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Selecting Technology Acquisition Strategy through Applying PROMETHEE Method: An Industrial Automation Equipment Manufacturer

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Abstract

Selecting the proper acquisition strategy for needed technologies, is one of the key strategic decisions in formulating technology strategy for a company. There are a number of factors were found to be influential in the selection of technology acquisition strategy. This paper deals with selecting technology acquisition strategy as a multiple criteria decision making (MCDM) problem. The proposed solution to the problem in this paper is the PROMETHEE method. In this paper, after depicting Technology Tree for a given product and selecting a Strategic Technology Unit (STU), PROMETHEE method was employed for selecting the best strategy for acquiring required technology based on several criteria such as: Cost, Time, Learning, Current Capability and Competitive advantage. A case of an industrial automation equipment manufacturer named Geshm Voltage is presented for the illustration of the our proposed approach. The proposed approach is expected to effectively help decision making on which strategy is adopted for acquisition of required technologies.

Keywords:
Technology Strategy, Technology Acquisition, PROMETHEE, Industrial Automation Industry, Qeshm Voltage

Introduction

Effective formulation and implementation of technology strategy has been considered as a major driver for competitive advantage of a company [1,2]. Although much debate is still going on about how to define the scope of technology strategy, from quite specifically focusing on technology development, to very broad knowledge-based definitions [3], what the literature has in common is that technology strategy can be viewed as a process composed of a series of steps requiring strategic decisions and actions, such as acquisition, management and exploitation [4,5,6]. One of the critical strategic decisions in formulating technology strategy is how to acquire the required technology. Technology acquisition concerns whether to acquire technologies through internal development, cooperating with other firms of institutions, or purchasing the technology [7]. A variety of technology acquisition strategies available and the complexity of modern business environments have led the decision to be intractably difficult [8].

Several empirical studies have been conducted to identify key factors affecting the selection of technology acquisition strategy [9,10,11,12]. Various approaches, based on mathematical programming, statistical analysis, or multiple criteria decision making (MCDM) methods have been proposed to aid decisions both prior to and posterior to selection of technology acquisition mode: selection of technologies to be acquired among identified alternatives, such as technology selection [13], R&D project selection [14], and decisions under the selected acquisition mode such as technology supplier selection [15], go/no-go decision of R&D projects [16], identification of core technologies [17,18]. However, very few systematic approaches have been proposed to selection of technology acquisition strategy.

This paper deals with the selection of technology acquisition strategy as a MCDM problem. In MCDM, decision makers evaluate several alternatives using multiple conflicting criteria. The decision environment of selecting technology acquisition strategy constitutes a typical form of the MCDM [8]: selecting the appropriate option among several technology acquisition strategy as alternatives by considering various influential factors as criteria. Among a variety of MCDM methods, PROMETHEE[1] is employed in the proposed approach. In this paper, after depicting Technology Tree for a given product (HMI[2] system), PROMETHEE method was employed in order to select the best strategy for acquiring a Strategic Technology Unit (STU) based on several criteria including: Cost, Time, Learning, Current capability and Competitive advantage. A case of an industrial automation equipment manufacturer named Geshm Voltage is presented for the illustration of the proposed approach. The remainder of this paper is organized as follows: Section 2 reviews the PROMETHEE method steps and its application in previous studies. The proposed approach is explained in Section 3 and illustrated with the case of Qeshm Voltage company in Section 4. The paper ends with conclusions and suggestions in Section 5.

PROMETHEE

PROMETHEE is one of the most popular outranking method introduced by Roy [19]. Also, PROMETHEE is a MCDM method developed by Brans and Vinke [20]. In this method, the intensity of the preference for alternative "a" over alternative "b" with regard to each criterion "j" is measured in terms of a preference function Pj(a, b), which is evaluated based on the generalized criterion for each "j". Brans et al. proposed the following six possible types of generalized criterion [21]:

- *Type I (usual criterion):* It is a basic type without any threshold and very seldom used.
- *Type II (U-shape criterion):* It uses a single indifference threshold, which is generally used with qualitative criteria.
- *Type III (V-shape criterion):* It uses a single preference threshold and often it is used with quantitative criteria.
- *Type IV (level criterion):* It is similar to U-shape but with an additional preference threshold and it is mostly used with qualitative criteria.
- *Type V (V-shape criterion with indifference threshold criterion)*: It is similar to V-shape but with an additional indifference threshold and often used with quantitative criteria.
- *Type VI (Gaussian criterion):* It is seldom used.

In order to define these criterions and evaluate the preference functions, one or two of the following thresholds have to be fixed [22]:

- *Indifference threshold (q).* It is the lowest value of dj(a, b) below which the decision maker considers, there is indifference between "a" and "b".
- *Strict preference threshold (p).* It is the lowest value of dj(a, b) below which the decision maker considers, there is a strict preference of "a" and "b".
- *Standard deviation (s).* It is a well-known parameter directly connected with standard deviation of a normal distribution.

A weighted average of the preference functions is calculated to obtain a rank ordering of the alternatives. "PROMETHEE I" provides a partial pre-ordering of the alternatives through a pair-wise dominance comparison of positive and negative outranking flows, while, "PROMETHEE II" provides a complete pre-ordering through a comparison of net outranking flows [22,23]. Stepwise procedure for PROMTHEE II was presented in Figure 1.

[1] Preference Ranking Organization Method for Enrichment Evaluation
[2] Human Machine Interface

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Step 1. Determination of deviations based on pair-wise comparisons

$$d_j(a,b) = g_j(a) - g_j(b) \qquad (1)$$

Where $d_j(a,b)$ denotes the difference between the evaluations of a and b on each criterion.

Step 2: Application of the preference function

$$P_j(a,b) = F_j[d_j(a,b)] \qquad j=1,\ldots,k \qquad (2)$$

Where $P_j(a,b)$ denotes the preference of alternative a with regard to alternative b on each criterion, as a function of $d_j(a,b)$.

Step 3: Calculation of an overall or global preference index

$$\forall a,b \in A, \qquad \pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j \qquad (3)$$

Where $\pi(a,b)$ of a over b (from 0 to 1) is defined as the weighted sum $p(a,b)$ of for each criterion, and w_j is the weight associated with jth criterion.

Step 4: Calculation of outranking flows/ The PROMETHEE I partial ranking

$$\phi^+(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a,x) \qquad (4) \qquad \text{and} \qquad \phi^-(a) = \frac{1}{n-1} \sum_{x \in A} \pi(x,a) \qquad (5)$$

Where $\phi^+(a)$ and $\phi^-(a)$ denote the positive outranking flow and negative outranking flow for each alternative, respectively.

Step 5: Calculation of net outranking flow/ The PROMETHEE II complete ranking

$$\phi(a) = \phi^+(a) - \phi^-(a) \qquad (6)$$

Where $\phi(a)$ denotes the net outranking flow for each alternative.

Fig 1. Stepwise procedure for PROMTHEE II [23]

A review of literature on PROMETHEE revealed that it has received wide attention and has been applied in diverse areas including: nuclear waste management [24], location selection [25], advanced manufacturing technology [26], water resources planning [27], environmental assessment [28], information system planning [29], Information technology as a national strategy [30], stock trading [31], supplier evaluation and management [32], and selection of lean manufacturing system [22] and lean improvement of the chemical emissions of motor vehicles [33].

The Proposed Approach

This section develops a proposed approach for selection of technology acquisition strategy. The goal of this proposed approach is to select the best option for acquiring the required technology among the alternative strategy. Our proposed approach consist of five steps including (Figure 2): 1-Selecting a product based on company strategy; 2-Depicting Technology Tree for selected product; 3-Selecting a Strategic Technology Unit (STU) as a key component or part of selected product; 4- Establishing decision matrix base on identified alternatives and criteria; 5- Applying PROMETHEE method in order to select best technology acquisition strategy for selected STU.

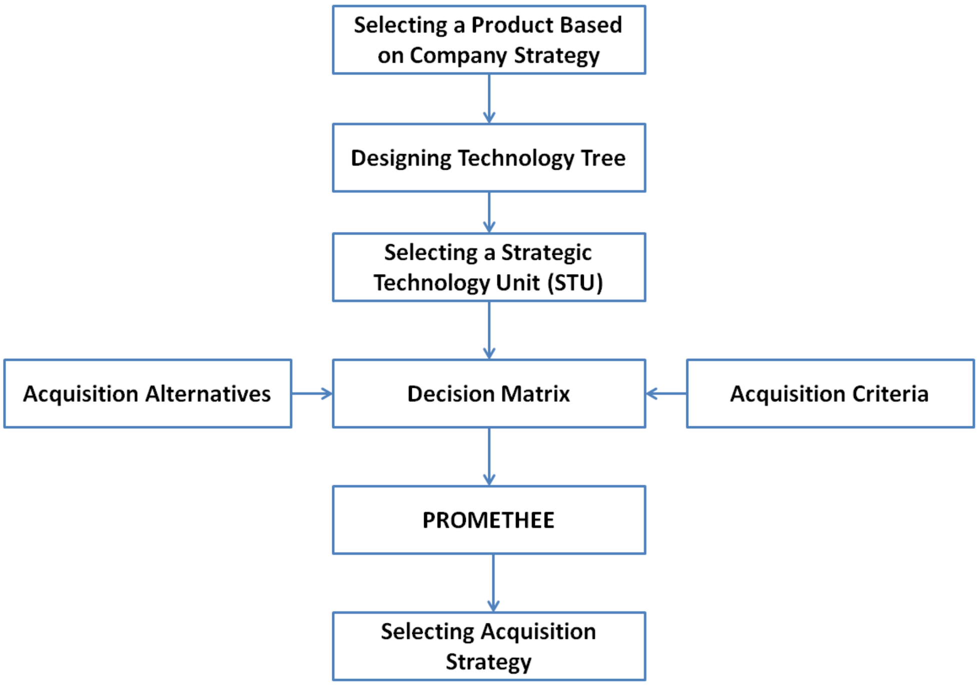


Figure 2. Proposed Approach for Selecting Technology Acquisition Strategy

Case Illustration and Results

The proposed approach was applied to select technology acquisition strategy in an industrial automation equipment manufacturer located in Iran named Qeshm Voltage. Over the last decade, the company has developed and provided a range of industrial automation equipment such as Programable Logic Controller (PLC), Flexible Manufacturing System (FMS) and etc. The company has decided to produce an advanced product named Human Machine Interface (HMI). The problem to be faced is how to acquire required technologies related to some strategic technology unites (STU). In the following, we illustrated all steps of our proposed approach in order to solve above-mentioned problem.

Depicting Technology Tree

Technology tree is a diagram that depicts all technologies, components and their functions in a specific product or system. Technology tree can help to making efficient and effective technology related decisions through facilitating the process of identifying and selecting key technologies [34]. Technology tree for HMI system was presented in Figure 3.

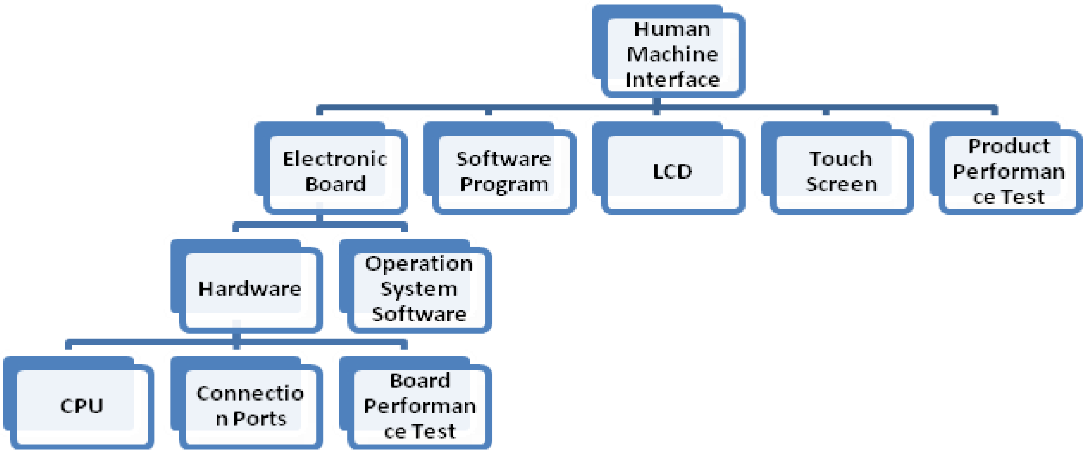


Figure 3. Technology Tree for HMI System

Selecting Strategic Technology Unit (STU)

At first, STU was defined as the technologies embodied in a certain product and its production process by Hax and Majluf [35], but later it was considered as the skills and disciplines that are applied to the firm's products and processes in order to gain technological advantages [36]. In other words, STU is a key and critical technology in a given product or system. In our case and based on company's managers and specialists opinion, Operation System Software (OSS) was selected as a STU. In the following, all steps required for selecting technology acquisition strategy for OSS are explained.

Decision Matrix

In order to establishing a decision matrix, several alternatives and criteria have to be identified based on the main problem. In general, a number of technology acquisition strategy are available, such as [7]:

- *Acquisition* (a company acquires another company in order to access a technology of interest)
- *Merger* (a company merges with another one that possesses a technology of interest, and a new company emerges from the two existing companies)
- *Licensing* (a company acquires a license for a specific technology
- *Joint venture* (a company establishes a formal joint venture with equity involvement and a third corporation is created, with a definite objective of technological innovation)
- *Joint R&D* (a company agrees with others to jointly carry out research and development on a definite technology, with no equity involvement)
- *R&D contract* (a company agrees to fund cost of R&D at a research institute or university or small innovative firm, for a definite technology)
- *Alliance* (a company shares technological resources with other companies in order to achieve a common objective of technological innovation without equity involvement),
- *Consortium* (several companies and public institutions join their efforts in order to achieve a common objective of technological innovation without equity involvement)
- *Outsourcing* (a company externalizes technological activities and then, simply acquires the relative output)
- *Networking* (a company establishes a network of relationship, in order to keep the pace in a technological discipline and to capture technological opportunities and evolutionary trends)
- *In-house R&D* (internal efforts done by company in order to acquire needed technology with company’s budget and man powers)

In this paper we have considered three broad categories of the technology acquisition strategy as the alternatives of our proposed approach: Research and Development, Collaboration, and Purchasing. Also, the literature review was conducted to identify factors that need to be considered when evaluating the appropriateness of the acquisition strategy. Some Factors affecting the selection of technology acquisition strategy include: Research and development resources [37], Research and development manpower [10], Research and development experience [38,39], Acquisition urgency [4], Importance to a firm [39,40], Technology life cycle [41,42], Development cost [43], Easiness to imitate [44], Market size [45], Competitive intensity [37,39], Availability of external source and Quality of external technology [11].
In this paper, we have selected five main criteria including: Cost [43], Time [6], Learning [36], Current capability [10] and Competitive advantage [37]. Some of these criteria are quantitative like cost and time, while some of them are qualitative such as learning, current capability and competitive advantage. In addition, the mentioned criteria were classified in two categories including: direct (performance grows while measure increases) and indirect (performance grows while measure decreases). The decision matrix for our problem is shown in Table 1.

Table 1. Decision Matrix

		Decision Criteria				
		Cost (Indirect/ Quantitative)	**Time (Indirect/ Quantitative)**	**Learning (Direct/ Qualitative)**	**Current Capability (Direct/ Qualitative)**	Competitive Advantages (Direct/ Qualitative)
Alternatives	**Research & Development**	500,000 $	24 Mounts	5	2	5
	Collaboration	250,000$	12 Mounts	3	4	3
	Purchasing	1,000,000 $	6 Mounts	1	5	1

Applying PROMETHEE Method

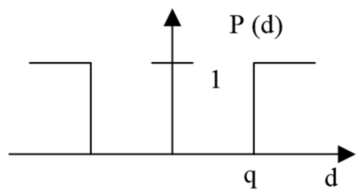
In the following, PROMETHEE method steps are explained.

Choosing Proper Preference Function

We chose V-shape preference function for cost and time as quantitative criteria, and U-shape preference function for learning, current capability and competitive advantage as qualitative criteria based on the guideline proposed by Routroy and Kodali [46]. U-shape and V-shape preference function are shown in Figure 4.

Type II: U-shape criterion

$$P(d)=\begin{cases}0 & |d|\le q\\ 1 & |d|>q\end{cases}$$



Type III: V-shape criterion

$$P(d)=\begin{cases}\dfrac{|d|}{p} & |d|\le p\\ 1 & |d|>p\end{cases}$$

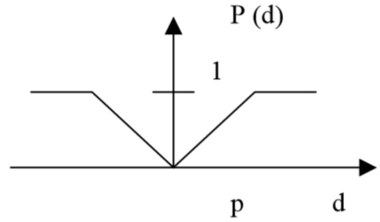


Figure 4. U-shape and V-shape Preference Function

Calculating the Preference Index

The preference index is defined as equation 1 [22]:

$$\pi(Ai, Ai') = \sum_{j} wjPj(Ai, Ai') \quad Equation\ 1$$
$$i = 1,2,\dots,m\,;\,j = 1,2,\dots,n$$

Where, Wj refers to the weight assigned to the criterion j and Pj(A1,A2) is represented as Pj[dj(A1,A2)]. Where, Pj(A1,A2) refers to the value of the preference function according to the difference between the evaluations of the alternatives A1 and A2 on the criterion j, where dj(A1,A2)=gj(A1)-gj(A2). Preference Value of Each Alternative in Comparison to Other Alternatives are shown in Table 2. π (A1,A2) represents the intensity of preference of the decision maker of alternative A1 over action A2, when considering simultaneously all the criteria. It is a figure between 0 and 1 and:

- π(A1,A2)=0 denotes a weak preference of a1 over a2
- π(A1,A2)=1 denotes a strong preference of a1 over a2

Table 2. Preference Value of Each Alternative in Comparison to Other Alternatives

Criterion C1	**Criterion C2**	**Criterion C3**	**Criterion C4**	**Criterion C5**
V-Shape Preference Function	**V-Shape Preference Function**	**V-Shape Preference Function**	**V-Shape Preference Function**	**V-Shape Preference Function**
A1=24 A2=12 P1(A1,A2)=1/2 P1(A2,A1)=1	A1=500,000 A2=250,000 P2(A1,A2)=1/2 P2(A2,A1)=1	A1=5 A2=3 P3(A1,A2)=0 P3(A2,A1)=0	A1=2 A2=4 P4(A1,A2)=0 P4(A2,A1)=0	A1=5 A2=3 P5(A1,A2)=0 P5(A2,A1)=0
A1=24 A3=6 P1(A1,A3)=3/4 P1(A3,A1)=1	A1=500,000 A3=1,000,000 P2(A1,A3)=1 P2(A3,A1)=1/2	A1=5 A3=1 P3(A1,A3)=1 P3(A3,A1)=0	A1=2 A3=5 P4(A1,A3)=0 P4(A3,A1)=1	A1=5 A3=1 P5(A1,A3)=1 P5(A3,A1)=0
A2=12 A3=6 P1(A2,A3)=1/2 P1(A3,A2)=1	A2=250,000 A3=1,000,000 P2(A2,A3)=1 P2(A3,A2)=3/4	A2=3 A3=1 P3(A2,A3)=1 P3(A3,A2)=0	A2=4 A3=5 P4(A2,A3)=0 P4(A3,A2)=0	A2=3 A3=1 P5(A2,A3)=1 P5(A3,A2)=0

for all criteria The preference index for each alternative was calculated and shown in below. We chose same weight (0.2) for all criteria.

$$\pi(A1,A2)=0.2(0.5+0.5+0+0+0)=0.2$$

$$\pi(A1,A3)=0.2(0.75+1+1+0+1)=0.75$$

$$\pi(A2,A1)=0.2(1+1+0+0+0)=0.4$$

$$\pi(A2,A3)=0.2(0.5+1+1+0+1)=0.75$$

$$\pi(A3,A1)=0.2(1+0.5+0+1+0)=0.5$$

$$\pi(A3,A2)=0.2(1+0.75+0+0+0)=0.35$$

Computing Positive and Negative Outranking Flows

Positive (where alternative is dominating) and negative (where alternative is dominant) outranking flows for each alternative were computed according to equations 2 and 3 [22]. Positive and Negative Outranking Flows are shown in table 3.

$$\varphi+(Ai)=\frac{1}{m-1}\sum_{Ai\in A}\pi(Ai,Ai')\quad i=1,2,\dots,m\,;\,i'=1,2,\dots,m \qquad \text{Equation 2}$$

$$\varphi-(Ai)=\frac{1}{m-1}\sum_{Ai\in A}\pi(Ai',Ai)\quad i=1,2,\dots,m\,;\,i'=1,2,\dots,m \qquad \text{Equation 3}$$

Table 3. Positive and Negative Outranking Flows

	A1	A2	A3	ø+
A1	-	0.2	0.75	**0.475**
A2	0.4	-	0.75	**0.575**
A3	0.75	0.35	-	**0.55**
ø-	0.575	0.275	0.75	

Computing the Net Flow

Net flow for each alternative can be computed by equation 4 [22]. The higher the leaving flow and the lower the entering flow, the better the alternative. The net flow for each alternative was computed and shown in below.

$$\varphi(Ai) = \varphi + (Ai) - \varphi - (Ai) \quad Equation\ 4$$

ø(A1) = 0.475 – 0.575 = -0.1

ø(A2) = 0.575 – 0.275 = 0.3

ø(A3) = 0.55 – 0.75 = -0.2

Selecting Acquisition Strategy

Based on the results obtained from net flow of all alternatives, it's clear that Technological Collaboration, Research and Development and Purchasing have priority as technology acquisition strategy respectively. Considering the Figure 5, it can be concluded that Technological Collaboration is the best strategy for acquiring OSS technology.

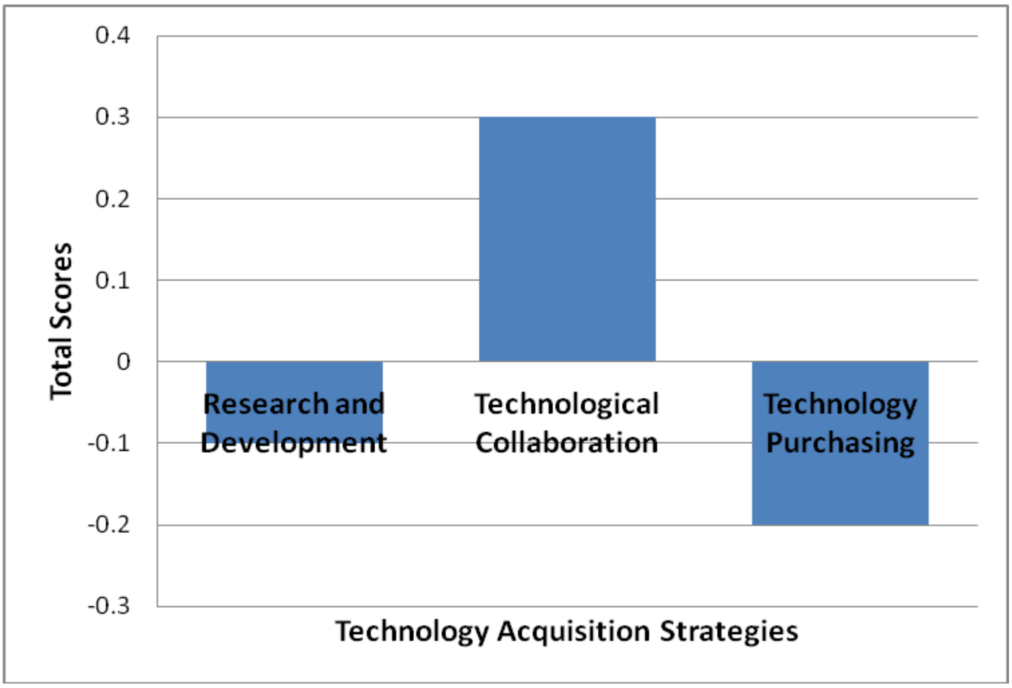


Figure 5. Net Flow of Each Alternative (Technology Acquisition Strategy)

Conclusion

This paper started with the following questions: how the managers or executives of a company have made a decision about technology acquisition strategy? What factors are influential on making such decision? Which alternatives are available in this kind of decision making process? What decision-making methodology the managers can used to make such decisions? A detailed step-by-step approach was presented in this paper including: 1) Selecting a product based on company strategy; 2) Depicting technology tree for selected product; 3) Selecting a strategic technology unit (STU) as a key component or part of selected product; 4) Establishing decision matrix base on identified alternatives and criteria; 5) Applying PROMETHEE method in order to select best technology acquisition strategy for selected STU. The proposed approach evaluates the appropriateness of alternative strategy for technology acquisition (Research and Development, Collaboration and Purchasing), in terms of Cost, Time, Learning, Current capability and Competitive advantage. The case of an industrial automation equipment manufacturer was presented for the illustration of the proposed approach. In current paper based on employing a proposed approach, we found that collaboration is the best strategy for acquiring OSS technology as a strategic technology unit embedded in HMI system. Also, it was shown that the PROMETHEE was successfully employed for producing the priorities of the alternative strategy. It is advisable to employ PROMETHEE method in order to select key technologies embedded in a product or process. In addition, future researches can apply this method in order to select best strategy among collaboration strategy like joint R&D, alliances, joint venture, consortium and etc.

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