# Comparison of training methods based on Merrill's Principles and ELECTRE 1

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# Abstract

Several studies state that competitiveness of international markets and the speed of technological evolution require companies to master and transfer their knowledge for greater performance and flexibility. Organizational performance often depends more on an ability to turn knowledge into effective action and less on knowledge itself (Alavi and Leidner 2001). This can result from good or bad choice concerning Knowledge Management tools. In this article, we focus on training as a frequently used knowledge management tool and propose a decision aid model for comparing training methods and choosing the most adequate one for each situation. Multi-criteria decision support methods have been in widespread use for a long time. The model, presented herein, is based on a combination of ELECTRE 1 method and the First Principles developed by Merrill in 2002. An application to industrial cases supports how this model can be useful for companies looking for more efficiency. Two types of training are studied and concerned consecutively Tacit and Explicit Knowledge.

**Keywords :** ELECTRE 1; Merrill's First Principles; Knowledge Management; MCDA; Training, Training methods

# **1. Introduction**

Nowadays global companies are experiencing a context of competitiveness never known before. With globalization and internationalization, cost optimization is a survival issue. At the same time, companies need more and more efficient human resources, which explains the maintenance of training and development investment budgets but with more expectations in terms of efficiency. In order to ensure the successful completion of a training action, it is necessary to focus on the analysis of the need but also the evaluation and the detailed comparison of the alternatives opened after this analysis. A good decision is money saved and a guarantee of efficiency.

In this article we propose a model to compare between several training methods based on the multi-criteria decision aid method and using criterion from Merrill's First Principles. In the following section, we will review the place of training in business development. We will then give an overview of the Merrill's model of training evaluation. Section 4 will present the ELECTRE 1 outranking method, and we propose, in the last part, two applications of our framework to two types of training that mobilized tacit knowledge for the first one and explicit knowledge for the second. Both cases are studied with multinational industrial companies based in Morocco, but the model is applicable to all sectors and to all types of training.

# 2. Training as a performance lever

# 1.1 Training and business performance

Training is a very old concept whose usefulness is no longer questionable today. So many studies focused on the impact of the training on the business performance. It's now proven that competitiveness and survival of companies depends on the development of their people and consequently on the effectiveness of training process (Alvarez et al. 2004). Even if the training return on investment is still difficult to assess, researchers and practitioners agree that it's

an essential tool to fill the gap between available and needed skills (Aragón-Sánchez et al. 2003) (Ward Peter T. et al. 2007).

If well-used, training aims to serve the company's performance through its contribution in several processes, Knowledge Management (Rahman et al. 2013) (Alavi and Leidner 2001). Quality Management (Saraph Jayant V. et al. 2007)(Monden 2011) (Deming 2000), Corporate Social Responsibility ("Corporate Social Opportunity! | Seven Steps to Make Corporate Social Responsibility Work for your Business | Taylor & Francis Group" 2004), Human Resources Development (Bartel Ann P. 2008) (Raghuram 1994) and certainly others.

Although training is a highly studied and experienced subject, it is still not mastered and continues to be among the issues of HR professionals. Deloitte's Human Capital Trends survey, which asks annually more than 10,000 business and HR leaders from 140 countries about their HR issues, reveals that since 2015 learning is in the top 5 of HR trends and obviously there is a real capability gap. In 2015, 74% of respondents admit the high importance of learning and development but they feel ready to handle it only at 46% which is three times worse than 2014's rate ("Global Human Capital Trends 2015" 2015; "Introduction—The new organization" 2016; Walsh and Volini 2017). It's now urgent for companies to develop and transform their learning and training strategies for efficient results (Walsh and Volini 2017).

## **1.2 Training evaluation and challenges**

Companies invest important budget in training the employees but fail to draw the full potential of the learned knowledge (Rahman et al. 2013), that's "because not all the knowledge obtained from the training is properly transferred and applied to the organization" (Rahman et al. 2013). In fact, Training transfer "generally refers to the use of trained knowledge and skill back on the job" (Burke and Hutchins 2007) (Baldwin Timothy T. and Ford J. Kevin 2006). Lisa A. et al (2007) (Burke and Hutchins 2007) studied 170 articles and identifies three primary factors influencing training transfer: learning characteristics, intervention design and delivery, and work environment influences (Alvarez et al. 2004) (Baldwin Timothy T. and Ford J. Kevin 2006) (Ford J. Kevin and Weissbein Daniel A. 2008) (Cannon-Bowers Janis A. et al. 2006).

The fact is that the three factors depends on subjects' witch are still under study. Neurosciences and cognitive psychology have not finished digging brain's and personality mysteries; information and new technologies develops every day new solutions for learning and education systems; organizations and work environments are changing for more agility regarding to the specifications of new employee generations and globalization conditions. We can conclude that training transfer is a variable in the permanent search for balance and depends on variables in continuous evolution

Training can succeed if the process is well executed in all its stages: previous analysis of training needs, development and implementation of an adequate training plan and evaluation (Cheng and Ho 2001).

Over its rule in measuring the ROI (Return In Investment), evaluation is very important to improve the process and have more data to success the future decisions (Beywl and Speer 2004). It was developed by many researchers on different models and frameworks ((Kirkpatrick 1975); (Phillips 1997); (Hamblin 1974); ("Determining a Strategy for Evaluating Training" 1992); (Kaufman Roger and Keller John M. 2006); ("The flawed four-level evaluation model - Holton - 1996 - Human Resource Development Quarterly - Wiley Online Library" 1996)). This experimental form to evaluate training, is unavoidable but remains insufficient when companies face a dilemma whether to invest in learning despite of its deficiency (Burke and Hutchins 2007). (Walker 1965) argued that "training requirements became progressively more complex" and "the choice of training techniques required a serious analysis of the various alternatives". (Aragón-Sánchez et al. 2003) analyzed the data from 457 European SME's and concluded that "different types of training have different impacts on the results obtained by the company (in terms of both effectiveness and profitability)". Faced to significantly more numerous training methods, the decision should be well thought out and scientifically sound regarding to adequate criteria (Walker 1965).

## 3. Merrill's first principles model

While analyzing over 400 impact studies to identify training and development failure reasons, (Phillips and Phillips 2002) suggest that, when designing a training, the application and impact should be considered with as much interest as learning. Referring to this study and many others in the literature, (Villachica et al. 2011) have identified 5 good practices for successful training strategy and recommended at the 3rd point to use the Merrill's model to create sound training programs.

Merrill's First Principles of instruction is the most used and cited model in the literature since 2002. It is an instructional theory based on a broad review of many instructional models and theories (Reigeluth 1983) (McCarthy

and Germain 1996) (Illeris 2009 pp. 106–115) (Reigeluth 1983 pp. 240–268) (Reigeluth 1983 p. 161-181) (Reigeluth 1983 p. 225-239).

Merrill's principles, described in Table 1, consist of four phases centered on the problem: activation, demonstration, application and integration. Merrill considers the principle is 'always true under appropriate conditions regardless of program or practice' (Merrill 2002).

These principles are relevant to use as criteria to evaluate the effectiveness of a training modality or to compare several of them. Betty Collis and Anoush Margaryan developped a model Merrill+criteria for guiding the design and evaluation of courses emphasizing work-based activities and the blend of formal and informal learning ("Design criteria for work-based learning" 2005). Jieun Lee also based his analysis on Merrill's principles for investigating training design factors that facilitated and hindered transfer in a blended training context. Moreover, the author provides an interesting distribution of Design factors for transfer for each phase of the principles (Lee 2010).

Merrill's principles are relevant because they integrate a large part of the models developed in the literature two decades before, and also the four pillars of learning advocated by psychologist Stanislas Dehaene: attention, active engagement, feedback and consolidation (Dehaene 2012).

Our proposal is to use the corollaries of the principles as basic criteria and to supplement them, if necessary, by additional criteria according to the specificities of the case under consideration.

Principle	Description	Corollary	Description		
Principle 1— Problem- centered	Learning is promoted when learners are engaged in solving real-world problems.	Show task	Learning is promoted when learners are <b>shown the task</b> that they will be able to do or the problem they will be able to solve as a result of completing a module or course.		
		Task level	Learning is promoted when learners <b>are engaged</b> at the problem or task level, not just the operation or action level.		
		Problem progression	Learning is promoted when learners solve a <b>progression of problems</b> that are explicitly compared to one another.		
Principle 2— Activation	Learning is promoted when relevant previous experience is activated.	Previous experience	Learning is promoted when learners are directed to recall, relate, describe, or apply knowledge from <b>relevant past experience</b> that can be used as a foundation for the new knowledge		
		New experience	Learning is promoted when learners are provided relevant experience that can be used as a foundation for the new knowledge.		
		Structure	Learning is promoted when learners are provided or encouraged to recall a structure that can be used to organize the new knowledge.		
Principle 3— Demonstration (Show me)	Learning is promoted when the instruction demonstrates what is to be learned rather than merely telling information about what is to be learned	Demonstrati on consistency	Learning is promoted when the demonstration is consistent with the learning goal: (a) examples and nonexamples for concepts, (b) demonstrations for procedures, (c) visualizations for processes, and (d) modeling for behavior.		
		Learner guidance	Learning is promoted when learners are provided appropriate learner guidance including some of the following: (a) learners are directed to relevant information, (b) multiple representations are used for the demonstrations, or (c) multiple demonstrations are explicitly compared.		
		Relevant media	Learning is promoted when media play a relevant instructional role and multiple forms of media do not compete for the attention of the learner.		
Principle 4— Application (Let me)	Learning is promoted when learners are required to use their new knowledge or skill to solve problems	Practice consistency	Learning is promoted when the application (practice) and the posttest are consistent with the stated or implied objectives: (a) information-about practice—recall or recognize information, (b) parts-of practice—locate, and name or describe each part, (c) kinds-of practice— identify new examples of each kind, (d) how to practice—do the procedure and (e) what-happens practice—predict a consequence of a process given conditions, or find faulted conditions given an unexpected consequence		
		Diminishing coaching	Learning is promoted when learners are guided in their problem solving by appropriate feedback and coaching, including error detection and correction, and when this coaching is gradually withdrawn.		
		Varied problems	Learning is promoted when learners are required to solve a sequence of varied problems		
Principle 5— Integration	Learning is promoted when learners are encouraged to integrate (transfer) the new knowledge or skill into their everyday life.	Watch me	Learning is promoted when learners are given an opportunity to publicly demonstrate their new knowledge or skill.		
		Reflection	Learning is promoted when learners can reflect on, discuss, and defend their new knowledge or skill.		
		Creation	Learning is promoted when learners can create, invent, and explore new and personal ways to use their new knowledge or skill		

Table 1. Merrill's First Principles with their corollaries

# 4. Multi Criteria Aid Decision with ELECTRE 1

Multiple-criteria decision-making (MCDM) or multiple-criteria decision analysis (MCDA) is a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision making. Many methods are proposed by literature (Mena 2000). From the study of (Schärlig 1985), (Figueira et al. 2016), (Figueira et al. 2013), (Guitouni and Martel 1998), (Mareschal et al. 2008), the most suitable method for our investigation is ELECTRE I.

The ELECTRE 1 method was developed in 1968 by Bernard Roy (Roy 1968a). It is the first in a series of methods whose acronym stands for Elicitation and Choice Translating Reality (Figueira et al. 2016). It is a partial aggregation method which consists of construction of performance comparison relationships for each pair of solutions. Unlike conventional optimization methods which formulate the problem in the form of a cost function and seek its optimum (Lesourne 2000), here we compare the solutions 2 by 2, criteria by criterion thus putting forward a preference/indifference of a response to another and resulting in an upgrade matrix. This method has the advantage of accepting situations of incomparability with sometimes qualitative and incommensurable criteria (Maystre et al. 1994a).

The ELECTRE method respects the following steps:

## 4.1 Definition of potential actions

This step consists in selecting a subset, as small as possible, of alternatives  $A_i$ , i=1...n; considered very close to the solution. These Alternatives or actions will be analyzed, evaluated and compared with other actions during the decision process.

### **4.2** Construction of criteria

A criterion is a function  $g_j$ , j=1...m, defined on the set of potential actions in such a way that it is possible to reason or describe the result of the comparison of two actions  $A_1$  and  $A_2$  from g ( $A_1$ ) and g ( $A_2$ ) in the following way:

$$g(A_1) \ge g(A_2) \Longrightarrow A_1 S A_2$$

Where  $A_1 S A_2$  means that "  $A_1$  is at least as good as  $A_2$ ", here g is a criterion to be maximized. This phase is the most important and decisive of the method. The choice of criteria must be based on the following three axioms:

#### a. Completeness:

gj (A1) = gj (A2), 
$$\forall j =>$$
 No preference between A1 and A2

Do not forget a decisive criteria and avoid putting too much at risk of obtaining an analysis that is too complex.

#### b. Consistency:

$$gj (A1) = gj (A2), \forall j \neq k$$
  

$$g_k (A_1) = g_k (A_2)$$

$$\implies A1 \text{ is preferred to } A2$$

If there is still a hesitation between A1 and A2, it is because the criteria of the family were not built coherently.

#### c. Non-redundancy:

Deleting a criterion results in a postponement involved one of the two previous axioms. Each action is judged according to each criterion. All assessments can be presented in a double-entry table, called a performance matrix

### 4.3 Determination of preference and indifference thresholds

ELECTRE methods have the advantage of considering the hesitations and preferences of the decision maker. This is reflected through the thresholds of preference  $p(g_j)$  and indifference  $q(g_j)$ . Between the two thresholds exists an ambiguity zone in which the decision maker hesitates between indifference and the preference.

Where:

- P is a preference relation;
- Q is a law preference relation that reflects a hesitation between preference and indifference;
- I is an indifference relation.

## 4.4 Attribution of weights

For a given criterion, the weight, wj, reflects its relative importance relative to the other criteria, which may give more or less favor in the upgrade process. The weights do not depend on the rating scales and is different from veto thresholds (used in the version ELECTRE Iv) (Figueira et al. 2016).

#### 4.5 Construction of the concordance and discordance matrices:

The construction of an outranking relation is based on two major concepts:

- **a.** Concordance: "For an outranking A<sub>1</sub>SA<sub>2</sub> to be validated, a sufficient majority of criteria should be in favor of this assertion" (Figueira et al. 2016).
- **b.** Non-discordance: "When the concordance condition holds, none of the criteria in the minority should oppose too strongly to the assertion A<sub>1</sub>SA<sub>2</sub>" (Figueira et al. 2016).

Assertion aSb is valid only when both conditions are true.

Concordance/Discordance matrices are composed of the set of concordance/discordance indices computed from the comparison of every pair of different alternatives in the set A.

Concordance Index is calculated as following:

$$C(A_1 A_2) = \frac{\sum_{j \in J} g_j(A_1) \ge g_j(A_2) w_j}{\sum_{j \in J} w_j}$$

Where J is the set of the indices of the criteria and  $\{j : g_j(A_1) \ge g_j(A_2)\}$  is the set of indices for all the criteria belonging to the concordant coalition with the outranking relation A<sub>1</sub>SA<sub>2</sub>.

Discordance Index is calculated as following:

$$D(A_1, A_2) = \frac{\max_{j:g_j(A_1) < g_j(A_2)} \{g_j(A_2) - g_j(A_1)\}}{\delta}$$

Where  $\delta$  is the maximum difference between 2 actions given for the same criterion.

### 4.6 Construction of the outranking matrix:

The outranking matrix depends on the concordance and discordance thresholds.

The concordance threshold (c) is the parameter that will judge whether the concordance with the outranking hypothesis is strong enough to admit that it is true. This threshold "expresses the minimum concordance required for the hypothesis "  $A_1$  outranks  $A_2$  " not to be rejected" (Maystre et al. 1994b).

The concordance test is therefore completed when:

$$C(A_1, A_2) \ge c$$

The discordance threshold (d) has the same function as the concordance threshold. It "expresses the maximum of tolerated discordance so that the hypothesis "  $A_1$  outranks  $A_2$  " is not rejected" (Maystre et al. 1994b). Discordance test is validated if:

$$D\left(A_1,\,A_2\right)\,\leq d$$

The two thresholds are between 0 and 1 and can be set freely by the decision maker. But, it is clear that values of  $c \le 0.5$  and  $d \ge 0.5$  do not make sense.

The outranking relationship is therefore true if and only if the following 2 conditions are satisfied:

$$A_1 S A_2 \iff \begin{cases} C(A_1, A_2) \ge c \\ D(A_1, A_2) \le d \end{cases}$$

Thus, after calculating all the indices, only one option will be possible for each pair of alternatives (Figueira et al. 2016):

- A<sub>1</sub>SA<sub>2</sub> and not A<sub>2</sub>SA<sub>1</sub>, i.e., A<sub>1</sub>PA<sub>2</sub> (A<sub>1</sub> is strictly preferred to A<sub>2</sub>).
- A<sub>2</sub>SA<sub>1</sub> and not A<sub>1</sub>SA<sub>2</sub>, i.e., A<sub>2</sub>PA<sub>1</sub> (A<sub>2</sub> is strictly preferred to A<sub>1</sub>).
- A<sub>1</sub>SA<sub>2</sub> and A<sub>2</sub>SA<sub>1</sub>, i.e., A<sub>1</sub>IA<sub>2</sub> (A<sub>1</sub> is indifferent to A<sub>2</sub>).
- Not  $A_1SA_2$  and not  $A_2SA_1$ , i.e.,  $A_1RA_2$  ( $A_1$  is incomparable to  $A_2$ ).

ELECTRE I method proposes a graphical representation of the outranking relations. It allows to visualize the kernel defining the best alternatives. More details concerning the exploitation principles are available in the following literature (Maystre et al. 1994a) (Lenca 2004) (Mena 2000) (Roy et al. 1986) (Roy 1968b) (Figueira et al. 2016) (Maystre et al. 1994b).

## 5. Application to two training cases in industrial environments

We decide to apply our model of training methods comparison to two cases of training both in Moroccan industrial companies. The model is obviously applicable to all sectors and types of training. More applications to other sectors could be developed to support the model proposed.

First application concerns training of new assemblers to the execution of operations in an aeronautic industry. Manual assembly operations rely heavily on the expertise developed by assemblers over the practice. Experience is then a key factor of their performance. But in a globalization and internationalization context, companies must develop competent and efficient resources within very tight deadlines. The development of skills essentially involves training as a knowledge management tool. The knowledge concerned for assembly tasks falls largely in the category of tacit knowledge. The type and method of training chosen must then take into consideration the nature of this knowledge and promote its acquisition.

Second application is very different from the first one regarding to the nature of knowledge concerned. In fact, the content of this second action is mainly an explicit knowledge and can be formalized and transferred under several forms. Indeed, we propose to help a Multinational food company based in Morocco to choose the best method to train its quality staff on the new version of ISO 9001:2015 Standard.

### 5.1 Technical training: task work in aeronautic industry

We consider the case of a Moroccan company specialized in the assembly of components of airliners. The company is currently preparing the launch of a new assembly line and is in the process of finalizing a training plan for new assemblers assigned to this line. This line is a duplicate of an existing line in another country site. Following a training engineering, several training modalities are proposed. The issue of training that will be provided to employees is critical. In this field, the parts handled by assemblers are very expensive. Production delivery times are generally managed by just-in-time. Indeed, an unsuccessful learning increases the risk of error on the operations carried out and can lead to great financial losses as well as a disruption of several hours, days or even weeks in the overall production chain.

We will apply the steps of ELECTRE 1 to identify the most appropriate method for our case.

### a. Definition of potential actions and criteria

The main objective of the training is to deliver assemblers as efficient as the senior ones from the first production unit. A detailed analysis of the educational objectives guided us to several methods of training. Each one has its own advantages and disadvantages. We will call "A" the set of possible alternatives composed of:

A1: vestibule training for all new assemblers

A2: Individual coaching or tutoring by experienced assemblers in another site during the production of 2 or 3 units

A3: Online training including demonstration videos and instructions + Simulators for the practical part of training

A4: Blended: Instructor-Led Training including demonstration videos and instructions + On-The-Job Training with an expert coaching for the execution of the first three production units

**A5:** Blended: Instructor-Led Training including demonstration videos and instructions + On-The-Job Training with Technology-Based Learning using mixed reality (HoloLens for assembly assistance) during the production of 3 units + Mentoring by an expert.

To compare the relevance of these actions, our criteria are the fifteenth corollaries of Merrill's Principles explained in the section 3 of the article. It should be recalled that these criteria can be enriched by others depending on the particularities of each situation.

#### b. Modelization and result exploitation:

A consultation with the training manager and the Operations Manager allowed to carefully evaluate weights and preference and indifference thresholds; and then to assess the alternatives regarding to the fifteen criteria. The treatment of the performance matrix leads to the following concordance and discordance matrices:

Table 2. Global Concordance Matrix									
	A1	A2	A3	A4	A5				
A1	1	1	1	1	0,95				
A2	0,29	1	0,19	0,56	0,33				
A3	1	1	1	1	0,95				
A4	0,73	1	0,63	1	0,75				
A5	0,88	1	0,88	1	1				

Table 3. Global Discordance Matrix								
	A1	A2	A3	A4	A5			
A1	0	0	0,6	0,2	0,42			
A2	1	0	1	1	1			
A3	0	0	0	0	0,28			
A4	0,8	0,125	0,8	0	1			
A5	0,85	0	0,85	0,2	0			

We consider concordance and discordance thresholds as following



Figure 1. Outranking graph

### c. Results analysis:

Many values of concordance and discordance thresholds were experimented and it always brings out the same result of kernel. The outranking graph "Fig. 1," shows that the actions  $A_5$  and  $A_4$  stand out as good alternatives but still incomparable. The company chooses the solution  $A_4$  for this transfer and is studying the possibility of implementing the solution A<sub>5</sub> for the transfer that will follow.

## 5.2 Procedural training: standard revision in food company

In order to support the usefulness of our model, we propose to help a Multinational food company based in Morocco to choose the best method to train its quality staff on the new version of ISO 9001:2015 Standard.

This second case is very different from the first one regarding to the nature of knowledge concerned. In fact, the content of this second action is mainly an explicit knowledge and can be formalized and transferred under several forms.

The analyze is still under process. We will present the results once they are validated with the company's managers.

## 6. Conclusion

The training function meets more and more challenges and must be performant from the conception to the execution, the multi-criteria decision support method is an effective tool to help decision-makers to make rational and justified choices of training methods and techniques.

This article proposes a model to compare training methods before engaging the investment. The Model is a combination of ELECTRE 1 method and Merrill's First Principles.

The case studied, in section 5, gives a demonstration on the contributions of this new model as well as the interest of its use in the companies in search of performance. The second case will bring a better understanding of the tool.

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