On the Use of MCDM Technique for Identifying Key Technology: A Case of Auto Company

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Abstract— In today's world, technology strategy development for industries is one of the most important tasks in proposing technology roadmap. Moreover, identifying strategic technology is main part of strategy development. This article tries to apply MCDM methods in finding key strategic technologies from identified technologies from in order to provide appropriate technology strategy. TOPSIS method helps in finding key strategic technologies from identified technologies from in order to provide appropriate technology strategy. At last Efficient TOPSIS method used for determining key strategic technology in Auto Company and key technology are derived from identified technology so as to develop technology strategy.

Index Terms— Multiple criteria decision analysis, TOPSIS, Distance-based ranking, Key Technology, Technology management

I. INTRODUCTION

TODAY, technology plays a crucial role in firms' competitiveness. It needs therefore, like other sources of competition, to be managed based on a strategic point of view. The first and most important step of technology management is to develop a long-term strategic plan which determines firm's investment priorities and preferences in the field technology development, called "Technology Strategy".

TS is concerned with, but not limited to, the following questions [Lindsay 1999]:

1. What are the technologies which the company's sustainable competitiveness depends on?

2. Are these technologies all available or feasible?

3. What are the appropriate ways of acquisition for those technologies should be acquired from outside?

4. How can we ensure that we make best ROI in technological assets/ capabilities/ competencies?

Different models and frameworks have been developed by practitioners as well as academicians in order to help companies' top manager in TS formulation. But, firms in different sectors, with different sizes and thus different characteristics may find it difficult to choose the proper model, the most pertinent to their own situation. This is because for majority of firms' managers is difficult to identify differences between models. While, for selecting an appropriate model, we should be able to compare different

models and be aware of their strengths and weaknesses and their limits of applications.

This paper uses TOPSIS method in finding key strategic technologies from identified technologies from in order to provide appropriate technology strategy. Identifying strategic technology is main part of strategy development. Efficient TOPSIS method for determining key strategic technology helps decision maker in decision about strategic technology strategy development.

II. CONCEPT AND DEFINITIONS

A. Strategy

1) Assigning long time objectives of an organization and chose action for allocation sources in order to achieve goals [1].

2) A procedure of assigning organization objectives for long time, executive plan and priority in sources allocation [2].

3) A design and or plan in order to array fundamental objectives, policy, organization constant action drastically [3].

B. Technology strategy

1) Institute decision regarding to investment, development, applying technology of production and processes [4].

2) Assigning investment priority on technology development with considering long time objectives [5].

3) Technology strategy is an operation strategy and interpreted as organization general strategy on technology context, a prior situation or gaining long run objectives assigned by technology development [6].

According to Drejer who in 1996 presented historical classification of different procedures of technology management, generally, these procedures are:[16]

- R&D management,
- innovation management,
- technology planning,
- strategic management of technology

each of which has been considered by institution in different time intervals. Important point in examination of historical path of different views on technology in interactions of organizations.

C. Operation strategy

Operation strategy is organization general strategy in a specific segment, in other hand a way of fulfilling general strategy in the segment of organization [7].

D. Benchmarking

Finding other firms function fulfilled better in order to implementing them and or improves it [8].

E. Strategic planning

1) A process encompasses sources allocation for gaining organization and general goals and mission in competitive environment [9].

2) Assign and build organization mission and long run objectives and achieving a way to gain goals [10].

F. Technology

According to dictionary the meaning of technology is scientific study, engineering and scientific application use [11].

A scientific use of science in order to human needs provision [12].

Skill and science required for producing goods and or providing services resulting from mental ability and human perspectives and existed fundamental and phenomenal regulation combination [13].

Technology encompasses the whole factors which cause an idea to be changed to product. And lead to increasing income and entails factors such as reconstruction of main activity product technology, process technology, skills and know how, systems and experiences, data services, supporting, logistics, and management approaches [14].

In a simple language, technology is ability entails skills and science, and could be studied in here context: 1. Product technology, 2. Process technology and 3. Management procedures.

1. Product technology

A kind of technologies which are used in combination of goods and services and could be perceived via discipline and application contexts [15].

2. Process technology

A kind of technologies which are used in producing of a goods process could be perceived via four factors: hardware, info ware, human ware and or aware [16].

3. Management procedures

Contains techniques and procedures for handling administrative better, total quality management (TQM), just in time, risk management, and so on.

G. Technology selection

Technology as a major source of competitive advantage for manufacturing industries is widely accepted by practitioners, governments and academics. An enterprise can waste its competitive advantages by investing in wrong alternatives at the wrong time or by investing too much in the right ones (Torkkeli & Tuominen, 2002). A country can obtain its competitive advantages by investing in emerging technologies with comparative advantages (Lee & Song, 2007; Yu et al., 1998). In order to realize this competitive advantage, it is vital to understand both the specific technologies, and the ways in which organizations can best manage technology (Phaal, Farrukh, & Probert, 2001). Gregory (1995) has proposed that management of technology is comprised of five generic processes: identification, selection, acquisition, exploitation, and protection.

Among these processes, technology selection is defined as involving the choice of technologies that should be supported and promoted (Gregory, 1995). In the phase of technology selection, decision makers have to gather information from various sources about the alternatives, and evaluate these alternatives against each other or some set of criteria (Lamb & Gregory, 1997). Accordingly, Gregory (1995) separates the ''identification'' and ''selection'' phases where the former is concerned with gathering alternatives and the latter is concerned with the action to decide on an alternative. In contrast, Dussauge, Hart, and Ramanatsoa (1992) define the technology selection process as identification and selection of new or additional technologies which the firm seeks to master. In sum, a key theme in these definitions is that technology selection is a ''process'' that is closely linked to organizational objectives and is associated with the broader technological and market environment (Shehabuddeen, Probert, & Phaal, 2006; Stacey & Ashton, 1990).

However, it is becoming more difficult to identify the right technologies because the number of technologies is increasing and the technologies are becoming more and more complex (Torkkeli & Tuominen, 2002). Additionally, decision makers need to face other challenges such the rising cost of technological development, abundance of technological options, and rapid diffusion of technologies (Berry & Taggart, 1994; Lei, 2000; Steensma & Fairbank, 1999). For example, technology accounts on average for more than one-third of all business capital spending (Bakos, 1998). The abundance abundance and complexity of technological options makes the task of accessing suitable technologies and selection of the most suitable option more difficult (Cantwell, 1992). Ronde (2001) selects 98 specific technologies of future possibilities in the field of biotechnology in France. Using the same foresight technique, Ronde (2003) respectively introduces 40, 51, 39 and 50 potential areas in the fields of elementary particles, energy, natural resources and environment for Germany and France. Lee and Song (2007) also provide 56 research areas in nano-technology field for South Korea.

Besides the increasing cost of technological development and the abundance of technology options, many studies have shown that companies fail to assess new technologies. Hackett (1990) and Greenberg and Canzoneri (1995) point out that projects to incorporate new technology in a majority of companies are failing or are not fulfilling expectations. Huang and Mak (1999) argue that the failure of a chosen technology often results from poor management and assessment. Some of the causes have been attributed to the inability to consider the wider relationship of technology to the industrial context and the technology investments (Schroder & Sohal, 1999). These studies demonstrate the necessity for a careful assessment to overcome the difficulties of technology selection before introducing a new technology (Efstathiades, Tassou, Oxinos, & Antoniou, 2000).

III. TECHNOLOGY STRATEGY MODELS

A. Porter Model (1980)

Early in 1980s, Michael Porter examined relation between technology strategy and commercial strategy of an firm. Based on his view, competitive strategy and competitive advantage provide a **proper** and **effective** and for formulating technology strategy. In commercial strategy, competitive advantage is the characteristic for finding proper competitive environment, an environment in which institution of obtaining a stable competitive advantage. In Porter's examination, decision- making is based on

commercial action's area and situation of that area's changes.[33]

B. Mogen model (1982)

In this model, technology strategy development process includes four main stages or steps, shown in the below figure. In Mogen model, after identifying institution's important technology, it's necessary to perform evolution of this technology, Mogen specially considers two groups of: 1. basic criteria, technology' attractiveness evaluation criteria, 2. and criteria of ability evolution of proposed institution in identified technology's area.

C. Porter- Mogen composite model(1884)

deficits of Porter model for not presenting a clear way to evaluate attractiveness and ability of identified technologies as well as developing technology strategy based on those evolutions, are solved by use of tools presented by Mogen (attractiveness-ability matrix). In order to determine investment priorities and its proper methods., Identification of technologic changes procedure in key technologies of organization that was considered as one of critical steps in Porter model, is also important indirectly in Porter- Marin composite model and performed in step of attractiveness evaluation of selected technologies for investment of the composite model.

D. Hax and Mazlov model (1984 and 1991)

- A valuable work to understand technology strategy
- Their conceptual and mental theme was based on Poter framework.
- Their theory specially made clear classification of the main decision- makings related to technology strategy[5,31].
- In this model, institution considering its mission, strength & weakness points, strategic threats and its competitive plans, should provide macro- strategy.. By developing this strategy, technological requirements field is specified in macro form.

E. Chaplet and Twistiga model(1984)

Chaplet and Twistiga model(1984)believe that technology development strategy of an organization should be developed considering key factors of success in the market (KFS). From their view, key factors of success are a set of needs, requirements and demands which are applied to the organization by customers, suppliers, rivals, distribution channels, government and ect. Level of success or failure of organization, severely depends on their level of proper, timely and fast responsiveness to KFS s in the market.

F. Little model(1987)

Unlike chaplet & twistiga, some of other researchers believe that technology must be based on core competencies or in other words, basic capabilities of the organization. It's clear that paying attention to requirements, needs and demands of the market is necessary for survival of the organizations but organizations have different abilities in providing for demands and needs. In development process of technology strategy and making decision about that which technologies are important and what actions are required for their development, managers naturally tends to begin with technology without considering other considerations.

G. Booz - Alen & Hamilton (1981)

- A method for technology strategic management which is based on the following:[38]
- Path & time required for gradual development of required technology could be determined by pervious knowledge and anticipation.
- Technology should be seen as a capital asset.
- Homogeneity of investment in technology and commercial strategy fields is a necessary fact which leads to successful technology management.

H. Mc Kenzy model[1998]

In 1998, Foster presented another theory which focused on technologic changes and institution's ability to facing them. Base of analysis is S diagram behavior. In the beginning of a R&D progress in this stage is slow, then progress rate increases and finally, considering its limitations, technology is formed and progress rate becomes slow.

Now it's time to move toward another technology management which has more fluent changes. Foster suggests that finding technological decline (decadence) of existing technologies is very important. Technological decline effects in an institution are:

- decrease of R&D efficiency of the institution
- orientation of the institution toward losing last R&D opportunities
- change from R&D based on product to R&D based on process
- change in sell growth resources toward a little section of market share
- tendency toward important changes among rivals for investment on R&D
- unsatisfaction of performing an emerging R&D management orientation toward competition with smaller & weaker rivals in industries.

I. Parhald and hamel capacity theory (1989)

In 1989, Hamel and Prahald named this as "strategic intent". Then, to obtain required objectives a path should be designed and its details should be specified. In fact, in defining these intents, and important aspect which should be considered is that actions required for performing it as well as the path which should be followed should be considered. This action is named strategic architecture and makes capabilities which should be accumulated for competition and specify the way of obtaining them. Of course this (strategic architecture) should be designed with required freedom degree and flexibility any action should be based on meeting customers' needs and their satisfaction. Products are considered as a set of functions which are performed to response to costumers and make value for them. (Abel theory, 1980). Product functions are more stable than technologies and product itself. Therefore, functions of a product are basis of an organization that should be developed in long term strategy and lead the institution toward special actions which cause resources accumulation in this special direction.

J. D Aveni's ultro-competitive theory(1994)

In 1994, D "Aveni emphasized that dynamic property of competition is so intrinsically deep that it couldn't be considered as a secondary subject in strategic thinking. He emphasized that markets, are so changing and dynamic that evolution is the most basic power in strategic actions. In thoughts based on resources, the most important aspect of competition is not current situation of the institution but changes are made by dynamic interactions of competing firms.

K. Itami and Numagmi model(1992)

In 1992, Itami & Numagami performed an interesting examination about dynamic interaction between technology and strategy. Based on this, there are three kinds of interaction between strategy and technology:

- Interaction between current strategy and current technology
- Interaction between current strategy and future technology
- Interaction between future strategy and current technology

First case which is introduced as abilities of strategy in technology focuses on simultaneous consistency between institution's strategy and adoption of proposed technologies. Basic hypothesis is that technology could influence strategy in three ways:

- As an amour which distinguishes the institution from it's rivals.
- As a limitation with which institution should become consistent
- As a threat against which institution should protect itself

L. Chieza model.(2001)

Technology strategy formulation in dynamic environments of this section presents a structure of formulate technology in competitive dynamic environment. In the past section, basic principles and key characteristics of technology strategy formulation in dynamic environment were defined.

Decisions are made based on data collected from future form of competition & industry, technologic advances prediction and evolution of internal & external environments. This data collection provides base of future scenarios, which is consistent with strategy foundation. This step is called future- recording of environment and is the key to enter decision-making step.

IV. OVERVIEWS OF MCDM AND TOPSIS

A. MCDM technique

The analysis of an MCDA problem can be summarized as the following three steps (Chen, Kilgour, & Hipel, 2006): (1) Problem construction, in which the DMs objectives are identified, all possible alternatives are identified, and criteria are determined where by Successes in achieving the objectives are measured; (2) Preference Elicitation and aggregation, in which the DMs preferences within and across criteria are obtained and aggregated; (3) Implementation, in which a constructed preference model is

utilized to evaluate all alternatives, there by the "problématique" selected by the can be solved. The analysis results can be employed as an aid to the actual decision making process.

Step (1) aims to structure an MCDA problem. Let the set of alternatives be $A = \{a^1, ..., a^i, ..., a^{|A|}\}$ and the set of criteria be $C = \{c_1, ..., c_j, ..., c_{|C|}\}$, where $|x|$ represents the cardinality of a set X. When step (1) is completed, the consequence of alternative a^i on criterion c_j, denoted by m_j^i, will be measured for every $i = 1, ..., |A|$ and $j = 1, ..., |C|$, constituting the (i, j) entry of a $|A| * |C|$ matrix called the information (or performance)matrix. The structure of this matrix is shown in Fig.1. Note that a consequence is a direct measurement of an alternative according to a criterion

		Alternatives			
		a^1	a^2	...	$a^{|A|}$
Criteria	c_1				
	c_2				
	...			m_j^i	
	$C_{|C|}$				

Fig. 1. Performance matrix in MCDA, adapted from Chenetal. (2006)

(e.g. cost in dollars). Generally speaking, a consequence is an objective physical measurement.

The DMs preferences are crucial in reaching a final recommendation for an MCDA problem, and different approaches to modeling preferences of the same problem may lead to different conclusions. Formally, as we interpret MCDA procedures, a DM may have preferences on consequences, called values, and preferences over criteria referred to as weights.

Preferences on consequences, or values, are refined data obtained by processing consequences (original and raw information) according to the needs and objectives of the DM. This is a necessary step to convert and normalize consequences in to a common comparative ground as consequences on different criteria of ten assume significantly different formats. The general relationship between consequences and values can be expressed as a mapping from consequences to values, $v_j^i = f_j(m_j^i)$ where $v_j(a^i)$ and m_j^i are a value and a consequence measurement, respectively. The DM's values overall criteria for alternative a^i constitute a value vector, $\mathbf{v}(a^i) = (v_1(a^i), ..., v_{|C|}(a^i))$. It is often assumed that criteria are preference monotonic along consequences: (1) benefit criteria: the larger the consequence value, the better; (2) cost criteria: the smaller the consequence value, the better.

Preferences on criteria, or weights, refer to expressions of the relative importance of criteria. The weight for criterion $c_j \in C$ is denoted by $w_j \in R^+$, usually it is required that $\sum_{j=1}^{|C|} w_j = 1$, and the DMs weight vector is denoted

by $\mathbf{w} = (w_1, \ldots, w_j, \ldots, w_{|C|})$. After an MCDA problem is structured and preferences are obtained, a global model is required to aggregate preferences and solve the specified problématique. For $a^i \in A$ the overall evaluation of alternative a^i is denoted by $V(a^i) \in R$ where $V(a^i) = F(\mathbf{v}(a^i), \mathbf{w})$. Here, $F(.)$ is a real-valued mapping from the value vector $\mathbf{v}(a^i)$ and the weight vector $\mathbf{w}$ to a numerical evaluation of a^i. A typical example is the linear additive value function, $V(a^i) = \sum_{j=1}^{|C|} w_j . v_j(a^i)$ (Hwang & Yoon, 1981).

B. The TOPSIS method

The TOPSIS analysis procedure can be summarized as the following steps (Shihetal., 2007):

- Construct a performance matrix: establish a $|A| * |C|$ matrix called the performance (information, decision) matrix as shown in Fig. 1.
- Normalize the performance matrix: Apply a normalization process to the performance matrix to convert the original consequence data to values. Assume that $\forall m_j^i \in R^+$ three widely used normalization functions, mapping from m_j^i to $v_j^i (0 \leq v_j^i \leq 1)$ are listed below (Chen, Kilgour, & Hipel, 2010; Chen,

(1) Vector normalization: $v_j^i = \dfrac{m_j^i}{\sqrt{\sum_{i=1}^{|A|} (m_j^i)^2}}$;

(2) Sum-based normalization: $v_j^i = \dfrac{m_j^i}{\sum_{i=1}^{|A|} (m_j^i)}$.

(3) Min-Max-based normalization: $v_j^i = \dfrac{m_j^i}{max_{i=1}^{|A|} m_j^i}$

(c_j is a benefit criterion) and $v_j^i = \dfrac{min_{i=1}^{|A|} m_j^i}{m_j^i}$ (c_j is a cost criterion);

- Define ideal and anti-ideal points: set an ideal point, a^-, and an anti-ideal point, a^-, as the combination of maximum or minimum values of $v_j(a^i)$ for all $a^i \in A$ and $c_j \in C$, respectively. For example, for a benefit criterion c_j, using vector normalization, $v_j(a^+) = min_{i=1}^{|A|} v_j^i$ and $v_j(a^-) = min_{i=1}^{|A|} v_j^i$.
- Assign weights to criteria: set $w_j (w_j \in R^+$ and $\sum_{j=1}^{|C|} w_j = 1)$ to represent the relative importance of the criterion, c_j.
- Calculate the distances from a^+ to a^-: the p-norm distance functions

$$D(a^i)^+ = \left\{ \sum_{j=1}^{|C|} w_j |v_j(a^+) - v_j(a^i)|^p \right\}^{1/p} \qquad (1)$$

and

$$D(a^i)^- = \left\{ \sum_{j=1}^{|C|} w_j |v_j(a^i) - v_j(a^-)|^p \right\}^{1/p} \qquad (2)$$

are often employed, where p is a pre-defined distance norm, usually set as 1 or 2; and $|x|$ represents the absolute value of x.

- Obtain an overall assessment of a^i: construct an overall distance function for a^i to aggregate the aforesaid two distances into a final evaluation result. The overall distance $D(a^i)$ can be expressed as Hwang and Yoon (1981)

$$D(a^j) = \frac{D(a^i)^-}{D(a^i)^- + D(a^i)^+} \qquad (3)$$

Obviously, a large values of $D(a^i)$ represents a better overall performance.

C. Hypothetical scenarios for the future

1. Expansion strategy NGV stations due to lack of development and lack of adequate levels in the reservoirs locating insoles stop.
2. With government support use of NGV in the market increases, but due to the relatively limited growth rate and position limited survey, the production of two burnt cars still be on the agenda.
3. Growth and rapid expansion of fuel stations in terms of number and distribution in the country with the change in the insoles vehicles, specifically the possibility of selling natural gas vehicles and two vehicles burnt with the petrol tank of less than 14 liters built only for emergencies, be provided.

D. Classified in terms of access technologies

- Technologies in the production stage

Technologies are already available for manufacturers and suppliers, and its well known to use whenever they decide to be in the car are applying.

- Technologies in the commercialization stage

Past research stage, and by a limited number of suppliers and manufacturers are commercial but still they continue to develop and standardize.

- Technologies in development stage

Past research stage and are being developed. Enough to understand them very well and gained about 5 to 10 years, will be available at mass.

E. Engine Technologies

1. Technologies in the production stage

- Reduce mechanical friction and other losses / Hydrodynamic
- Utilizing advanced low-friction oils
- A multi-valve mechanism (more than two valves per cylinder) so camshaft
- variable valve timing (VVT)
- Variable valve timing and displacement (VVLT)
- Inactivation cylinders
- Develop and improve side components
- Engine downsizing with bulimia
- Multi-track weather variables (VLM)
- Engine style building with plastic materials

2. Technologies in the commercialization stage

- Suffocation valve engine through the air (IVT)
- Astoqumetric direct injection gasoline engines (GDI)

3. Technologies in development stage

- Direct injection engines, fuel poor (Lean Burn GDI)
- Cam valve without stimulation (CVA)
- Two types of CAM to stimulate valves
- Variable compression ratio (VCR)
- Auto ignition under (HCCI)

Table 1- List of current and developing engines of vehicles

Family Engine	Variant code Engine	Name Engine
X	XG181	XU7/JPL3
	XG18-41	XU7/JPL4
	XN192	XUG – 8V
T	TB16-41	TU5G
	TG16-41	TU5
	TG131	TU3
F	FN17-4V1	EF7/1.7L – NA
	FN17-T1	EF7/1.7L – TC
	FN14-41	EF7/1.4L-NA
P	PG162	Peykan OHV
	PN173	Peykan OHVG
K	KG16-41	K4M

F. Evaluation Factors

- Fuel Reduction Co2 (% or qualitative)
- Emission reduction (No_x)
- Drivability increscent

G. Identified Technology

Table 2- List of Identified Technology

No.	Identified Technology
1	Closed Coupled Catalyst
2	Palladium Containing Catalyst
3	Catalyst Design & Formulation
4	Cold Start Retard & Enlearnment
5	Rich Start & Secondary Air
6	Transient Adaptive Learning
7	EGR
8	Fast Light-off Lambda sensors
9	Electrical Heated Catalyst
10	Gasoline Burner
11	Exhaust Gas Ignition
12	HC Trapping Systems
13	GDI Lean Burn
14	GDI Stoch.
15	Nox Cat.
16	Controlled Auto Ignition
17	VVT
18	VCR
19	Low Idle Speed
20	Cylinder Deactivation
21	Electric Accessories
22	AMT
23	Lock-up Zone
24	Turbo Charging
25	Supper Charging
26	Low Crevice Volumes
27	Start Catalyst
28	Double-wall Exhaust Pipe
29	Exhaust line with low thermal
30	Dual oxygen sensors
31	Sequential fuel injection
32	Model based transient control
33	Model based canister purge
34	Canister load adaptation
35	4 V
36	Magnesium Alloies Material
37	VLM
38	V-TECH(lift-timing)
39	Assy Cams
40	Direct Oil Pump
41	HCCI
42	Modularity

H. Deriving Key Technology by TOPSIS Method

Table 3- List of Selected Technology

No.	Selected Technology
1	VCR
2	Low Idle Speed
3	Cylinder Deactivation
4	Electric Accessories
5	Magnesium Alloies Material
6	Oil Pump Controling
7	GDI Lean Burn
8	GDI Stoch
9	Controlled Auto Ignition
10	VVLT
11	VVT(full or intake)
12	Turbo Charging
13	Supper Charging
14	4 V (Multi Valve)
15	VLM (Variable Length Manifold)
16	V-TECH(lift-timing)
17	HCCI
18	Direct Oil Pump

V. CONCLUSION

This paper applies TOPSIS method in finding key strategic technologies from identified technologies from in order to provide appropriate technology strategy**.** Identifying strategic technology is main part of strategy development. Efficient TOPSIS method for determining key strategic technology helps decision maker in decision about strategic technology strategy development.

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