Managing Global Transitions: Globalisation, Localisation, Regionalisation
Proceedings of the 8th International Conference of the Faculty of Management Koper
20–24 November 2007 · Congress Centre Bernardin · Portorož, Slovenia

DEVELOPMENT OF THE TECHNOLOGY AUDIT MODEL

Slavko Dolinšek, University of Primorska, University of Ljubljana, Slovenia
slavko.dolinsek@fm-kp.si

Aleksander Janeš, University of Primorska, Slovenia
aleksander.janes@fm-kp.si

Predrag Čosić, University of Zagreb, Croatia
predrag.cosic@fsb.hr

Sabahudin Ekinović, University of Zenica, Bosnia and Hercegovina
sekinovic@mf.unze.ba

ABSTRACT

Companies, while striving for their efficiency and effectiveness, often need to evaluate and improve their technological capabilities. Because there are no standard requirements about evaluating technological capabilities like for quality management system e.g. ISO 9001:2000 or EFQM model, the technology audit is often based on experiences. Companies for the purpose of internal technology audit engage employed experienced auditors who are trained for different types of evaluations. We can find some analogy between audits of systems of quality management and audits of technology capabilities based on systems approach. However many companies are developing 'their own' Technology Audit Model (TAM) through preparation of audit, accomplishment of audit and audit report with recommendations and corrective measures. Our main goal is to discuss applicability and benefits of the existing TAM for evaluating technological capabilities. On that basis we are further testing and developing applicability and supportability of the TAM model in relation to the technological capabilities of Slovenian companies.

Keywords: Audit, TAM, Technological capabilities, Quality management, Evaluation

INTRODUCTION

Technology can be defined as 'the way we do things' and it consists of the means by which we achieve objectives (Khalil 2000). The notion of Management of Technology (MOT) is continually evolving (Van Wyk 2004b, Dolinšek 2006). Within this contribution, technology can be defined as: theoretical and practical knowledge and skills which can be used for development of products or services, their productive and providing systems, and which can be incorporated in processes, materials, equipment, and systems employed in the creation of goods or in providing services (Khalil 2000, Dolinšek 2004, Thamhain 2005). Technology, as being identified by Porter (1998), is one of five forces that drive industry competition. MOT is an interdisciplinary field concerned with technological development, utilization and the impact of technology on companies and society. MOT can address the strategic and operational needs of the management system in the following ways by:

- Integrating business and technology strategies.
- Expanding utilization of quality standards, excellence models and Total Quality Management (TQM) philosophy into the field of MOT.

- Integrating the technology audit model into generic internal auditing practice of the company.
- Gaining support and benefits from the internal technology audit (Khalil 2000, Karapetrovic, Wilborn 2000, 2002).

The challenge to managers is to continuously and consciously manage their knowledge assets for the growth of technological capabilities of the company (Leonard 1998). In respect of that, the technology audit is defined as a tool to evaluate and identify the strengths and weaknesses of the technological capabilities of the company. The TAM model (developed by Garcia-Arreola in 1996) is supportive in the sense of determining current technological status, surviving areas of opportunity, and taking advantage of the company's strongest capabilities (Khalil 2000). One of the main goals is also to establish the technological position of the company in regard to its competitors and the state of the art. After the audit and assessment a company can develop objectives that form the core of its strategy (Khalil 2000). Technology strategy should be a part of the company's overall strategy. According to M.E. Porter (1996) a proper link between strategy and manufacturing operations is a key to developing sustainable competitive advantage.

Companies while implementing the system of quality management are regularly practicing quality audits. However, there are no standard requirements about evaluating technological capabilities like quality audits that are one of the integral requirements of the ISO 9000 series. One of the important areas of a company's generic audit should be an evaluation of their technological capabilities by an internal technology audit. We can assume that many companies are developing 'their own' TAM model through preparation of audit, accomplishment of audit and audit report with recommendations and corrective measures. Some companies have already adopted and included the TAM evaluation practice in their generic audit system.

The pilot test of the TAM model applicability was performed for the Slovenian service and manufacturing companies. The methodology approach was a survey which consisted of a TAM evaluation form. Respondents were answering to the evaluation form, which consists of twenty assessment areas and a five-point Likert scale. The results on a five-point Likert scale are an average for most categories. Companies from both industries are evaluated as relatively equal but with some advantage for the manufacturing industry. From the results it is evident that further improvements are needed, above all in the categories of innovation processes, acquisition and exploitation of technology.

Qualitative and quantitative analysis indicates the general applicability of the TAM model in both industries and a new viewpoint for some respondents and users. Although the paradigmatic orientation of this research is quantitative by its nature, it is too early to constitute if the research will further develop in a qualitative (e.g. ISO 9001) or quantitative model.

TECHNOLOGICAL CAPABILITIES AND STRATEGY

MOT is characterized as a unique combination of many constituent elements that links engineering, science and business management and emphasizes the multi-disciplinary nature of the field (Van Wyk 2004b). According to the US National Research Council (NRC), the MOT knowledge can make important contributions to industry, such as:

- Integration of technology into strategic objectives of the company.
- Efficient evaluation of the technology.
- Accomplishment of the technology transfer and new product development time.
- Management of interdisciplinary systems and internal use of technology (Li-Hua 2006).

In respect of that, technological capability of the company is the ability to effectively and successfully exploit the MOT knowledge. Technological capability has a strategic impact on company's competitive position in its business environment. With the increasing complexity of the business environment, MOT focuses more and more on managing the processes and employees who are involved with them (Thamhain 2005). A framework (model) of the technology management activities consists of identification, selection, acquisition, exploitation and protection. On that basis, a technology management assessment procedure has been developed. The main benefit of the Gregory's five process technology management model is in providing a conceptual framework that can be used to amalgamate all activities of the MOT and enable an assessment and management of this important area (Phaal 2001).

The key factor of company competitiveness is the successful acquisition and/or absorption (Balbinot, Bignetti, von Zedtwitz, Jin 2007) of technology in order to enable R&D and manufacturing of the innovative products and services. Here is room for further improvement of technological capability with management of innovations in the company's area of competitiveness. An integrated road-mapping methodology provides an opportunity for objective selection and assessment of a portfolio of the technology projects. Technology road-mapping is a management tool for improving strategic technology planning processes by linking the acquisition of technology to strategic objectives (Nabil 2006). The process of decision through which acquisition of the technologies is accomplished can significantly impact on a company's capabilities and performance (Baines 2004).

Auditing practice is mostly bound to the quality audits, which are an independent and objective collection of evidence balanced against the audit criteria. Within the system approach, like standard ISO 9001, an audit is a set of interdependent activities using human, financial, information, technological, and technical resources (Karapetrovic, Wilborn 2000a). Audit systems can make use of the generic management guidelines, such as the ISO 9000 series of quality management system standards. Its effectiveness is modeled using the concepts of reliability, availability and suitability (Karapetrovic, Wilborn 2000a). Quality audits are one of the integral requirements of the ISO 9000 series. In the case of quality audits, the theory and practice of management systems must be of real value as well (Rajendran 2005).

Auditors, while practising audits, encounter weak or non-existing linkages with business planning, narrow focus on quality assurance, inability to measure efficiency and lack of motivation. For that reason further improvement in efficiency of the methodology is required. One of the areas where quality audits are lacking is performance improvement. The study by Karapetrovic and Willborn shows that although they cannot replace quality audits, self-assessments have gained excellence in the performance improvement (Karapetrovic, Wilborn 2002a, Leonard 2002, Bou-Llusar et al. 2003, Boys et al. 2005). When audits are used primarily for management control, it is likely that they are bound to cause dissatisfaction among employees and to result in failure. In such cases, the management gets what they want to hear. Quality audits should be encouraged to promote efficiency and economically

favorable results. The main goal of the audit must be improvement, and the consecutive continuous process of improvement can correct most of the quality problems (Szakonyi et al. 1999).

With the growth of global competition, management systems are becoming more complex and diverse. Management systems audits seem to be following the same path. According to Karapetrovic and Willborn, further research is suggested not only in quality auditing and self-audit concept, but also in other areas of auditing practice e.g. health and safety, environmental, maintenance, financial, etc. (Karapetrovic, Wilborn 2000b,2002a). In this regard, we can append to the areas of auditing practice a technology audit as well.

Khalil (2000) lists several issues which were identified and recommended to the National Science Foundation of America. The five enabler categories could be used for efficient utilization of technological resources, and the following areas are considered critical for the company's competitiveness: (1) methods of performance assessment, (2) measurements of technology performance, (3) measurements of benefits from R&D activities, (4) new tools for optimizing decisions and (5) alliances as alternatives to rivalry. Under the methods of performance assessment it is stated that traditional performance audits are biased against technological innovation. More holistic methodology is needed in order to integrate all the factors driving the company. There are several principles that can help management to deal with the MOT paradigm like: (1) value creation, (2) innovation, (3) integration and quality, (4) responsiveness and agility as well as (5) teaming and fairness (Khalil 2000).

Value-creating activities for society are the basis of social responsibility of the company. The key to the long-term survival of the company lies in its products, services or processes nature. That means how they add value for the customer and how that value can be increased. After the audit and assessment a company can develop the core of its strategy. It should then select an optimal strategy for acquiring and exploiting technology. To achieve a sustainable competitive advantage in managing technologies an appropriate organizational structure and processes are also needed (Khalil 2000).

TAM METHODOLOGY

The internal audit is in general intended for evaluation, determination, and providing a position statement of existing status in a company. Evaluation, gained through the internal technology audit, can be used for encouragement of technological development in the company. The internal technology audit is a tool for a gap determination between the existing and the desired technological situation and, respectively, offers an evaluation about possibilities for upgrading technological capabilities. The main reasons for having an internal technology audit are:

- Positioning of the technological development.
- Estimation of probabilities for change of the existing status.

The applicability of the TAM model was tested, for purposes of the internal technology audit, in more than fifty Slovenian service and manufacturing companies. That is expressed in percentage, 50% of the service companies and 50% of the manufacturing companies. The majority of these already have implemented quality system management and are certified according to the requirements of at least one of the following standards; ISO 9001, ISO 14001, ISO/IEC 17025, ISO TS 16949, QS 9000, etc. Our interest was in testing if this

instrument (TAM) gives any useful answers about technological capabilities of the companies and it can be used for purpose of the internal audit like in case of the ISO 9001:2000. The methodology approach was an inquiry which consisted of a TAM evaluation form and a review of the company's documentation (e.g. annual reports, AJPES, web pages).

The TAM evaluation form includes important areas of technological capabilities of the company and is a holistic process oriented tool for the internal technology audit process. At the same time it makes possible a quantitative evaluation of the technological capabilities. The respondents were very different employees who are performing this function. They were responding to the quantitative evaluation form, which consists of twenty assessment areas and a five-point Likert scale. A score of 5 is outstanding, 4 is good, 3 is average, 2 is below average, and 1 is poor (Khalil 2000). They also presented their comments as well. Results from the TAM evaluation form are presented in findings below. Main benefits of the internal TAM evaluation are:

- Arrangement and review of existing relevant documentation of the quality system management and supportive key technologies.
- Identification of the technological assets and capabilities of the company.
- Determination of the key company competencies for strategy review and change support.
- Technology mapping support and portfolio of technology development projects.

EMPIRICAL FINDINGS

Discussion on the basis of the TAM evaluation form results

With the comparison of the TAM evaluation form results for service and manufacturing companies we come to conclusions listed below.

1. Technological environment (TE):

Service companies: Service companies have been evaluated by the highest average in technological environment category, which consists of the senior executive leadership and orientation, technology strategy, organizational structure, technology culture and employees as a company's most important assets. There is, however, still room for improvement in merging company's strategy with technological strategy, teamwork and reorganizations. That could mean changing the technological culture and treatment of people in the company, because the technological improvement could be based on the values and needs of all employees.
Manufacturing companies: Manufacturing companies had been scored as average in this category, which is somewhat higher than in the case of service companies. The key strategic technologies for development and diminution of business threats are identified, organization structures are manufacturing oriented, and a critical number of high-skilled employees is maintained. All these encouraging facts are a good basis for achieving business excellence. On the other hand, some improvements should be made in the case of empowerment and the reward system.

2. Technologies categorization (TC):

Service companies: Company's level of existing technologies, identification of external and basic technologies and technology trends were scored as average. Technologies categorization is mainly perceived as knowledge and information technology. More knowledge and awareness about one's own technologies and monitoring of important potentially competitive technologies are needed.

Manufacturing companies: Technologies categorization was evaluated with a somewhat greater average for the manufacturing companies. They have been investing in technologies for computer aided rapid product development, modeling, prototyping and manufacturing, and are expecting benefits from their investments. Some of them had received EU funds for the investments in education and qualification of employees. Process and marketing technologies should be subject to revision and improvement.

3. Markets and competitors (MC):

Service companies: A more profound understanding of market needs with, in time, inclusion of market trends in the overall strategy, assessment and benchmarking of competitor's status, could be the answer to the average evaluation for the service companies in this category. Also a periodic benchmarking of the best internal and external practices is an issue for further improvement.

Manufacturing companies: Average evaluation is higher for manufacturing companies, but there still remains room for improvement in productivity and the value added chain. Some good results are evident in a quality-price relation and flexibility, responsiveness and development support for the customers. In spite of that, foreign rivalry companies still have the advantage with their economy of scale.

4. Innovation process (IP):

Service companies: Innovation process is a category scored with the lowest average. The challenge in this category is an awareness of one of the most important issues: to encourage all employees to offer suggestions of new ideas in services or processes. Reward systems must be reestablished to financially motivate innovations within the whole company. This lowest score among all categories of the service companies could be a consequence of the stated facts from the first three categories.
Manufacturing companies: Innovation process is evaluated as average but still remains the lowest average between all evaluated categories of the manufacturing companies. Employees should be encouraged and rewarded to suggest new ideas for products or processes. More knowledge about market needs among employees is suggested.

5. Value/added functions (VAF):

Service companies: Cross-functional teams, projects portfolio and measures of all important variables of the processes and technologies in harmony with the environment are the areas for further improvement. In this category service companies have reached average. From the score of this category we could assume that they are on a good path to further improvement.

Manufacturing companies: Research and development is the key factor for planning and realizing strategic goals of the companies. With a proactive, preventive and systematic approach it is noticeable that harmonization with environment has been increasing and

process effectiveness had significantly improved. This category has the highest average score among all categories and indicates some potential for achievement of business excellence for the manufacturing companies.

6. Technology acquisition and exploitation (TAEP):

Service companies: Effective adoption of technology is dependent on the process of implementation which is the opportunity for improvement in this category, evaluated as average. This requires more systematic, process oriented transfer of the adopted technology and knowledge flow from vendors to the buyers and users of technology.

Manufacturing companies: The average score in this category indicates the need for further improvement for an investment in new technologies, development of global network, innovative manufacturing and protection of knowledge by patenting. Transfers of the new technologies and people are also an area to be given a greater significance in this category.

From the mostly average results one can recognize the increasing awareness of how important a part of the company's assets are the technological capabilities. With a higher average score are evaluated categories such as technological environment and value-added functions for the manufacturing companies, while there was no good evaluation between all categories. In all categories manufacturing companies have reached somewhat better scores than the service companies. This could be the consequence of the fact that technologies are more important to the manufacturing than to the service companies. Because of the latter's outlook, technology is regarded as being more in the context of industrial engineering than as an asset.

There are also some lower average results in innovation process and in acquisition and exploitation of technology. Companies from both industries are evaluated as relatively equal but with some advantage for the manufacturing industry. From the results it is evident that further improvements are needed, above all in the categories of innovation processes, acquisition and exploitation of technology.

Discussion on the basis of the Factor Analysis

From the factor analysis, which was conducted with standard statistical software SPSS 14.0 for Windows, is evident that correlation between variables is significant at 0,01 level (2 tailed). Between variables exists relatively strong correlations (from 0,417 to 0,712) and the data used in the analysis are adequate. With use of principal axis factoring we can assume that we deal with one independent factor with strong influence on variables which explains the variance with 66,928% (Table 1.).

Table 1. Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,016	66,928	66,928	3,643	60,723	60,723
2	,680	11,330	78,258			
3	,428	7,141	85,399			
4	,359	5,977	91,376			
5	,271	4,516	95,892			
6	,246	4,108	100,000			

Extraction Method: Principal Axis Factoring. (Source: Janeš, Dolinšek, 2007)

Further analysis with method of maximum likelihood with no rotation and method of maximum likelihood with rotation brings us to a conclusion of having only one influent factor which could represent technological capability (Leonard 1998, Baines 2004, Van Wyk 2004b, Janeš, Dolinšek, 2007, Balbinot, Bignetti, von Zedtwitz, Jin 2007) of the Slovenian companies.

Table 2. Factor Matrix(a)

	Factor
	1
1. TE	,836
2. TC	,846
3. MC	,793
4. IP	,786
5. VAF	,595
6. TAEP	,793

Extraction Method: Principal Axis Factoring. a 1 factors extracted. 5 iterations required.(Source: Janeš, Dolinšek, 2007)

CONCLUSION AND FURTHER RESEARCH

With the increasing complexity of the business environment, MOT (knowledge) focuses more and more on managing the processes and employees who are involved with them. While striving to effectively and successfully exploit the MOT knowledge companies often need to evaluate and improve their technological capabilities. The audit system is already accepted as an integrated part of the management system based on TQM. In the years of implementation and development of quality system management, many companies have stated that one generic audit consisting of different audit areas is a rational solution. Particularly in the area of technology management a lack of performance improvement was noted. For that reason, a more holistic approach is the challenge to support the implementation of the Integrated Management System (IMS) in order to encourage technological innovation, productivity, nourishment of common values, preservation of the environment and the commitment to excellence approach.

As we can see from the literature review, cases, testing experiences and from model development if the companies wish to remain competitive in this globally strengthening world, and to improve their management system, they must increase awareness and exploitation of their technological capabilities. The TAM model could offer a basis for application and support of improvements in that area. It is a model which is relatively easy to integrate into the management system because of its complementing nature and also worth for further development. Interest of our investigation was in testing if this instrument (TAM) gives any useful answers about technological capabilities of the companies and it can be used for purpose of the internal audit like in case of the ISO 9000 series. From the literature review we didn't found out any similar research. It is important to know that is, on basis of this unexperienced model, very difficult to determine the assessment of the industry. Although the paradigmatic orientation of this research is quantitative by its nature, it is too early to constitute if the research will further develop in a qualitative (e.g. ISO 9001) or quantitative model.

Qualitative and quantitative analysis indicates the general applicability of the TAM model in industry and a new viewpoint for some users. This quantitative oriented study has some

limitations. First of all findings cannot be generalized because of the pilot test of the TAM model applicability. Another limitation is the fact that this investigation was conducted only for Slovenian companies. Comparison (benchmarking) and evaluation between different approaches and/or models to internal technology assessment should be an issue for further research. On that basis we are further testing and developing the applicability and supportability of the TAM model in relation to the technological capabilities of the industry.

REFERENCES

1. Baines, Tim, (2004). An integrated process for forming manufacturing technology acquisition decisions. *International Journal of Operations & Production Management* 24 (5): 447-467.
2. Balbinot, Zandra, Luiz, Paulo, Bignetti. (2007). *Technological Capabilities of High Technology Firms in Cross Border Alliances.* San Diego:Elsevier Ltd.
3. Bou-Llusar, Carlos J., Ana, B. Escrig-Tena, Vicente, Roca-Puig and Inmaculada, Beltran-Martin. (2003). To what extent do enablers explain results in the EFQM excellence model? *International Journal of Quality & Reliability Management* 22(4):337-353.
4. Boys, Kathryn, Anne, Willcock, Stanislav, Karapetrovic and May Aung. (2005). Evolution towards excellence: use of BE programs by Canadian organizations. *Measuring Business Excellence* 9(4): 4-25.
5. Dolinšek, Slavko. (2006). Definicija in pomen MOT. *IRT 3000*. 1(2): 60-62.
6. Dolinšek, Slavko. (2004). *Management tehnologij: Učinkovito obvladovanje tehnoloških sprememb. Skripta*. Koper: Fakulteta za management.
7. Janeš, Aleksander, Dolinšek, Slavko. (2007). Assessing the applicability of the technology audit model for Slovenian firms. V: SHERIF, Hashem (ur.). Management of technology for the service economy. Miami: IAMOT,
8. Karapetrovic, Stanislav, Walter, Wilborn, (2000a). Quality assurance and effectiveness of audit systems. *International Journal of Quality & Reliability Management* 17(6): 679-703.
9. Karapetrovic, Stanislav, Walter, Wilborn, (2000b). Generic audit of management systems: fundamentals. *Managerial Auditing Journal* 15(16): 279-294.
10. Karapetrovic, Stanislav, Walter, Wilborn, (2002a). Self-audit of process performance. *International Journal of Quality & Reliability Management* 19(1): 24-45.
11. Karapetrovic, Stanislav, (2002b). Strategies for the integration of management systems and standards. *The TQM Magazine* 14(1): 61-67.
12. Khalil, Tarek, (2000). *Management of Technology: The key to competitiveness and wealth creation.* New York: McGraw - Hill.
13. Leonard, Denis, Rodney, McAdam. (2003). Impacting organizational learning: the training and experiences of quality award examinrs and assessors. *Journal of European Industrial Training*. Vol. 27, No. 1, pp. 16-21.
14. Leonard, Dorothy, (1998). Wellsprigs of Knowledge: Building and sustaining the sources of Innovation. *Harvard Business School Press*.

15. Li-Hua, Richard, Tarek, M. Khalil, (2006). Technology management in China: a global perspective and challenging issues, *Journal of Technology Management in China*, Vol. 1, No. 1: 9-26.

16. Nabil, N.Z. Gindy, Bülent, Cerit and Alla, Hodgson, (2006). Technology road mapping for the next generation manufacturing enterprise, *Journal of Manufacturing Technology Management,* Vol. 17, No. 4: 404-416.

17. Phaal, R., C.J.P., Farruk and D.R., Probert, (2001). Technology management process assessment: a case study, *International Journal of Operations & Production Management,* Vol. 21, No. 8: 1116-1132.

18. Rajendran, M,. S.R., Devadasan, (2005). Quality audits: their status, prowess and future focus, *Managerial Auditing Journal,* Vol. 20, No. 4: 364-382.

19. Porter, Michael E., (1998). *On competition*. Boston: Harvard Business School Press.

20. Szakonyi, Robert, et al., (1999). *Technology Management*. Boca Raton, New York, Washington, D.C.: CRC Press LLC.

21. Thamhain, Hans J., (2005). *Management of Technology:Managing effectively in technology – intensive organizations.* New Yersey: John Wiley & Sons.

22. Van Wyk, Rias J. (2004b). *Report to the education comitee International association for Management of Technology (IAMOT)*, http://www.iamot.org/homepage/2004-MOTTemplate-Education.pdf [7 November 2006].

23. Von Zedtwitz, Mawimillian, Jun, Jin. (2007). Process of Technological Capability Development: Cases from China`s Mobile Phone Industry. San Diego:Elsevier Ltd.