

Technology Assessment in the Manufacturing Enterprise: A Holistic Approach

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Abstract

Modern technology plays a key role in the ability of manufacturing enterprises to be productive and competitive. Today, most companies accept the fact that they must acquire relevant technology to strengthen their technological capabilities and core competencies. The task of management however, is to implement and exploit technology in all facets of business and not only as isolated technology islands within the enterprise. The question is how the holistic impact of new technology on productivity and competitiveness can be assessed and optimised.

This paper investigates the use of an enterprise-based model to assess the impact of new technology on the productivity and competitiveness of manufacturing enterprises, from a holistic point of view. The business lifecycle, basic manufacturing enterprise functions and organisation hierarchical structure are considered important parameters for the analyst to do a holistic assessment of new technology. The impact of technology on the enterprise can be mapped by using these parameters through the interaction of the various types of processes within the business. The holistic assessment framework is an additional audit tool to be used in the technological assessment process and not a replacement for conventional capability audit techniques.

Typical examples of the holistic assessment process are discussed, including both focussed and integrated technology applications. It is also discussed how the results of the assessment can be used as input to the development of technology growth strategies for smaller and larger companies.

Keywords: Technology assessment; Manufacturing technology; Management of technology; Technology strategy; Assessment frameworks.

Introduction

For a modern manufacturing organisation to be a global competitor, continuous updating of technology is of major importance. A direct relationship exists between the efficient use of technology and the competitiveness of the organisation, assuming that the right technology is exploited. Competitiveness in the manufacturing environment can typically be characterised by so-called world class manufacturing principles. Such principles would for example include the manufacture of products at competitive cost, supply of products at competitive price, high quality, short lead times and variety of product features. A major role of technology is to optimise these characteristics, and the direct impact of technology in the organisation can thus be seen in the fewer, faster, cheaper and more accurate processes within the product development, manufacturing and supply cycles.

Although most manufacturing organisations accept the fact that they must acquire relevant technology to strengthen their technological capabilities, the task of choosing and exploiting the newly acquired technology to get optimum results, remains a difficult one. Porter [1] realised when he developed his value chain theory, that technology should be exploited in all facets of the business lifecycle and not only as isolated technology islands within the organisation. Only by practising this holistic approach to technology utilisation, manufacturing organisations will experience technological change as a principle driver of competition.

In order to make appropriate decisions regarding investment in new manufacturing technology, management needs to know what impact different combinations of technology would have on the competitiveness of the manufacturing organisation. Proper assessment of the organisation's existing, as well as future technological status, would be necessary. However, assessment of the impact of new technology on the organisation's competitiveness, especially from a holistic point of view, is not an easy task and needs some closer investigation.

Basic Technology Assessment Principles

Technology has been defined in many ways, but fundamentally it can be described as the integration of people, knowledge, tools and systems with the objective to improve people's lives [2]. Certain relationships exist between the elements in the definition, as shown in Figure 1. These relationships are the skills that people need to operate the tools and systems, procedures that contain the knowledge needed to operate the tools and systems and new knowledge generation that includes training. Assessment of the technology would mean that these six parameters should at least be quantified in terms of predefined value systems.

The impact of a technology on the competitiveness of a manufacturing organisation, can be determined by mapping the changes in these quantified values over time, against each one of the world competitiveness parameters. An example is the increase in the accuracy of a machine tool and the impact it has on the quality of the manufactured product. Another example can be found in the increase of knowledge related to a manufacturing process which impacts in the reduction of the number of processes needed to manufacture a product, and which on its turn leads to lower manufacturing costs and shorter lead times.

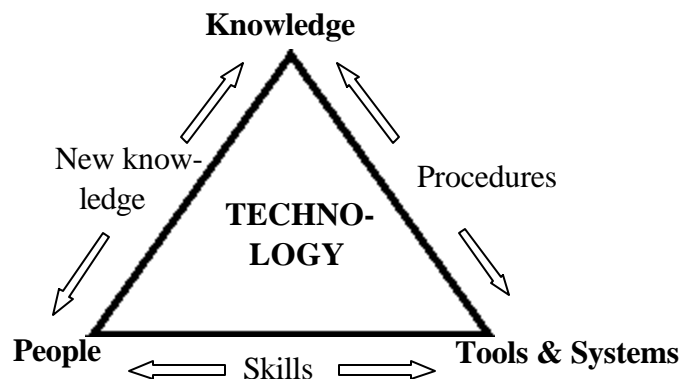


Figure 1: Definition of technology.

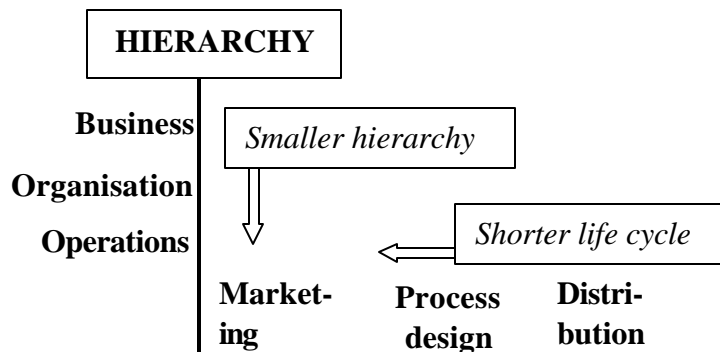
Although the basic method of technological assessment provides the analyst with essential information regarding the current and future status of technology in the organisation, it is an approach where individual technologies are being assessed. The wider perspective on the holistic impact of a set of technologies on the manufacturing organisation still lacks. A framework is needed to map the assessment results of individual technologies to get an enterprise-wide perspective of the impact of the total range of technologies in the manufacturing organisation.

The Manufacturing Enterprise Framework

A 3-dimensional model was developed [3] to assess the impact of different technologies on the manufacturing enterprise. The model was developed from the basic principles of systems theory as applied to manufacturing enterprise structures, see Figure 2.

The first dimension of the framework contains the fundamental functions [4] the manufacturing organisation must fulfil in order to survive in a competitive global environment. These fundamental functions include transformation-, information-, measurement- and co-ordination activities and are essential elements of a process to be classified as intelligent or cybernetic. Business and manufacturing processes are typical examples of intelligent processes. The second dimension in the framework is the business cycle of the manufacturing organisation and includes for example the typical phases of marketing, product and process development, production, distribution and service. From the viewpoint of intelligent systems, the business cycle possesses certain characteristics like feedback channels, a logic sequence of process execution, etc. The third dimension is represented by the organisational hierarchy, which ranges for example from workstation level up to top management level. The hierarchy contains people related aspects like responsibilities, knowledge and skills needed to manage and control the processes and technology in the enterprise framework.

Interpretation of the framework can be done as follows: a transformation function exists within each phase of the business cycle, forming a chain of transformation activities. Simultaneously, responsibilities, knowledge and skills regarding the transformation activities exist within the organisational hierarchy. The same interpretation can be done for the other fundamental functions of information processing, measurement and co-ordination. In summary, a 3-dimensional structure exists, consisting of chains of transformation, information, measurement and co-ordination functions across the business life cycle. A network of responsibilities, knowledge and skills can at the same time be projected from the hierarchical structure onto the chains of fundamental functions.



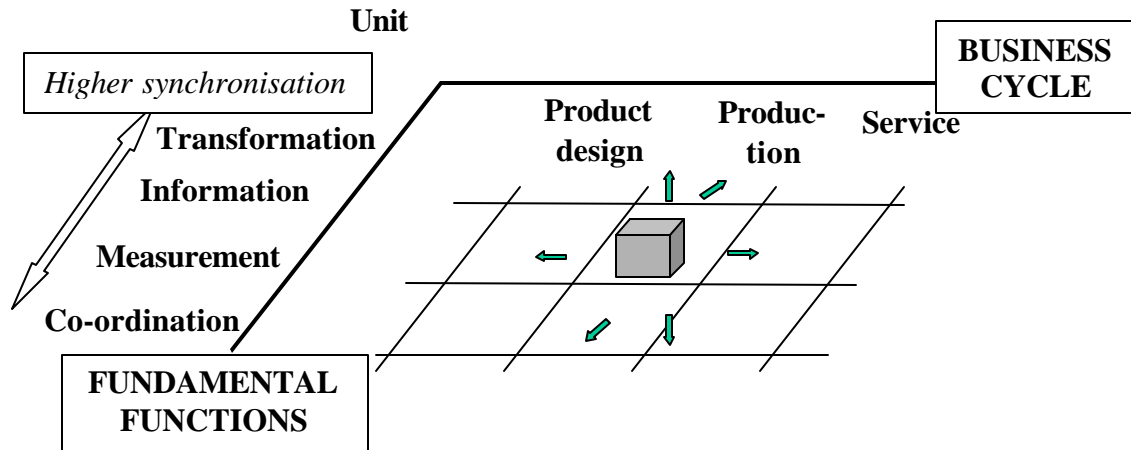


Figure 2: A manufacturing enterprise framework.

A new market requirement would trigger the dynamic structure of the manufacturing enterprise to perform a series of activities to satisfy the requirement to world class standards. As all the activities within the business life cycle are manifested in the processes in the 3-dimensional network, the level of performance of the manufacturing enterprise would depend on the optimum structuring of the process network. Processes can be integrated in series or in parallel where certain relationships would exist between the input and output parameters of the various processes. Looking at the element in Figure 2 as an information activity in the production phase at unit level in the hierarchy, different relationships with other elements in the 3-dimensional space can be identified:

- elements in the previous phases of the information life cycle
- elements in the later phases of the information life cycle
- elements in the other fundamental functions
- elements in the various hierarchical levels

The purpose of bringing new technology into the manufacturing enterprise is to assist in the optimisation of these interfaces and process structures. Automation technology would for example create the possibility for processes to be integrated in parallel in such a way that one process is totally absorbed into another, with the effect of a reduction in events that must take place to produce the output. The impact of new manufacturing technology on the process structure due to the integration of technology, can be summarised as:

- a reduction in the number of processes in the different phases of the business life cycle
- shorter processes and process lead times
- processes of higher quality
- more cost effective processes

The synchronisation factor between the fundamental functions of the manufacturing enterprise determines the dynamic performance of the process structure. The principles of concurrency and timing are important aspects influencing the synchronisation. The principle holds that at any specific time, all resources would be available to elements in the framework,

and through proper scheduling the timing of process execution would be optimal. In practise, this means that for a specific manufacturing operation to be executed at optimal conditions, the co-ordination function must ensure that the supply of material and equipment, information and measuring requirements must be synchronised. Technology plays a major role in the synchronising of the fundamental functions. The holistic effect of new technology on the enterprise framework, namely higher synchronisation of functions, a shorter life cycle and a smaller hierarchy is illustrated in Figure 2.

Mapping Technology In The Framework

The impact of a new technology on the manufacturing organisation can be assessed through the use of the 3-dimensional enterprise framework. Figure 3 shows the projection of a technology on the plane of fundamental functions versus business cycle. It is important to remember that the framework must be seen as an additional audit tool and that the basic quantification of the various technology parameters in the definition also needs to be done.

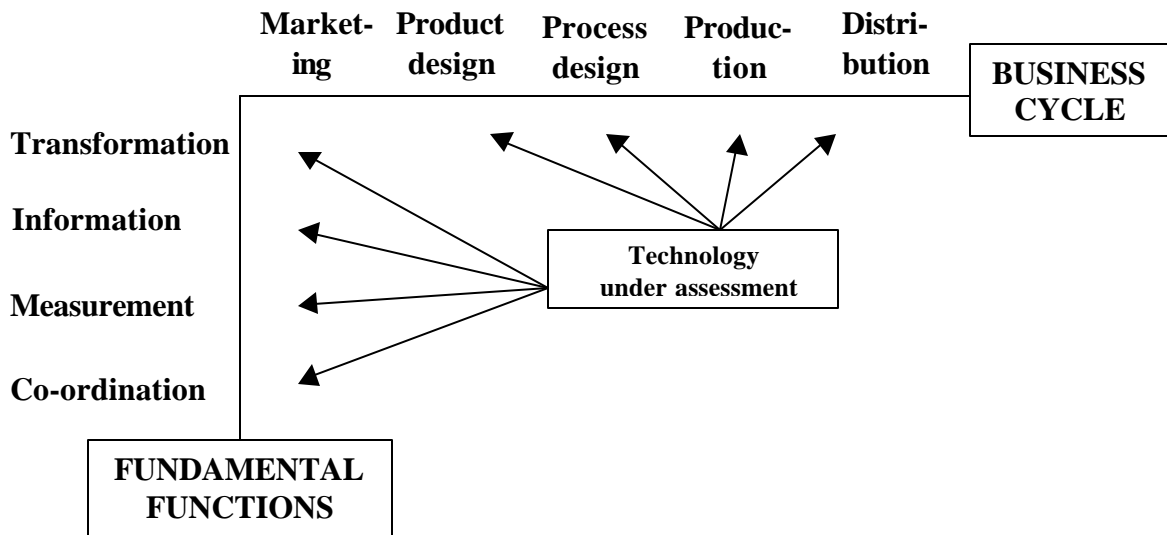


Figure 3: Characterising the technology in the framework in 2 dimensions.

The first step in the holistic assessment process is to characterise the technology in terms of the fundamental functions. The primary fundamental function of the technology under assessment needs to be determined, and the quantification of the synchronisation profile between the four fundamental functions being done. In order to do this quantification, a value system for the technology levels has to be defined. The second step in the holistic assessment process is the projection of the technology onto the different phases of the business life cycle. The primary phase of the technology is determined and the various interfaces with the other relevant phases in the 2-dimensional plane defined. The interfaces between the phases in the life cycle are specified in terms of their input and output relationships. The third step is the projection of the technology under assessment onto the hierarchical dimension, which is not shown in Figure 3. In this part of the holistic assessment, the responsibilities and capabilities identified in each phase are compared and related to those in the other phases.

The purpose of the analysis is to identify possible areas of duplication so that the technology under assessment can be utilised to eliminate the inefficiencies. An example will illustrate the application of the holistic assessment concept.

Assessment of Machining Centre Technology

Consider the case of machining technology where a machining centre is being evaluated as a possible technology to be acquired to improve the technological capability of the manufacturing plant. The design configuration of the machining centre is defined as a basic machine equipped with a computer numerical control system, an in-process gauging facility, an automatic tool changer and an automatic part-loading unit. The machining centre is a stand-alone unit under supervision of a machining technician.

Projecting the machining centre technology onto the fundamental functions dimension of the framework, reveals the following regarding the configuration of the machining centre as a technological system:

- transformation function - the primary function of the technology (material removal)
- information function - computer numerical controlled equipment
- measurement function - in-process gauging capability but not linked to SPC software
- co-ordination function - stand-alone centre not linked to plant control systems

To draw the synchronisation profile for the machining centre technology, a value system needs to be defined. In this example, the value system is based on the level of automation of the different fundamental functions. Manufacturing organisations often experience the problem of a concentration of technology in one phase of the business cycle, while some essential activities in the same process chain have no comparable technology support. This situation leads to synchronisation inefficiencies between the fundamental functions and across the total life cycle. Figure 4 illustrates a typical synchronisation profile for the machining centre configuration defined above. From this profile it is clear that although the machining centre as a stand-alone system seems to be highly automated, holistic interfacing with other fundamental functions are not that good.

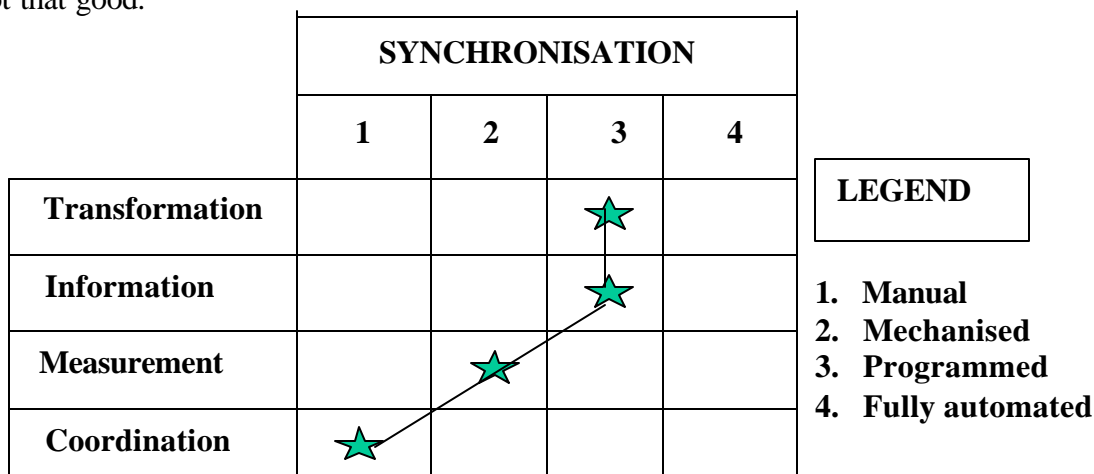


Figure 4: Synchronisation profile for machining centre technology.

The primary function of the machining centre, namely the physical material handling and machining, is fairly well automated, although the workstation is not linked to a fully automated material handling system. From an information processing point of view, the workstation is computer numerical controlled but not directly linked to a CAD-CAM workstation where programming can be done in advance and transferred to the machining centre, at a scheduled point in time. In-process gauging is done on the machine but the data is not transferred to SPC software or higher-level integrated quality systems. Being a stand-alone workstation, all the management control has to be done manually.

By projecting the machining centre technology onto the business cycle, some relevant interfaces can be identified. The machining centre technology primarily belongs to the production phase, but has important interfaces with marketing, product design and process design for example. Marketing can supply customer specifications and drawings in digital format, which requires specific technological interfaces with the process designers and production technicians. The interfaces are defined in terms of specific input and output parameters. The task of the production engineer is to ensure that the new technology is specified to meet the interfacing requirements.

The machining centre technology must also be projected onto the hierarchical dimension of the framework in order to determine the responsibilities, knowledge levels and skills needed from employees at the different levels in the organisation. Specifying the various interfaces in hierarchical context is essential for the design of appropriate training programmes to support the efficient utilisation of the new technology in a networked environment.

The same 3-dimensional technology assessment approach can be applied to the existing technology that is to be replaced by the new technology. A comparison between the two sets of audit results defines certain technological capability gaps. These gaps are the focus of the future technology projects. The approach to evaluate a technology using the 3-dimensional framework, is an additional assessment step over and above the standard assessment where the basic parameters of the technology definition are quantified.

Holistic Perspective: Integration Of Technology

The assessment of an individual technology from a holistic point of view, using the 3-dimensional framework, will already put the technology analyst in the position to assess the wider impact of the technology on the organisation as a whole. The next step in the analytical process is to look at the combined impact of different technologies that are utilised in the manufacturing organisation. The typical modern manufacturing organisation uses technologies like enterprise resource planning systems, concurrent engineering systems, computer integrated manufacturing systems, stand-alone manufacturing cells, etc. An assessment of manufacturing technology will have to include the synergistic impact of all these technologies. The assessment will thus include the mapping of the various technologies in the 3-dimensional framework.

Figure 5 shows the mapping of such technologies in the fundamental versus business cycle plane of the framework. Concurrent engineering technology can primarily be classified as information technology supporting the product and process design phases in parallel, with strong

interfaces to marketing and production. The enterprise resource planning systems, although basically being information systems, support the co-ordination function and cover all the phases of the life cycle. A detail technological analysis of a computer integrated manufacturing system shows that it is actually a synergistic and synchronised build-up of the combination of transformation-, information-, measurement- and co-ordination technologies.

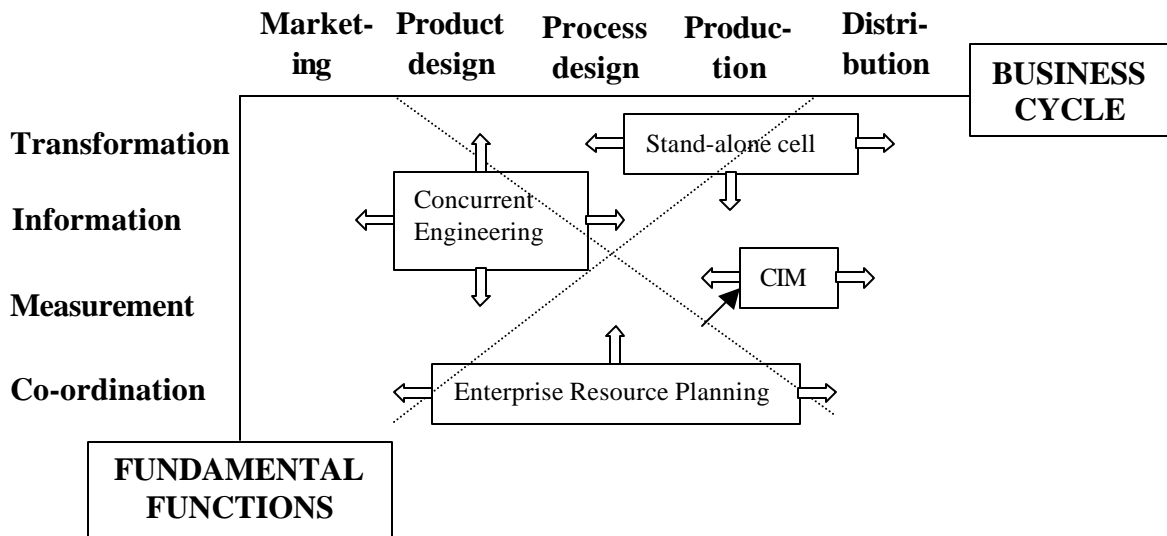


Figure 5: Mapping of different manufacturing technologies.

The task of the technology analyst is to synthesise the different manufacturing technologies in the 3-dimensional framework in such a way that optimal integration of the technologies can be achieved. This is done by matching the various synchronisation profiles, integrating the various input and output relationships of processes in the business cycle and restructuring the hierarchy by optimising the different responsibilities, knowledge requirements and skills that are related to the different technologies under assessment.

The Framework As Strategic Tool

An important task of top management is to make decisions regarding technological investment. With the results obtained from the conventional and holistic assessment exercises, management has a clear view of what the investment requirements for the future would be. From the holistic assessment point of view, one could however get the impression that high productivity and competitiveness can only be found in large investments in complex technology. Although such a strategy could lead to radical improvements in productivity and competitiveness, the effects of a strategy of incremental improvements in technology could also be substantial over the medium term. The mapping of technology in the 3-dimensional framework gives the analyst a detail picture of how technology can be developed and integrated in incremental steps. It is thus possible to develop a strategic technology growth path in which capability can be build up in a modular way.

It was pointed out that the impact of technology in a manufacturing organisation improves as the synchronisation factor between the fundamental functions improves. The result

of this improvement can be seen in the shorter life cycles and the smaller hierarchies. This sequence of improvement can also work in the opposite way. Productivity improvements can also be accomplished by optimising the hierarchical structure of the existing technology-network. The 3-dimensional framework can be used to analyse the current responsibilities, knowledge and skills requirements and this can also lead to shorter life cycles, although the impact would be smaller than the approach where new technology is introduced and optimised.

Conclusion

Conventional technology assessment techniques, based on the quantification of the basic parameters in the technology definition, are essential to characterise a specific technology and can in fact be seen as the first step in any technology assessment process. However, to get the best return on technological investment, it is necessary to also assess the holistic impact of a specific or a network of technologies in the manufacturing organisation.

The design of the framework is purely based on the structure and requirements of the specific manufacturing organisation. In that sense the framework is a flexible tool for assessment. Due to the nature of the 3-dimensional framework, analysts will also find it useful to get a clearer picture on business reengineering and process redesign projects.

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