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DEVELOPING A MODEL FOR TECHNOLOGICAL CAPABILITY ASSESSMENT — CASE OF AUTOMOTIVE PARTS MANUFACTURERS IN IRAN

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Technology assessment provides the requirements for decision-making with regard to development of technological capabilities. This paper presents a model for assessment of technological capability level of firms. This model was tested on 10 manufacturers of automotive parts in Iran. We choose some technology capability assessment models as the basis of our assessment model. Then, using field study by questionnaire and site visit, these firms' capability level was assessed. Results indicate that in most cases there are lack of appropriate soft aspects of technological capability like managerial, human and knowledge aspects, smooth and balanced technological capability, and appropriate tacit knowledge.

Keywords: Technology strategy; technology capability assessment; technological gap; manufacturers of automotive parts.

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1. Introduction

Today, technology plays a crucial role in firms' competitiveness. Therefore, it needs, like other sources of competition, to be managed from a strategic point of view [Arasti, 2006]. Strategic view of technology should consider different aspects of technological capability (TC) of the firm, and therefore assessing the TC will lead to better strategic planning and technology development. In the manufacturing industries, impact of technology as a source of competitive advantage is widely accepted and developed [Phaal *et al.* (2001, 2004)]. Van Wyk [2004] pointed out that: "We need a simple, comprehensive grasp of technology. We need to understand

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at the macro-level how technology is composed, how it evolves and how it interacts with other systems." However, its impact is complex and is often difficult to be integrated into strategic management process. There is now a broad consensus among different academics, industrial experts and policy-makers that a manufacturing organization to be competitive in the global market, must be able to produce required high quality products, being reliable and economic (efficient) by easiest ways of production [Shamsuddin and Bititci (2006)].

Automobile industry is one of the most important manufacturing industries in Iran, and it has very important role in national economy. A very important element in this industry is automobile parts suppliers. Therefore, focusing on their capabilities and developing strategies to improve them is very important in Iran economy.

Technological aspects can be added to other aspects of competitiveness such as quality, cost and financial elements through technological capability assessment (TCA) of company in this industry. In this work, to assess these technological capabilities in automobile parts suppliers in Iran and to help improve management of technology, a model will be suggested. TCA must be incorporated into the overall performance indicators of a firm. Performance measurement systems (PMS) allow mindful decisions to be made and actions to be taken as because it quantifies the efficiency and effectiveness of the past activity (operation) through the acquisition, collation, sorting, analysis and interpretation of appropriate data. Incorporating technological competency measures into the PMS helps decision-makers adopt, adapt, absorb and utilize the appropriate technologies. From the technology management perspective, different activities like identification, assessment, selection, acquisition, utilization and protection of technology are very important [Phaal (2001)], therefore TCA will lead to better management of technology. In addition, the assessment process improves quality and expands existing and potentially new technology bases of a company [Panda and Ramanathan (1996)]. The assessment also benchmarks and identifies the strengths and weaknesses of a company [Panda and Ramanathan (1996)], and will improve the capability of strategic technology planning and technology development in a company.

SAPCO[a] is the biggest automotive parts supplier in Iran, and many of SMEs[b] have close relationship with it. In this paper, 10 automotive parts manufacturers, which are under the superintendence of SAPCO, have been analyzed.

In this paper, we first tried to define the technology and examine different aspects of its nature. After studying different models of TCA and their efficiencies, a number of these models were selected as the foundation of assessment model. However, considering that utter use of these models and their proposed indices have no effective application (are not effectively applicable) in Iran, so localized model was formulated, and then, using questionnaire, automotive parts manufacturers were appraised with regard to capability level.

[a] Supplier of automotive parts company.
[b] Small and medium enterprises.

2. The Concept of Technological Capability Assessment

2.1. *Technology and its nature*

What is technology? What is its origin and its nature? To assess, what aspects of technology should be considered? These are the fundamental questions about technology and its capability. In this section, the focus will be on the answers to the above questions.

Technology has been defined in several ways. Some define technology as a process of converting input into output with the aim of facilities and methods [Porter (1985)]. According to Khalil [2000], "Technology can be defined as all the knowledge, products, processes, tools, methods, and systems employed in the creation of goods or in providing services." He continues, "Only when knowledge is practically implemented to create new things, operate a system, or provide a service that we enter the realm of technology." But the most important aspect of the technology is the capability. We must consider that technology should be seen as a created capability. According to Wyk [1988], "Technology is a created capability: it is manifested in artifacts the purpose of which is to augment human skill." Key concepts are as follows:

— *Created*: Technology is not an endowment nature: it does not come about by itself. It is the product of deliberate action. If technology is to be employed as a resource, it has to be cultivated, nurtured and supported.
— *Capability*: This concept refers to a particular type of skills, namely that of manipulating aspects of the physical world.
— *Artifacts*: This is the generic term for all devices, tools, instruments or machines. Artifacts are the repositories of capability.
— *Augment*: This concept is used to convey two meanings: on the one hand, enhancing human ability, such as adding instrumentation to human activity, and on the other hand replacing human ability, by substituting it with competent artifacts [Shamsuddin and Bititci (2006)].

With another definition, technology is the application of knowledge, scientifically derived or otherwise, to the creation or modification of things and processes [Smith (1986)]. And same as Smith, Aldridge [1990] definition of technology is, "Technology depends on (cannot exist without) knowledge of how to apply other knowledge to create or modify useful things or processes where knowledge has been derived scientifically or otherwise."

Draaijer and Boer [1995] define technology as comprising not only plant and equipment (physical) but also the knowledge and experience (know-how) of the people. In another definition, technology is a combination of means, such as hardware, software and skill associated with a specific field of technical competence [Pretarious and Wet (2000)].

In a classification, technology has been used with different meanings:

— USAGE 1: HARDWARE (OR ARTIFACTS): Possible denotation: non-natural objects, of all kinds, manufactured by humans.

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— USAGE 2: SOCIOTECHNICAL SYSTEM OF MANUFACTURE. Possible denotation: all the elements needed to manufacture a particular kind of hardware, the complete working system including its inputs: people, machinery, resources, processes, and legal, economic, political and physical environment.
— USAGE 3: The information, skills, processes, and procedures for accomplishing tasks: Possible denotation: KNOWLEDGE, TECHNIQUE, KNOW-HOW, OR METHODOLOGY in the usual sense of these words.
— USAGE 4: A SOCIOTECHNICAL SYSTEM OF USE is a system using combinations of hardware and people (and usually — other elements) to accomplish tasks that humans cannot perform unaided by such systems — to extend human capacities [Kline (2003)].

In the APCTT [1989] definition of technology, there are four elements:

— Technoware: hard aspect of technology-like facilities and machines.
— Infoware: soft aspect of technology showing the information and explicit knowledge of technology.
— Humanware: soft aspect of technology showing the tacit knowledge in human activities.
— Orgaware: soft aspect of technology showing the organizational aspect of technology.

Therefore, technology is composed of hard and soft aspects. Facilities, skills and knowledge are the most important elements of technology [Zeleny (1986)]. The nature of technology is not fully explicit, but rather it has important tacit facets. The nature of technology has two aspects: its first aspect which is explicit in essence and is manifested in the form of information can be effortlessly transferred from place-to-place; and the second one is tacit taking the form of firm-specific knowledge which cannot be easily moved from a place to another one [Radosevic (1999); Cowan *et al.* (2001); Johnson *et al.* (2002); Nonaka and Takeuchi (2004)].

Our proposed model has incorporated both explicit and tacit aspects when assessing technology capability leading to an important result. Based on these arguments different approaches of TCA were studied and analyzed to see how they address the tacit and explicit elements of technology. In the next section we will address some important aspects of different approaches in TCA.

2.2. *Technological capability*

Over the past decade, firms' technological capability has been an important strategic resource for them to achieve competitive advantage within their industry, particularly in high-tech industries [Duysters and Hagedoorn (2000)]. TC has been defined by several researchers and is often used in different contexts. The definition of TC is varied in perspective, depending on the aims of the researchers [Zedtwitz and Jin (2004)]. Some define TC from strategic perspective and others define it in practical sense. TC is the ability to perform required technical activities within the firm, such as capacity to develop new products and processes and effective operation of facilities

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[Teece *et al.*, (1997)]. Panda and Ramanathan [1995] defined TC as a "set of functional abilities, reflected in the firm's performance through various technological activities, whose ultimate purpose is firm-level value management by developing difficult-to-copy organizational abilities". Based on this definition technological capabilities can be divided into three major categories. The first one, strategic technological capabilities, includes creation, design and engineering and construction capabilities. The second, tactical technological capabilities, encompasses all functional capabilities such as production, marketing and selling, and servicing capabilities and the third, supplementary technological capabilities, entails acquiring and supportive (training, planning, information support and networking, technology selling, and safety and security) capabilities [Panda and Ramanathan (1997)]. Lall [1990] defined TC as the ability to perform all the technical functions involved in operating, improving and modernizing the firm's facilities and to make them productive. From a different point of view, TC is the ability of the company to effectively capitalize on the technology management knowledge [Janeš and Dolinsek (2007)]. Zedtwitz and Jin [2004] defines TC as the capability to effectively explore the technical knowledge and skills, in effort to improve and develop new products, processes and existing technologies and to create new knowledge and skills so as to meet the challenges of increasingly competitive environment. Štrukelj and Dolinšek [2011] refer to TC as our capacity to utilize technologies to achieve our objectives in an effective and successful way. He continues, "Technological capability of companies refers to competence/capacity of companies to use technologies as well as knowledge and skills necessary for their proper use in a way that consequentially guarantees value maximization and profits for investors." Thus, TC enables firms to promote their innovation and improve their products and processes in an industry characterized by high levels of dynamism and rivalry [Ortega (2010)] and it is one of the most important sources of sustainable competitive advantage [Coombs and Bierly (2001)].

2.3. *Technology capability assessment approaches*

There are diverse approaches for TCA and in literature it is called technology auditing. These two terms are interchangeably used in this paper. Some of these approaches are broad and encompass all aspects of technology in the organization, but some others are narrow regarding technology in the organization. Table 1 classifies diverse methods and models briefly.

Simply defined, technology capability assessment or technology auditing, evaluates the internal technology status of an enterprise and compares it with the state-of-the-art examples in the world. It then matches the management capabilities of the enterprise with its technological standing.

APCTT [1989] has a way of assessing technology capability with four dimensions that include technoware, infoware, humanware and orgaware. Through this way, first the complexity of each dimension is assessed and then compared with state-of-the-art of technology. It is a quantitative approach which considers all aspects of technology in an organization.

Table 1. Technology auditing models [cited by Bagheri Moghaddam *et al.* (2011)].

Model or method	Explanation	Source
Value chain of activities	In order to assess the technological capabilities, activities in which these abilities are concealed will be evaluated. These activities will be compared with similar challenging activities.	Porter [1985]
Panda and Ramanathan method	Four sets of criteria are introduced for carrying out evaluation and standards are introduced for each. Then firms are compared based on these standards.	Panda and Ramanathan [1996]
Direct assessment of technological capability	Levels are introduced for technological capabilities which the author calls positions. The position of each firm is compared with the position of competitors or the ideal situation.	Arasti [2004]
Atlas	Based on the four perspectives of technology components, the technological capability of one firm or one country is evaluated. Based on these four perspectives, the index is defined for the technological capabilities of the system in mind.	APCTT [1989]
The technology management audit	Includes a set of guidelines for identifying and selecting technological opportunities and analyzing causes of technological gaps in the firm.	Lindsay [1999]
Technology management process assessment	By identifying important occupation unit, technology management activities are identified in a certain framework. Afterwards, these activities are assessed.	Phaal [2001]
Technology audit model (TAM)	This model, which includes a set of standards for technology audit, attempts at analyzing the company's position in technology management.	Khalil [2000]
Lin method	This method proceeds at analyzing technology management capability with focus on technology acquisition through transfer. On this basis, six sets of criteria are identified and indexes are defined for each. Then, based on these indexes, the firm's capability in transfer of technology is evaluated.	Lin [1997]
Technological capability audit model*	This model proposes a principle of TC audit in individual organizations. According to this model, first, appropriate model of TC should be developed, then assessment tools and methods are required, data analysis and possible problems and failures identification will come next, finally, based on an appropriate model of TC and audit results, possible solutions have to be developed.	[Štrukelj and Dolinšek (2011)]

*The "technological capability audit model" has not been in original table and was added by the authors.

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Phaal *et al.* [2001] developed a methodology for technology management assessment. They extended the work of Gregory [1995] who presented a five-process model of identification, selection, acquisition, exploitation and protection. They focused on the main functions of technology management and developed a model to assess different levels of technology management in the organization. Their assessment approach consists of three main stages:

— The strategic overview — defines a framework for linking technology with business objectives and enables selection of areas for more detailed appraisal.
— The process overview focuses on the business technology area selected in Stage (i), mapping and assessing technology management activities (Gregory's five-processes model) leading to the identification of specific processes for more detailed assessment.
— The process investigation focuses on mapping and assessment of specific process areas during Stage (ii).

The aim of this approach is to undertake a structured/systematic evaluation of a firm's technology management practices and to identify areas in need of improvement. This qualitative approach, instead of focusing on the content of technology, zeros in on the functions of technology management and its strengths and weaknesses in the development of the key technologies of organization.

Another approach akin to Phaal [2001] approach is the Ford approach. In this approach, technology capability of an organization is similar to technology management capabilities in selection, acquisition, utilization, development and diffusion of technologies. This approach is thoroughly qualitative and, regardless of the content of technology, only focuses on the functions of technology management [Ford and Saren (1996)].

Panda and Ramanathan [1996] suggest a five-step model in conducting TCA. The steps are:

— Identification of value adding stages.
— Identification of the TC needed to perform the necessary value addition.
— Development of a set of indicators for assessing each TC.
— Benchmarking of TC of the firm after a state-of-the-art company, finding the existing level of TC.
— Finding of the gaps in technological capability [Panda and Ramanathan (1996)].

This model is based on the evaluation of organizational capability in value-added creation and through these major criteria the technology is assessed. It is both qualitative and quantitative approach taking into account all aspects of technology in an organization. In this model both the tacit and explicit aspects of technology are analyzed.

Porter [1985], considering organizational value chain, proposed some implications for technology assessment in organization. Technologies are divided into two categories with respect to organizational value chain: core technologies and support technologies. In this model, based on the process approach, assessment of

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technologies will lead to performance assessment of the whole organizational value chain. Although this qualitative considers all aspects of technology in an organization, it overlooks the content and complexity of technology and just focuses on its output and performance. In this model just the explicit aspect of technology is analyzed and tacit aspect is not counted.

Chiesa [2001] takes into consideration the technology assessment and selection in the process of technology strategy and R&D strategy. This approach results in the prioritization of technologies and provides a condition for technology selection and development. It is highly qualitative and is not an inclusive approach for TCA.

The important steps in the technology assessment are:

— Identify the current technologies in the various sublevels.
— Characterize each technology in terms of people, processes and system requirements.
— Map the different technologies in the framework according to the characteristics of the fundamental functions, life cycle and hierarchy.
— Do a projection of the technology map onto the process map; this projection indicates which technologies are empowered by which processes.
— Quantify the impact of the technology on the company, using various analytical techniques [Shamsuddin and Bititci (2006)].

It is both qualitative and quantitative approach for TCA and it has a broad approach regarding assessment of technology in an organization.

With respect to these approaches, we can design an integrated model based on holistic approach to TCA in organization and consider both qualitative and quantitative indicators while analyzing both the tacit and explicit aspects of technology.

3. Developing a Conceptual Model for Technological Capability Assessment of Automotive Parts Manufacturers in Iran

In this section we propose a model for TCA of automotive parts manufacturers in Iran. In this model a holistic approach to TCA in organization is taken and both qualitative and quantitative indicators are included when analyzing both tacit and explicit aspects of technology.

Our overall conceptual model is shown in Fig. 1. Based on different approaches reviewed in the previous section, we shaped different dimension of our conceptual model.

Like APCTT [1989], Panda and Ramanathan [1996], Ford and Saren [1996] and Phaal [2001], we believe that organization, strategy and process of technology management must be considered in our conceptual model. Therefore, the first dimension of our model is *organizing and managing technological capability*. This dimension is characterized by more tacit knowledge and less explicit knowledge.

Based on technology definitions and some approaches suggested by APCTT [1989]; Porter [1985]; Panda and Ramanathan [1996] and Chiesa [2001] we concluded

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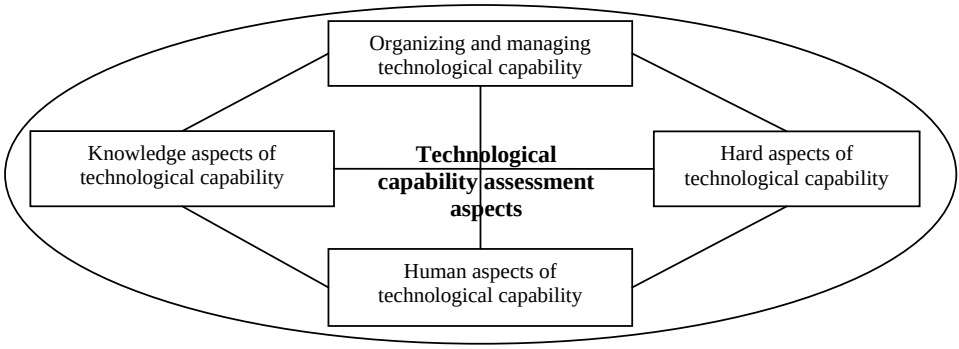

Fig. 1. Conceptual model for technological capability assessment aspects.

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that hard aspects of TC like machines and facilities are important. Therefore, the second dimension of our model is *hard aspects of technological capability*. This dimension is characterized by more explicit knowledge and less tacit knowledge.

In relation to technology definitions that encompass human aspects of technology such as skills and tacit knowledge rooted in human capabilities, and based on some approaches like APCTT [1989] and Panda and Ramanathan [1996] we concluded that human aspects of TC, must consider in our model. Therefore, the third dimension of our model is *human aspects of technological capability*. This dimension is characterized by more tacit knowledge and less explicit knowledge.

Finally, based on technology definitions that encompass the information and knowledge aspects of technology and with respect to some approaches like Porter [1985]; APCTT [1989] and Panda and Ramanathan [1996], we concluded that *information and knowledge aspects of technological capability* should be considered in our model. Therefore, the fourth dimension of our model is information and knowledge aspects of TC. This dimension is characterized by more explicit knowledge and less tacit knowledge.

To develop our indicators for TCA, we draw two axes in the model to illustrate them. These two axes are presented in Fig. 2 and are defined as follows:

— First axis depicts quantitative or qualitative indicators.
— Second axis exhibits tacit and explicit aspects of technology. It helps us assess these aspects of technology in the model which results in better indicators for their assessment.

In other words, to develop a holistic model, we should consider both tacit and explicit aspects, and on the other hand, both qualitative and quantitative aspects of technology. So there are two orthogonal axes, where one is a spectral of qualitative and quantitative aspects of technology and another is a spectral of tacit and explicit aspects of technology. And as a result four areas are formed.

Based on this categorization, the model includes all kinds of indicators in the TCA of organization. The first category of indicators, located in area one, is related

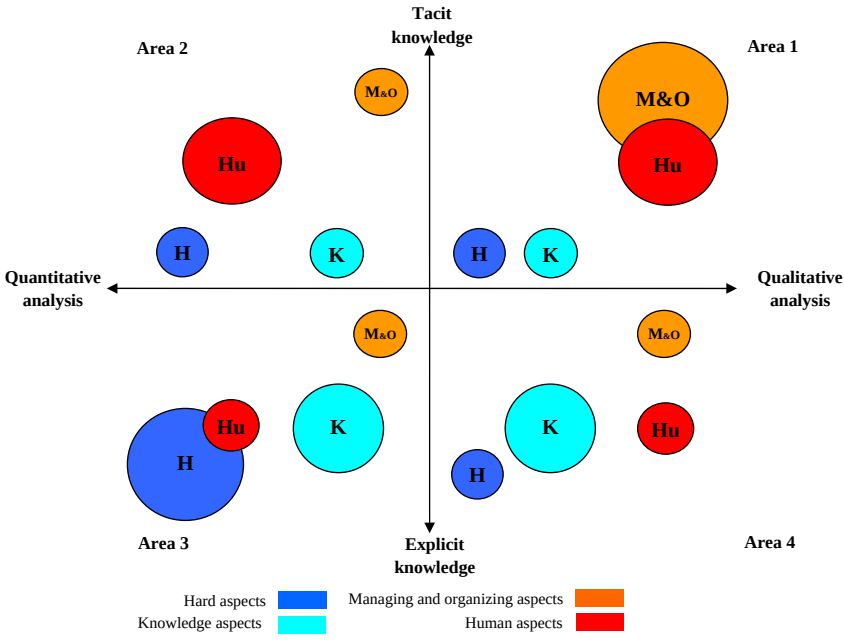

Fig. 2. Taxonomy of indicators for technology capability assessment in our model.

to qualitative assessment of tacit knowledge. The second category, located in area two, is related to quantitative assessment of tacit knowledge. The third, located in area three, is related to quantitative assessment of explicit knowledge. Finally fourth category, located in area four, is about qualitative assessment of explicit knowledge.

Then position of all aspects of TCA should be shown in each of these areas. In fact, some aspects of TCA are better related to some areas, so we should draw bigger circles to show this relatedness. Based on our model, managerial and human aspects are more related to assessment of tacit aspects of technology, and knowledge and hard aspects are more related to explicit assessment of technology.

Moreover, managerial and knowledge aspects are more related to assessment of qualitative aspect of technology, and hard and human aspects are more related to assessment of quantitative aspect technology.

Therefore, as shown in Fig. 2, our conceptual model encompasses composite indicators of TCA ranging from qualitative to quantitative indicators and from indicators of tacit knowledge to explicit knowledge.

Managing and human aspects of TC involve more tacit knowledge; therefore, many of their indicators can be placed in the first and second categories. But hard and information and knowledge aspects of TC have more explicit knowledge; therefore, many of their indicators can be included in the third and fourth categories.

After defining the model and its dimensions, through thorough desk research and interviews with automotive industry researchers and experts, indicators of dimensions were determined. We use 28 indicators for assessment of managerial aspects, 25 indicators for assessment of hard aspects, 11 indicators for assessment of human

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Table 2. Indicators of organizing and managing technological capability.

Indicators	Evaluation method
Technology-driven culture in organization (organization perspective on technology)	Qualitative
R&D management and organization	Qualitative
Proportion of R&D costs to sales	Quantitative
Proportion of technical personnel to whole	Quantitative
Proportion of R&D personnel to whole	Quantitative
Level of relationship with academics	Quantitative
Number of patents	Quantitative
Organization flexibility in product development and production	Qualitative
Level of process innovation	Qualitative
Level of product innovation	Qualitative
Level of improvement in product design	Qualitative
Level of organization efforts to implement 5S systems	Qualitative
Level of organization efforts to implementation of quality systems	Qualitative
Level of coordination and integration of production department with other departments	Qualitative
Level of customers needs identification and compliance	Qualitative
Organization ability in on-time delivery	Quantitative
Strategic planning and its documentation	Qualitative
Procedures for benchmarking and unremitting evaluation of competitors	Qualitative
Implementation of strategy of technology	Qualitative
Technology strategy in relation to organization strategy	Qualitative
Technology acquisition capabilities	Qualitative
Technology transfer capabilities	Qualitative
Technology utilization capabilities	Qualitative
Technology protection capabilities	Qualitative
The average time of developing new products (month)	Quantitative
Preventive maintenance culture and systems	Qualitative
Financing and investment in new projects	Qualitative
Contribute margin	Quantitative

aspects and six indicators for assessment of knowledge and information aspects. Tables 2–5 describe some of dimensions' indicators in detail.

Based on these arguments, we proposed our conceptual model and different indicators were selected to assess diverse aspects of TC in automotive parts manufacturers in Iran.

Table 3. Indicators of hard aspects of technological capability.

Indicators	Evaluation method
Level of equipments complexity	Qualitative
Intensity of labor (labor costs/production costs)	Quantitative
Intensity of capital depreciation (depreciation/production costs)	Quantitative
Intensity of material consuming (material costs/production costs)	Quantitative
Level of overhead costs (overhead costs/production costs)	Quantitative
Proportion of returned products to total production	Quantitative
Indicators of output quality (PPM internal)	Quantitative
Process capability index (CPK)	Quantitative
Reliability of equipments (OEE Indicator)	Quantitative
Set-up time	Quantitative

(*Continued*)

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Table 3. (*Continued*)

Indicators	Evaluation method
Level of applying ergonomics in equipments	Qualitative
Level of incidents	Quantitative
Optimized layout (transportation and waiting time/total production cycle time)	Quantitative
Type of transportation system (level of automation)	Qualitative
Adequacy of controlling equipments	Qualitative
Using level of process controlling methods and equipments	Quantitative
Novelty level of controlling equipments	Qualitative
Level of defects	Quantitative
Level of energy consuming in planet	Quantitative
Level of diversity use of technology	Qualitative
Level of technology novelty (technology situation in its life cycle)	Qualitative
Level of human errors control (making equipments unerring)	Quantitative
Level of novelty in production process and methods	Qualitative
Level of novelty in products	Qualitative
Completeness of production cycle	Qualitative

Table 4. Indicators of human aspects of technological capability.

Indicators	Evaluation method
Personnel education level	Quantitative
Education per capita	Quantitative
Personnel tendency to success	Qualitative
Personnel tendency to teamwork	Qualitative
Personnel familiarity with organization mission and goals	Qualitative
Level of adaptability between personnel job and education	Quantitative
Level of personnel flexibility and change acceptance	Qualitative
Personnel job experience on average	Quantitative
Level of operators expertise in applying and maintaining machinery	Qualitative
Level of human resource capabilities	Qualitative
Recommendations per capita (number of suggested, efficient and implemented)	Quantitative

Table 5. Indicators of knowledge aspects of technological capability.

Indicators	Evaluation method
Information updating procedures	Qualitative
Desirable information architecture based on standard methodologies	Qualitative
Level of IT tools utilization (intranet, website, etc.)	Qualitative
PC per capita	Quantitative
Level of information transmission smoothness	Qualitative
Level of information inclusiveness, accuracy and exactness	Qualitative

4. Research Methods

This research is applied down to the practical level. Considering this specialty, this research was based on the internal field study, site visit and closed questionnaire by asking engineers and managers who are directly involved in each activity of technology aspects.

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In this research the conceptual model and its dimensions and indicators have been determined and customized with regard to specifications and conditions of Iran's automotive industry. So for localized and applicable indicators a draft of the questionnaire was prepared based upon the indicators identified by literature review and desk research (Tables 1–4). All the possible indicators were allocated to each of the four dimensions and then we organized three expert panels with attendance of experts and managers of automotive parts manufacturers to test whether the indicators were relevant to each dimensions and whether they were easily understood and answered. The informants were also asked to delete those indicators that were not relevant to dimensions and add those that were relevant but which had hitherto not been included in the draft questionnaire.

The returned questionnaires showed that the respondents found some indicators which were not clearly described and some terms could not be easily or fully comprehended. Also, some factors were not relevant to the automobile industry. Furthermore, some questions could be answered only by senior staff such as general managers, directors, or senior engineering managers. Taking their comments into account, some of the indicators were modified, and as a result the final questionnaire was designed.

The final questionnaire was divided into two parts. The first part enquired about basic information concerning the respondent, such as work experience, job position, and the nature of his or her job. The second part of the questionnaire asked about the importance of each indicator. The respondents were also required to measure the extent of implementation of these indicators. Both the degree of importance and the extent of implementation were measured using a 1–5 scale.

To assess companies we need both quantitative and qualitative survey, given that our conceptual model includes composite indicator. So, a total of 120 copies of the questionnaire were sent to 10 automotive parts manufacturers and a total of 82 questionnaires were returned within four weeks time. For some qualitative survey and also to ensure there was no bias in answering questionnaire, 10 automotive parts manufacturers were visited and their personnel were interviewed.

In the next section, the implementation of the model and its results in 10 automotive parts manufacturers will be concluded.

5. Data Analysis and Results

We implemented the TCA model in 10 automotive parts manufacturers. We assessed the quantitative and qualitative indicators of this model using a questionnaire and gathered data from these companies. Moreover, the qualitative indicators were also assessed by on-site visit and interview with experts and managers of these companies.

The final results of the implementation phase are shown in Figs. 3 and 4 and Appendix. Figure 3 shows the comparative technological capability of 10 companies in each dimension and Fig. 4 illustrates overall comparative technological capability of these companies. Also assessment results for each company separately are shown in the Appendix.

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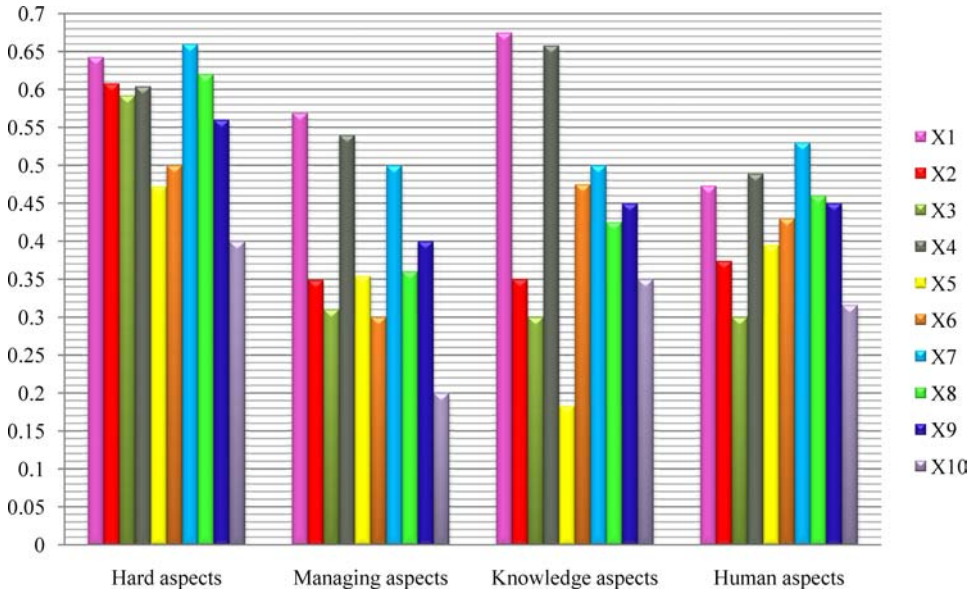

Fig. 3. Comparative technological capability of 10 companies in each dimension.

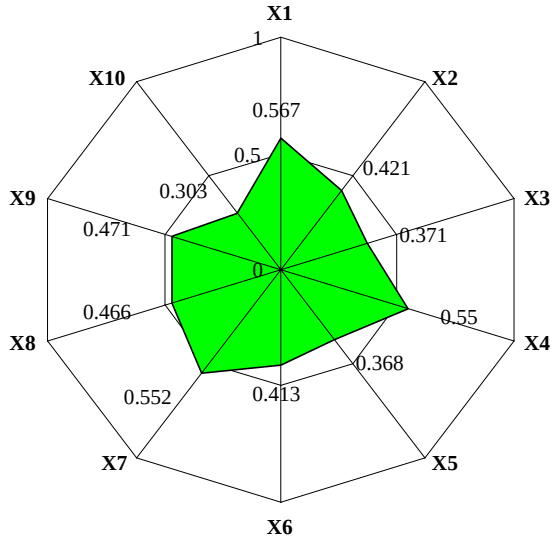

Fig. 4. Comparative overall technological capability of 10 companies.

As shown in Fig. 3, the first (X1) and the fourth (X4) manufacturers suffer weaknesses regarding human aspects of TC, but are stronger with respect to their capabilities in managing, hard and knowledge aspects. X2, X3, X8 and X9 showed weaknesses in human, managing and knowledge aspects of TC, but their capabilities in hard aspects are stronger. X5, X6 and X10 have weaknesses in all aspects of TC. Just X7 has smooth TC and strength in all aspects.

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Based on the results the following can be concluded:

— Lack of appropriate soft aspects of TC like managerial, human and knowledge aspects, in most cases.
— Lack of smooth and balanced TC, in most of cases.
— Weaknesses in all aspects of TC, in most of cases.
— Lack of appropriate tacit knowledge, in most of cases.

Therefore, this model provides an appropriate framework for assessment of TC in automotive parts manufacturers and graphically demonstrates the most important strengths and weaknesses of these companies.

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6. Conclusion

Having a realistic understanding about technological capabilities in a competitive industry such as automotive parts manufacturing industry, is a critical factor in any company's success. In this paper, diverse approaches to TCA and technology auditing were used to develop a model for assessment of TC. The split of these capabilities in their specific and detailed dimensions was the particular focus of this study.

As a whole, the paper poses two issues: first, nature and definition of technology and second, different approaches to TCA. Reviewing literature and developing localized and applicable indicators, we proposed a model for TCA in automotive parts manufacturers in Iran.

This model has four dimensions including aspects of management, hardware, human, and information and knowledge. Then, we implemented it in 10 automotive parts manufacturers in Iran. Based on implementation outcomes, we assessed different aspects of technological capabilities in these companies and determined their most important strengths and weaknesses.

Therefore, this TCA model provides an appropriate framework for assessment of TC in automotive parts manufacturers and has several interesting characteristics:

— It takes a holistic view about technology and TCA in an organization and encompasses management aspects, hard aspects, human aspects and knowledge aspects of TC.
— It encompasses composite indicators of TCA, both qualitative and quantitative.
— It includes both tacit and explicit aspects of technological knowledge.
— It can graphically visualize each TC dimension and the most important strengths and weaknesses.
— It can graphically visualize and determine whether TC dimensions of an organization is smoothed and balanced or not.
— It can assess the evolution of TC dimensions through assessing TC of an organization in different periods.

The main result of this paper is that TCA models prove to be powerful tools to analyze and compare the technological capabilities of different firms so as to select the most appropriate suppliers in the supply chain. Moreover, after implementing

this assessment, automotive manufacturers were assessed, identified their main weaknesses and select an appropriate strategy to improve them.

Lack of data was one of the limits of our research. This conceptual model has been developed for automotive parts manufacturing industry. So, future research may pursue discovering a suitable model for assessment of TC in high-tech industries or assessing companies' dynamic capabilities.

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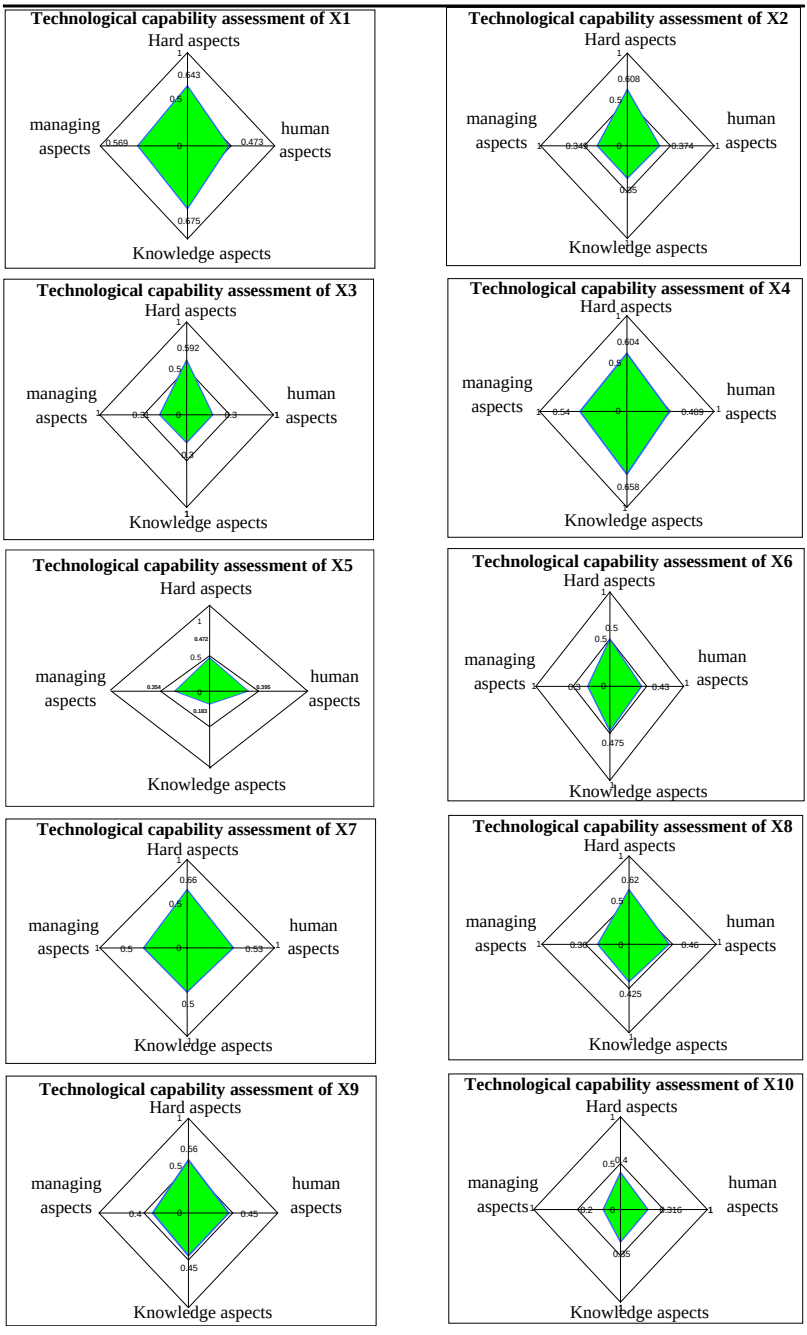
Appendix A

Table A.1. Results of the implementation of model in 10 automotive parts manufacturers.



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