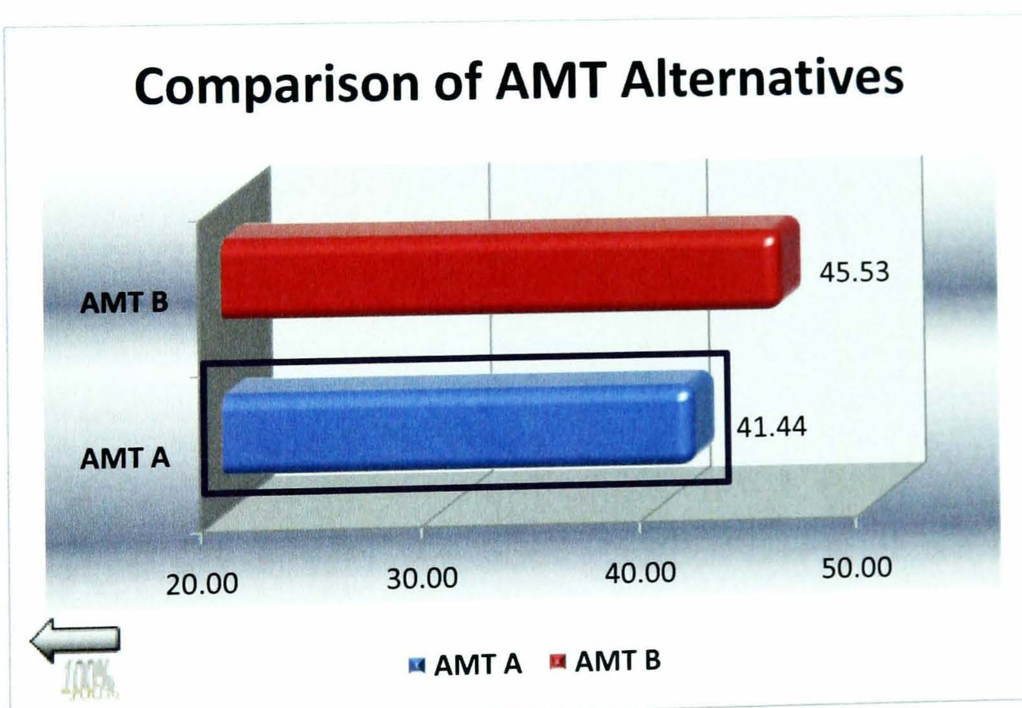


Figure 2 – The comparison between the technology alternatives

The group remarked that the 'winning alternative' was deemed more adequate because it dealt with human factors more highly ranked. In addition, the brand was quite well known in the market by its focus on transferable skills promoted in the training of customers. The executives felt that employees would be less resistant to this option due to its reputation.

Feedback:

The participants were satisfied with the results. According to the Industrial Director, "the company was able to see that there is a way to approach and measure human factors". The Purchasing Officer felt motivated by the approach and reflected that the process collaborated to broaden the firm's view of investments in technology. Finally, the group suggested that the decisions on the acquisition of AMT should have a sequence of assessments. First, the technical evaluation of the options to abandon upfront the alternatives judged inadequate. Second, the company should assess the AMT in economic and financial terms. Last, but not least, the human factors should be appraised through the proposed approach.

CASE H

PROFILE - COMPANY H

Company Profile – Case H	
a) Years of operation	b) Sector and main product (s)
49 years	Sound equipments
c) Annual turnover	d) Type of ownership
£24M (profits)	national
e) Number of employees	f) Latest acquisition of AMT / technology
380	- a CNC machine (£160,000.00)
Examined AMT acquisition	
Investment required: £230,000.00 Alternatives: Two brands (a Japanese / a Dutch manufacturers) (Alternatives A and B) Co-ordination group: Industrial Director (team leader) HR Supervisor Research and Development Manager	

PROCESS APPLICATION – COMPANY H

Point of entry (Stage 0):

The initial contact was made with the Industrial Director during the assessment interview. Some information was collected on the examined decision, the current decision-making process used by the company, people involved, and criteria for evaluation. The process was applied two weeks after the first contact.

Stage 1 – Identification of Human Factors:

As explained by the Industrial Director, the current decision involved two alternatives. The suppliers produced SMD technologies and had similar investment platforms. The SMD machines involved a joint solution including (1) a screen printer, (2) a pick and place machine, and (3) a refusion oven. The acquisition was two-fold: equipments and training / technical assistance. Even though foreign manufacturers were being evaluated, both had representatives in Brazil and nationalised equipments were being acquired. The training and technical assistance would be supplied locally as well. Initially, the participants identified three objectives for the acquisition (Figure 1).

WORKSHEET 1 – OBJECTIVES FOR THE TECHNOLOGY ACQUISITION	
Acquisition Objectives	**Description**
#1	Automate the production line to cope with the current technology conditions in the market
#2	Enhance quality by reducing the size of controller boards and reduce the human errors by automating the process
#3	Reduce labour costs through automation to cope with the new government regulations

Figure 1 – The acquisition objectives

The co-ordination group members, however, decided to combine these objectives and declared that updating the manufacturing process was imperative. This process would be associated with better quality and reduction in labour force and costs. From the acquisition objective, eleven human factors were listed by the team. Figure 2 shows the list of identified human factors.

WORKSHEET 2 – THE HUMAN FACTORS LIST	
Acquisition objective: Technological update, enhance quality and reduce labour costs.	
Category	***Human Factors***
Labour Flexibility	Training associated with the equipment, involving all collaborators
	New skills acquired through the automation
	Development of the expertise of employees related to the specificities in the sector
	Mitigation of the resistance to the technical change
Individual Capabilities	Increased capacity of diagnosing problems and proposing solutions on the spot
	Enhanced personal autonomy of workers to deal with manufacturing problems
	Enhanced technical knowledge to deal with quality issues with the product while in the machine
Employee Relations	Improved employee morale and empowerment by being assigned to the new technology operation
	Reduced stress due to the facilitation to perform tasks and better ergonomic conditions
	Better working conditions
	Improved work environment with controlled temperature, better luminosity conditions and reduction of the noise in the operation

Figure 2 – List of Human Factors

Stage 2 – Evaluation of Human Factors:

For the decision makers, the training on the new technology was the most important human factor. With the new skills, the workers would be able to more easily diagnose problems and propose solutions. The automation would also present good opportunities to improve the general working conditions due to a more controlled manufacturing environment. Table 1 presents the identified human factors, the minimum required level and the range of variance attributed by participants. While Table 2 represents the ranking and weights corresponding to the identified factors.

Table 1 - Ranking of human factors, minimum required level, range of variance

WORKSHEET 4 - RANKING OF HUMAN FACTORS, MINIMUM REQUIRED LEVELS, RANGE OF VARIANCES AND LOSS COEFFICIENTS					
Ranking	**Human Factors**	**Target (%)**	**Range (%)**	**Limit (%)**	**Loss Coefficient (*k*)**
1	Training involving all collaborators	**100**	**100-90**	**90**	**81**
2	New skills acquired through the automation	**100**	**100-90**	**90**	**81**
3	Increased capacity of analysing problems and solutions	**100**	**100-90**	**90**	**81**
4	Enhanced technical knowledge to deal with quality issues	**100**	**100-80**	**80**	**64**
5	Enhanced personal autonomy to deal with problems	**100**	**100-70**	**70**	**49**
6	Development of the expertise of employees in the sector	**100**	**100-90**	**90**	**81**
7	Improved employee morale and empowerment	**100**	**100-70**	**70**	**49**
8	Better working conditions	**100**	**100-60**	**60**	**36**
9	Mitigation of the resistance to the technical change	**100**	**100-40**	**40**	**16**
10	Reduced stress and better ergonomic conditions	**100**	**100-50**	**50**	**25**
11	Improved work environment	**100**	**100-40**	**40**	**16**

Formula:

$$L(X) = k\,(1/X^2)$$

Table 2 – Calculation of the weight of the factors based on the established ranking

	HF	Weight
	1	0.02
	2	0.03
	3	0.05
	4	0.06
	5	0.08
	6	0.09
	7	0.11
	8	0.12
	9	0.14
	10	0.15
	11	0.17
Total:	66	1.00
Calc.:	**Number in the ranking** / **Sum of the factors**	

Stage 3 – Prioritisation of AMT:

After the evaluation of participants (Table 3), it became clear, based on the identified human factors, Alternative A (46.17) was a better option than Alternative B (48.43). Table 4 represents the calculation of the weighted loss scores for each AMT. The rationale was that, as proposed in the approach, the lower the loss score, the better is the alternative, since it deviates less from the established target of 100%. Figure 3 shows the comparison of alternatives, according to their weighted loss scores.

Table 3 - Assignment of the perception of performance in addressing the human factors to the AMT

AMT	HF1	HF2	HF3	HF4	HF5	HF6	HF7	HF8	HF9	HF10	HF11
A	100	90	80	80	90	100	90	90	60	90	95
B	100	80	90	90	90	80	90	80	60	80	95

Table 4 – Calculation of the weighted loss score for each AMT alternative

k	A	B	Factors weights	Loss Score A	Loss Score B	Weighted Loss Score A	Weighted Loss Score B
81	100	100	0.02	81.00	81.00	1.23	1.23
81	90	80	0.03	100.00	126.56	3.03	3.84
81	80	90	0.05	126.56	100.00	5.75	4.55
64	80	90	0.06	100.00	79.01	6.06	4.79
49	90	90	0.08	60.49	60.49	4.58	4.58
81	100	80	0.09	81.00	126.56	7.36	11.51
49	90	90	0.11	60.49	60.49	6.42	6.42
36	90	80	0.12	44.44	56.25	5.39	6.82
16	60	60	0.14	44.44	44.44	6.06	6.06
25	90	80	0.15	30.86	39.06	4.68	5.92
16	95	95	0.17	17.73	17.73	2.95	2.95
			1.00	747.03	791.61	**53.51**	**58.65**

Calc. 1	**Loss score: Loss coefficient*(1/(Assigned perception/100))^2**
Calc. 2	**Weighted Loss Score: (Loss score*Factor weight)**

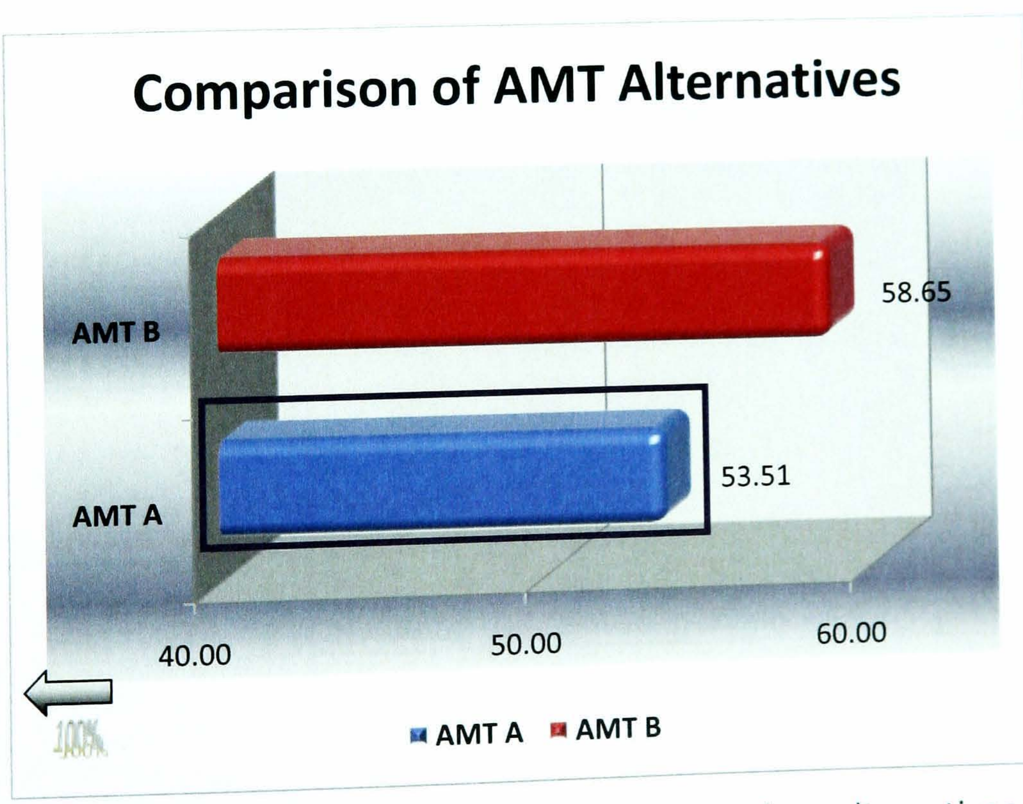


Figure 3 - The comparison between the technology alternatives

Feedback:

According to the Industrial Director, the process added new information to the decision-making. Furthermore, some of the human factors identified in Stage 1 could have been considered during the acquisition, but rather informally. The approach attributes structure to the task. The Director also suggested that the company was interested in adopting the proposed framework for other selection processes. Overall, the feedback was very positive and represented an encouragement towards the use of the approach by companies.

CASE I

PROFILE - COMPANY I

Company Profile – Case I	
a) Years of operation 62 years c) Annual turnover £90M e) Number of employees 1200	b) Sector and main product (s) Agro-industry and meat *in natura* and sub-products d) Type of ownership national, family-owned f) Latest acquisition of AMT / technology - a stacking machine (£70,000) - a transport bras (£50,000) - an energy generator (£3.5M)

Examined AMT acquisition
Investment required: £126,000 for a packing system Alternatives: One machine imported from Spain, through a local representative and a national brand used for testing purposes (Alternatives A and B) Co-ordination group: Industrial Director (team leader) Industrial Manager Production Supervisor HR Manager

PROCESS APPLICATION – COMPANY I

Point of entry (Stage 0):

Company I was used for the initial testing of the process. After the application, the company demonstrated interest in testing the developed approach. A new assessment interview with the Industrial Director was conducted to verify any changes or gather additional information related to the company's decision-making practices. The first interview was regarded as still relevant and no new information was reported. The process was applied a week later.

Stage 1 – Identification of Human Factors:

In the first stage, similar information was collected. The acquisition objective remained associated with the automation as means to obtain productivity with quality. However, a change in the identification of the human factors was noted. The focus, in the previous application, was placed on decreased contamination risks for employees. During the second process, the decision makers saw the technical change as going beyond the shift from manual to automated. The participants ranked the working conditions as the most important human factor. The focus became more general and placed on the environment generated for all employees, not only manufacturing operators. The remaining human factors listed by the group were consistent with the first application. Figure 1 presents the list of human factors.

Stage 2 – Evaluation of Human Factors:

The team was familiar with the proposed evaluation method, the Taguchi Loss Function. The second stage was completed quite quickly and the participants were pleased with the modifications applied to the process. The visualisation of the impact of the different human factors was welcome by the group. The use of the charts to communicate the results of each of the stages was associated with a higher level of confidence. Table 1 represents the ranking of human factors, minimum required level assigned by decision makers and the range of variance allowed for the items.

WORKSHEET 2 – THE HUMAN FACTORS LIST	
Acquisition objective: Automate to obtain productivity with quality.	
Category	***Human Factors***
Labour Flexibility	Decreased manual handling of products (new attitude toward job)
	Increased flexibility of labour
	Greater versatility in the job skills
	Decreased risk of product contamination by workers
Individual Capabilities	Enhanced knowledge on safety and contamination issues
	Superior knowledge on quality
Employee Relations	Better working conditions
	Improved ergonomic conditions
	Increased motivation through achievement of better working conditions
	Decreased risk of diseases and medical leaves of employees

Figure 1 - List of Human Factors

Stage 3 – Prioritisation of AMT:

In the third stage, new information emerged from the conversation with participants. Although, the Industrial Director had previously indicated that only one alternative was available in the examined decision, the Production Supervisor recalled that another option was considered. A national brand presented a similar packing system with a much higher price. The participants pointed out that this was the reason why this option never came up when the process was applied. This alternative was considered in the second application for learning purposes. Table 2 presents the assignment of the perceptions of decisions makers, disregarding price and associated conditions. Table 3 shows the calculation of the weights corresponding to the identified human factors. The comparison between the alternatives confirmed the result obtained in the previous study. Alternative A obtained 52.31 while Alternative B had 56.01 as weighted loss score. Thus, Alternative A was confirmed as the most adequate technology.

Table 1 - Ranking of human factors, minimum required levels, range of variances and loss coefficients

WORKSHEET 4 - RANKING OF HUMAN FACTORS, MINIMUM REQUIRED LEVELS, RANGE OF VARIANCES AND LOSS COEFFICIENTS					
Ranking	**Human Factors**	**Target (%)**	**Range (%)**	**Limit (%)**	**Loss Coefficient (*k*)**
1	Better working conditions	**100**	100-90	90	81
2	Increased flexibility of labour	**100**	100-95	95	90
3	Improved ergonomic conditions	**100**	100-90	90	81
4	Decreased manual handling of products	**100**	100-80	80	64
5	Greater versatility in the job skills	**100**	100-80	80	64
6	Superior knowledge on quality	**100**	100-75	75	56
7	Increased motivation	**100**	100-70	70	49
8	Enhanced knowledge on safety and contamination issues	**100**	100-70	70	49
9	Decreased risk of product contamination by workers	**100**	100-60	60	36
10	Decreased risk of diseases and medical leaves of employees	**100**	100-60	60	36

Formula: $L(X) = k\,(1/X^2)$

Table 2 - Assignment of the perception of performance in addressing the human factors to the AMT

AMT	HF1	HF2	HF3	HF4	HF5	HF6	HF7	HF8	HF9	HF10
A	90	95	95	95	100	100	90	90	100	80
B	90	95	90	90	95	90	90	90	100	80

Table 3 - Calculation of the weight of the factors based on the established ranking

	HF	Weight
	1	0.02
	2	0.04
	3	0.05
	4	0.07
	5	0.09
	6	0.11
	7	0.13
	8	0.15
	9	0.16
	10	0.18
Total:	55	1.00
Calc.:	**<u>Number in the ranking</u>** **Sum of the factors**	

Table 4 – Calculation of the weighted loss score for each AMT alternative

k	A	B	Factors weights	Loss Score A	Loss Score B	Weighted Loss Score A	Weighted Loss Score B
81	90	90	0.02	100.00	100.00	1.82	1.82
81	95	95	0.04	89.75	89.75	3.26	3.26
81	95	90	0.05	89.75	100.00	4.90	5.45
64	95	90	0.07	70.91	79.01	5.16	5.75
49	100	95	0.09	49.00	54.29	4.45	4.94
81	100	90	0.11	81.00	100.00	8.84	10.91
49	90	90	0.13	60.49	60.49	7.70	7.70
36	90	90	0.15	44.44	44.44	6.46	6.46
16	100	100	0.16	16.00	16.00	2.62	2.62
25	80	80	0.18	39.06	39.06	7.10	7.10
			1.00	640.42	683.06	**52.31**	**56.01**

Calc. 1	**Loss score: Loss coefficient*(1/(Assigned perception/100))^2**
Calc. 2	**Weighted Loss Score: (Loss score*Factor weight)**

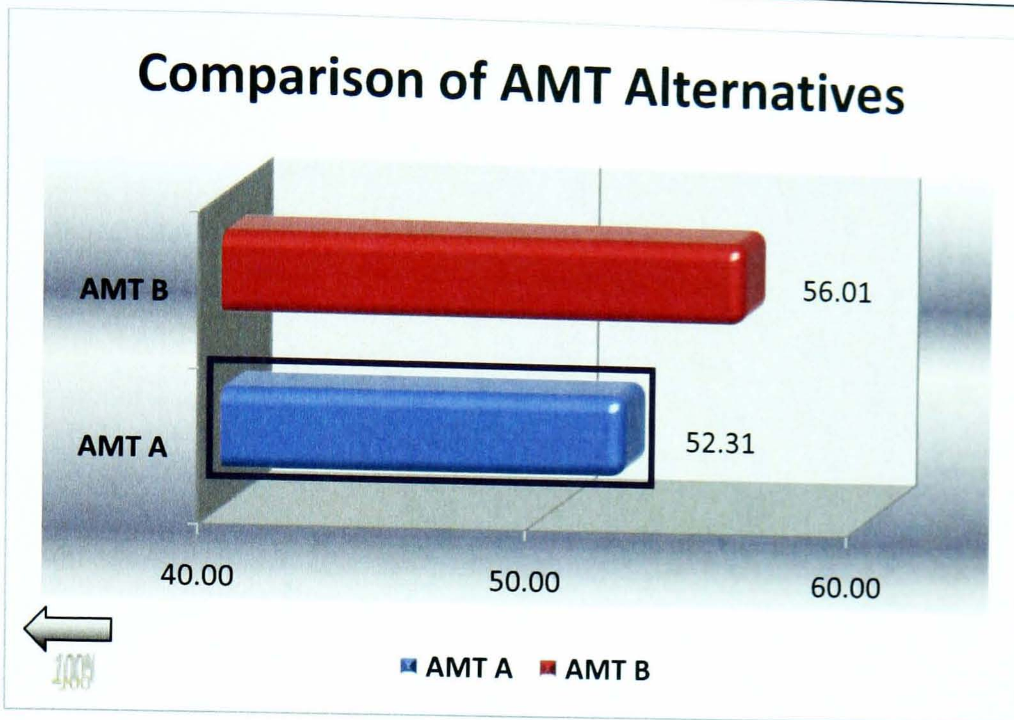


Figure 2 – The comparison between the technology alternatives

Feedback:

As shown in Figure 2, a comparison between two alternatives was conducted for testing purposes. Even though, Alternative B was abandoned after the economic analysis, it was used to test the approach. The participants felt confident in the results obtained in the process. According to the Industrial Director, the company decision makers have used the proposed approach informally, since its first application. Taking part in the testing was considered quite positive by the firm executives. The Industrial Manager and the Human Resources Manager revealed that they intended to employ the approach for future decisions. The participants remarked that the possibility of quantifying the human factors identified in the decisions triggered their interest. Furthermore, the dynamic among decision makers was also regarded as an important aspect. Overall, the structure of logical steps and activities proposed by the approach was the main advantage highlighted by team members and associated with the process.