TRAINING METHODOLOGY

Fostering the Adoption of ICT-enabled AMTs by European SMEs

Lead organization
ATLANTIS ENGINEERING

FAME – Fostering the Adoption of
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Referenced Documents

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Applicable Documents

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Executive Summary

Taking into account the needs of the SME target group as collected from previous phases of the FAME project, the next step is to create a methodology that defines the strategies and techniques which will be used to form and deliver the training modules to SMEs. The SME target group has certain characteristics which necessitate an SME oriented training methodology. In this case the training methodology will be action driven so that the SMEs will be immediately able to see the relevance of each action to their workplace and understand the benefits arising from their implementation. The design of the training methodology supports a set of elaborated winning AMT adoption strategies for the targeted sectors SMEs, increasing in such a way the AMT implementation. Based on the winning practices, different adoption strategies are designed in response to the needs of the target groups and their implementation is supported by the training methodology described in this document.

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1. Introduction

In the global business environment, technology is one of the salient elements for remaining competitive. Manufacturing inevitably has been influenced by re-definition of competitiveness and evolved to keep abreast of the latest market demands and the rapidly changing technological trends. SMEs should re-assess their manufacturing processes and strategies and, should define an environment which is the result of integration of the latest manufacturing strategies and business processes. Advanced Manufacturing Technology (AMT) is considered a viable solution to improve efficiency and lower costs of manufacturing firms and it has taken a determining role in this process (Darbanhosseiniamirkhiz & Wan Khairuzzaman Wan, 2012).

The benefits of adopting AMTs in the day-to-day process of SMEs are undoubtedly great and have been discussed and studied several times. The previous phases of the FAME project have shown a lack of ICT-enabled AMTs in SMEs that in most cases originates from the lack of expertise of the employees to include these technologies in their working tasks. In fact, maximising the performance of employed AMTs does not depend on the technology itself, rather than on how well it is implemented (Waldeck, 2007). Thus, a crucial factor that is connected to the better implementation of AMTs is how confident employees are in using the adopted technologies.

Many researchers have studied various determinants of SMEs' technology adoption strategies, and there are a small number of published studies which introduce one comprehensive framework through integrating their findings. The developed methodology described in the following sections of this document will act as a common framework to be followed by the FAME consortium while it develops the training modules for ICT-enabled AMTs adoption on the targeted SMEs.

1.1   Purpose

The purpose of this document is to describe the methodology that will be followed when designing and delivering the FAME training modules to the target SMEs and to define the strategies that will be addressed as the training proceeds. This report will also define the structure, content, methodology, delivery, evaluation and all other relevant aspects that comprise the FAME training activities.

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2. AMT Adoption Drivers & Barriers

A literature review has been conducted by Darbanhosseiniamirkhiz & Wan Khairuzzaman Wan, 2012, which sorts the determining factors in AMT adoption into three main categories:

- **Organisational context:** refers to organisational characteristics of the adopter (size of company, sector affiliation, existing know-how, available technical, financial and human resources, innovation strategy, etc.);
- **Environmental context:** refers to the arena in which the company conducts its business, including the value chain actors such as suppliers and customers, as well as competitors, research institutions, business associations, politicians, etc.;
- **Technological context:** refers to the nature of the technology adopted.

Each of the three categories includes factors that can affect directly the adoption of AMTs in SMEs. It is crucial that those factors are addressed during the development of the training modules to ensure that SMEs and especially managers are familiar will all factors defining a successful adoption of AMTs. Those factors are presented schematically in the figure below.
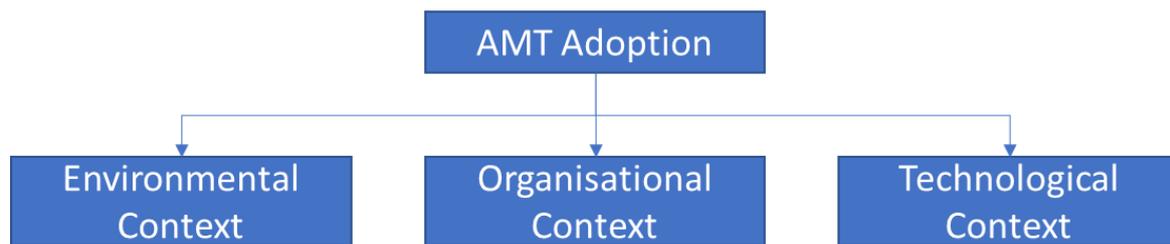
For the initial identification of barriers and drivers affecting AMT adoption, the European Commission groups AMTs in three main categories, namely:

- **Sustainable manufacturing technologies:** technologies to increase manufacturing efficiency in the use of energy and material and drastically reduce emissions (e.g. process control technologies, efficient motor systems, efficient separation technologies, novel sustainable process inputs, product lifecycle management systems);
- **ICT-enabled intelligent manufacturing:** Integrating digital technologies into production processes (e.g. smart factories);
- **High performance manufacturing:** Systems combining flexibility, precision and zero-defect mechanisms (e.g. high precision machine tools, advanced sensors, 3D printers).

The main barriers and drivers for each one of the above categories of AMTs are presented in Tables 1 through 3 respectively. Those data can act as initial values to define the context of the training modules that will be designed effectively to meet the needs of the targeted SMEs.

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Table 1. Barriers & Drivers in ICT-enabled intelligent manufacturing (Source: European Commission)

	Barriers	Drivers
Environmental Context	• Change of role and power in value chains • Management of political, regulatory, juridical, tax and labour environments in various countries • Difficulties in cost-benefit evaluation	• Tax policies supporting innovation and advanced manufacturing • Enhanced company performance in decision-making, reduced operative and administrative costs, improved business processes
Organisational Context	• Expectations of non-technology driven management • Increased inter-firm rivalry due to misalignment of motives and behaviours among partners • Resistance to change, challenging culture change management • Lack of skilled labour • Lack of innovative learning approaches and incentives	• Significance of intangible resources for business success • Improved supply chain visibility to improve understanding of the real system • Best practice work patterns
Technological Context	• Difficulties in demonstrating on industrial scale • Difficulties in accessing and retrieving data from partners and other systems • Lack of suitable development tools for highly changeable context	• Revenue growth fuelled by increasing responsiveness occurring at lower costs using fewer assets by reducing manufacturing cycle times, increasing inventory turns and improving accuracy and timeliness of information • Quick response to market demands • Allow evaluation during design stage

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Table 2. Barriers and drivers in high performance manufacturing (Source: European Commission)

	Barriers	Drivers
Environmental Context	• Difficulties in developing cost-efficient solutions • Difficulties in estimating required precision • Lack of basic processes common to manufacturing	• Cyber-enabled systems for validating documentation for quality control, cost minimisation and efficiency improvements • Reduction of pollutant emission and workers' health problems
Organisational Context	• Lack of managerial skills for advanced planning, user involvement • Lack of expert knowledge • Difficulties in conception, design and management of system complexity	• Cloud computing provides hosting platforms for new service models
Technological Context	• AMTs do not adapt well to dynamic environments • Selection of system for specific application is challenging • Integration of technologies is non-trivial • Difficulties in managing defects in implementation • Productivity of AMT is low • Lack of standards	• Lower power consumption • Promises of platforms tailored to a vast array of emerging applications: provides versatility, low costs, installation and operational flexibility, safety and reliable operation characteristics • New functionalities through new materials • Production of "impossible" products • Combining abilities of machines with those of humans (intuitive programming of robots)

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Table 3. Barriers and drivers in sustainable manufacturing technologies (Source: European Commission)

	Barriers	Drivers
Environmental Context	• Adverse human health effects of nanomaterials • Lack of health and safety practices • Need to balance business profit with environmental impacts and benefits • Life cycle assessment methodologies not mature enough to be applied at the scale of entire product portfolios	• Innovation, manufacturing scale and supply-chain development affect adoption of sustainable technologies • Policies for enhancement of sustainability • New materials form secondary sources or from waste • Increased visibility and awareness of energy consumption
Organisational Context	• Lack of employee buy-in, competence and time • Difficulties in combining multiple expertise • Dual goals of reducing variation and promoting variation	• Environmental implication of product and process innovations • Current IT systems can support collection of needed information for disassembly and recycling analysis
Technological Context	• Difficulties in gaining all information for recycling evaluation • Life cycle assessment methodologies are currently not mature enough • Difficulties in scaling up operations	• Sustained operation with consistent product quality, reduced equipment size, high-volumetric productivity, streamlined process flow, low-process cycle times and reduced capital and operating cost • Improved power monitoring enables energy efficiency and control of process stability • Unique advantages of nanotechnology

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The above list of drivers and barriers provides a pool of ideas for the creation of training courses and modules tailored specifically to the needs of the target SMEs of the FAME project. The training methodology that will be followed to develop and deliver those training modules is described in detailed in the following section

3.FAME Training Methodology

The objective of the project, as well as the nature of the project itself, deems appropriate the use of a blended learning model. Blended learning is an approach in education that combines online educational material and opportunities for interaction online with traditional place-based classroom methods. It required the physical presence of both instructor and student, with some elements of student control over time, place, path, or pace. Two models of the blended learning will be followed during the delivery of the training course, namely:

- **The rotation model:** in which students cycle through a schedule of independent online study and face-to-face classroom time. More specifically, the **individual rotation model** will be followed, in which the instructor sets individual timing for the student for rotation among different learning modalities. It is not required for students to undergo all training modules, only those most appropriate for their own skillset and objectives.

- **The online driver:** in which students complete an entire course through an online platform with possible teacher check-ins. All curricula and teaching are delivered via a digital platform and face-to-face meetings are scheduled or made available if necessary.

The combination of the above methods provides a unique framework for the training modules, specifically designed to meet the needs of SMEs as described both in the previous section of this document, and on previous FAME phases.

Given the new skill requirements necessary for AMT adoption, both structured and unstructured training modules should be designed for employees. Many SMEs prefer and rely on the unstructured on-the-job training as structured programs and modules offered by external consultants and experts are often either expensive or not need-specific. On the other hand, researchers strongly recommend structured training, and specifically suggest the developments of in-house training modules before the installation and operation of AMT equipment (Saraph & Sebastian, 1992).

Taking the above into consideration, the FAME ICT-enabled AMT training course should specifically include:

- Off-the-job classroom type training followed by structured and on-the-job experience;

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- Individualised and need-specific training modules;
- Repeated offerings of initial training courses to accommodate personnel turnover;
- Coupling of initial training with follow-on skill development training (hands-on training, etc.);
- Utilisation of alternative types of trainers such as supervisors and manufacturing engineers;
- Active learning methods (presented in more detail in the following sections);
- Periodic evaluation of training programs.

The training methodology comprises mainly of six interconnected learning techniques that are all employed to make the training modules specific and personalised for each employee's needs. Those learning techniques are:

1. Instructor-led classroom training
2. Interactive methods
3. Hands-on training
4. Computer-based and e-training
5. Video training

All the above techniques are further analysed and described in detail in the following sections.

a) Instructor-led classroom training

Classroom-style training is the most traditional and widely used training method. This method mimics other educational environments like a college course. A subject matter expert or a training manager prepares a classroom-based module and presents in front of a group of trainees. The benefits of this activity are mainly the personal interaction between trainer and trainee. Also, it provides the right environment and resources to interact or ask questions that in other cases might have been left unanswered. It also empowers the relationship between the trainer and the trainee, who are learning and growing together.

b) Interactive methods

The instructor-led classroom training technique can be enhanced by adding interactive and group activities to the training experience. Such activities are small group discussions, case study reviews, quizzes, demonstrations etc. This technique can be highly effective because it combats the one-directional transfer of knowledge which is the main attribute of the instructor-led classroom training method

c) Hands-on training

A training framework such as the one included in the FAME project could not be complete without hands-on training modules. AMT adoption is highly dependent on the skills of the trainees and their understanding on how to operate and handle new technologies. Hands-on training dives right into the practicalities that come along with the introduction of a new technology to a workforce, allowing trainees to quickly get their hands any technology. This

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approach is widely preferred by employees. On top of that, hands-on training offers a quicker learning process and boosts knowledge recollection and retention.

d) Computer-based and e-learning training

Computer based training (CBT) encompasses any type of training that takes place on a computer, while e-learning is specifically training that's hosted online via a website or a web app. These digital training techniques mimic classroom-style trainings modules, displaying visual content on screen that supports a lecture's voiceover. They can also include resources like videos and reading material to accompany coursework, similar to what is found in a classroom environment.

e) Video training

Over the past few years, video has emerged as a game-changing media both for external use (like marketing and sales) and internal use. Most businesses believe that videos help them train employees better and faster. Employees are also onboard with video training as the vast majority are more likely to watch a video rather than read e-mails, articles or documents. The benefits of video training are that videos are always accessible, unlike in-person training that requires physical meetings; they are affordable to produce; they streamline the learning procedures by explaining complex subjects using graphics, motion and voiceovers; and finally, they are dynamic, meaning that the content of a video training course can be easily modified to fit specific needs.

3.1   Phases of the FAME Training Methodology

The training methodology being developed for the needs of the FAME project leverages the blended learning approach for optimal results. The assets comprising this strategy of learning were described previously on this document. As in every training methodology, the following distinct shapes can also be identified in the FAME training methodology:

a) Identification of Training Requirements

Upon the commencement of the training process, the first task that will be performed will be a definition of the training requirements by analysing the scope of training and the target audience profile. It should be noted that training requirements will usually be defined in the context of skills management or continuous improvements activities.

b) Production of a Training Plan

Based on the requirement that will be identified in the context of the aforementioned task, a training plan will be produced that will comprise of:

- A training course that will be conducted in accordance to the training plan;
- A description of the training program;
- A description of the training material and associated documentation that will have to be produced;
- The specification of scenarios that will be used in the training tool;

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- A time-schedule for training;
- Training evaluation form(s), to be used in the context of training evaluation activities.

c) Training Execution

The training will be conducted in accordance to the training plan. Training will be conducted allowing the trainees to participate actively in the program by posting questions, expressing their preferences on the topics in which they want to be trained, etc. Hands-on training and short quizzes will also be part of the training courses to enhance the trainees' understanding of the training topics.

d) Training Evaluation

At the end of each training session, each trainee will be asked to complete an evaluation form, aiming to elicit information regarding the confidence that trainees have in the skills they obtained through the training module. The answers provided in the evaluation forms will then be processed, and along with the evaluation results from the training environment, may result in the determination of further training requirements that will be satisfied by organising supplementary training modules.

3.2   Structure of the FAME Training System

a) Delivery platform details

The delivery platform will comprise of two layers. The SMEs will need to provide certain input into layer 1 to be used by the "Genie" to personalise the training programme. Layer 1 will contain situational and behavioural questions. All questions will be multiple choice questions and based on the responses provided, the second layer will be customisable to the SME's needs. Layer 2 will display the training modules ranked in importance through the answers to the other Layer 1 questions. The modules will be presented with the names of the actions that can be chosen. Each action will be accompanied by indicators (in symbols) of multiple categories:

- Technical skills needed (low-medium-high)
- Language skills needed (low-medium-high)
- Action type

b) Usability – Accessibility

Using a mature e-Learning platform allows the user to gain a complete understanding of the presented information, by presenting activity results, solutions and interactive material that enhance the user's learning performance. Emphasis will be placed on ensuring that the system works as it should with any web browser technology. Furthermore, for the facilitation of disabled people and in line with the requirements of the EU regulatory framework [Article 16 Regulation (EC) 1083/2006], the project may attempt to minimise barriers and increase accessibility to services and structures to vulnerable social groups. For that reason, supportive technologies like

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text-to-speech may be evaluated and presentation of the text will exploit user agents that convert it into writing Braille (images and other multimedia content in every page will be described with equivalent texts). The final document for assessment will include both the assessment methodology and the tools that will be used in order to examine the compliance of the Graphical User Interface (GUI) with the Web Content Accessibility Guidelines. The specifications of the GUI will be accompanied by design suggestions that comply with the Web Content Accessibility Guidelines.

c) Financial Strategy Genie Functions

The strategy Genie is built around the "hardcoded" strategies described in the next section of this report. In other words, the Genie's purpose is to gather input from the SMEs, process this input in relation to the requirements for the implementation of the training and produce as output a personalised training plan for SMEs to achieve these strategies in a stepwise approach. To this end, data from layer 1 questions will be used to depict the "AS-IS" situation regarding the SME's strategies and its cross border e-Business aspirations in order to rank the e-Business modules of layer 2 and present them in order of importance to each SME. Then, SMEs start an interactive learning process by selecting modules and actions to implement

3.3. Training strategies

The FAME training modules will be based and built upon common strategies that cover the needs of SMEs concerning the adoption of ICT-enabled AMTs. Those needs are explored by the previous phases of the project and are supplemented from the barriers presented in the previous sections of this document. Thus, it is understood that the starting point for creating each strategy's context is to fully understand all aspects and drawbacks that SMEs encounter in their effort to adopt ICT-enabled AMTs. The strategies' context and generic titles are presented in the following sections.

a) Financial Resources

The insecure and often unstable financial position of an SME is one of the main barriers in adopting new manufacturing techniques and often leads to reluctance about new technologies. The availability of monetary assets is indispensably significant to managers and owners, and such subjects usually determine the fate of AMT adoption and implementation, especially in smaller manufacturing companies. Thus, what needs to be readdressed by the FAME training modules is the ability of SMEs to analyse their financial state and be able to maturely decide upon adopting new technologies in their daily process. Cost-benefit analysis (CBA) is a systematic approach to estimating the strengths and weaknesses of possibilities used to determine which options provide the best approach to achieving benefits while preserving savings. This method is generally not properly used, or often not used at all, by SMEs that lack the skills and experience to assess such matters, leading to misconception of the benefits of AMT adoption.

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b) Organisational Structure & Culture

Globalisation and constant innovation of technology result in a constantly evolving business environment. When an organisation undertakes projects or initiatives to improve performance, seizes opportunities or addresses key issues, they often require significant changes to processes, job roles, organisational structures and types and uses of technology. Change management (CM) is a collective term for all approaches to prepare, support, and help individuals, teams, and organisations in making organisational changes. It includes methods that redirect or redefine the use of resources, business processes, budget allocations, etc. AMT adoption is a technological change in which SMEs need to be prepared to undergo such a change in the most effective way. If individuals within an SME are unsuccessful in their personal transitions and do not embrace and learn new ways of working, the adoption will fail. On the other hand, if employees embrace and adopt changes required by this initiative, it will deliver the expected results. Change management is one of the aspects that needs to be stressed during the development of the FAME training modules, in order to ensure the AMT adoption by the targeted SMEs will be successful and lead to the expected output in the long-term.

Another factor that is also of great importance and falls under the culture changes expected from an SMEs for a successful adoption of ICT-enabled AMTs is innovation management (IM). Innovation management is a combination of the management of innovation processes and change management as defined above. It mainly refers to product, business process, and organisational innovation. It includes a set of tools that allow managers and engineers to cooperate with a common understanding of processes and goals. This allows the organisation to respond to external or internal opportunities and use its creativity to introduce new ideas, processes, or products. By utilising innovation management tools, such as brainstorming, prototyping, product lifecycle management, idea management, etc. managers can trigger and deploy the creative capabilities of the work force for the continuous development of a company. This mindset, along with innovation management tools, is often put aside by SMEs, but their significance composes the base for a successful adoption of ICT-enabled AMTs and shall be explicitly included in the FAME training modules.

c) Manufacturing Strategy

Generally, it is accepted that the operations and manufacturing strategies of a company consist of four significant competitive priorities:

1. Quality;
2. Cost;
3. Dependability / Delivery;
4. Flexibility.

The ability to deliver high quality products and services at premium price refers to the quality strategy of a company. The cost strategy focuses on lowering cost in the production and

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distribution of products in which ICT-enabled AMTs have significant benefits to offer. It is a measure of the efficiency of manufacturing operations, and conventionally it has been related to mass production and high volume. The Dependability/Delivery strategy deals with delivery schedules, which must be accurate and on-time. This strategy also refers to the responses, which should be swift, of a firm to its customer orders. And finally, the Flexibility is the degree of a company`s capability in moving, through matched actions and policies, from one product to another. The above strategies are directly linked to new-product designs through ICT-enabled AMTs and are of high importance for a successful AMT adoption by the targeted SMEs. Thus, FAME training modules shall address this area as well.

d) *Reskilling – Retraining*

The adoption of more basic AMTs, such as standalone technologies or even intermediate ones, can be planned and exercised easily at lower levels of management, compared to the adoption of integrated systems which require risky and complex investment decisions, independent of in-use technologies, and demands involvement of top level of decision makers. However, standalone AMTs, like 3D printing systems, VR and AR technologies, etc. are require basic knowledge to operate optimally. Those skills are often a major drawback when SMEs consider adopting a specific technology. The FAME training modules shall aim to provide the necessary skills training to employees to overcome technical barriers arising from the use of ICT-enabled AMTs. Through specially designed courses and hands-on sessions the aim shall not only be to train employees that will directly use the newly adopted technologies, but also to help them gain expertise to ensure the knowledge retention within the targeted SMEs.

e) *Digitisation*

Diving deeper into the types of AMTs that need to be adopted, the training modules shall cover a wide range of technologies that apply to the targeted SMEs. A common framework under which the training modules could be developed is the shift towards a digital process model. The new era of process streamlining requires the digitisation of many parts of the day-to-day processes of a business. The training modules designed by the FAME consortium shall take into consideration the aspects of digitisation which fall under the two main categories of hardware and software upgrading. From using sensors throughout the entire production line to data storage and processing, FAME training modules shall cover a wide area of tools and practices for SMEs to choose which best fits their needs. What is simple in theory but more complex to execute—especially for small businesses that lack the required skills and expertise—is the efficient and optimal communication between the hardware parts of their production lines and processes, with software that can maintain good control over the production line and provide crucial data that helps optimise the entire process. A good example of this connection is the Cyber Physical Systems (CPS) primarily for data storage and processing, Manufacturing Execution Systems (MES), Computerised Maintenance Management Systems (CMMS), or the Business Process Model Network (BPMN).

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f) *Standardisation*

A common barrier that forces SMEs away from the adoption of AMTs is the lack of standards covering the installation and operation of AMTs. Although there are some standards developed, mainly to create a common framework for using AMTs, such as LoRa and protocols like MQTT, many businesses are either unaware of them or choose not to follow them as they are often too generic to address specific needs. In cases where SMEs decide to invest in the adoption of AMTs, the investment often falls short due to lack of standardisation and absence of best adoption practices that have been tested on the field and could act as means towards a shorter and less risky adoption period.

4. Impact and opportunities

FAME will have to develop an extended blended learning strategy through the Virtual Learning Environment coupled with on-site classroom type modules and hands on sessions. This training module will act as the base for SMEs that want to invest in ICT-enabled AMTs but find it difficult due to specific barriers that they struggle to overcome. The training module will be personalised according to the SME's individual needs and will be the starting point for a smoother adoption. Through the FAME training modules, the knowledge is not only provided to the SMEs employees but is retained in the enterprises through constant support, evaluation and mentoring.

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