

A COMPUTERIZED TECHNOLOGY TRANSFER MODEL AND ITS APPLICATION TO PAINTING SYSTEMS TECHNOLOGY

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Abstract

This research presents a new model for technology transfer. The model is programmed using VISUAL BASIC. It has capabilities of calculating the need for a new technology, comparing behavior of candidate technologies at their original sources, estimating performance after transferring through calculation of the transfer index, and finally recommending a technology to be transferred. The program was implemented at ABB Arab (a leading company in Egypt) for transferring electrostatic painting technology. The implementation of the developed model at ABB Arab Company revealed that quality level and production rate have the highest priority over all other measures. The flexibility of the existing technology in terms of variety in size and color that can be used was the lowest measure, whereas environmental impact ranked as the fourth measure. Other results showed that, the technical aspects have the highest priority over the economic aspects. Based on pairwise comparisons, quality of the technology has the highest weight, followed by efficiency and productivity. The measures with lowest priority are innovation and environmental responsibility.

Keywords: computerized model, developing nations, painting technology, technology transfer.

Introduction

The current research describes a new technology transfer (TT) for engineering industries. The new model is composed of four main stages. During the first stage the need for the technology at destination (current of existing technology evaluation stage) is defined. In the second stage, the "Total Performance Index" (TPI) is calculated to assess candidate technology at the source. In the third stage, the "Ability to Transfer Index" (ATI) is estimated. Then the results of the second and third stages are combined to obtain the recommended technology to transfer (the fourth stage). A computerized model was built using VISUAL BASIC as modules. These modules correspond to the fourth stage of the new model.

Application Case

This section provides a general overview of the operation at ABB Arab (a leading company in Egypt), where the study was conducted. This company that specializes in electrical manufacturing was selected to test the applicability of the (TT) model.

ABB Arab was the first ABB manufacturing company established in the Middle East in 1979. The activities of the company include: manufacturing, machinery construction, service of low and medium voltage electrical switchgears and control boards up to 36KV, transformer kiosks, and a variety of electrical equipment and components. Currently the factory is located in the 10th of Ramadan City in Egypt over an area of 62,000 m² having more than 1,100 employees (ABB Arab Company Profile, 2002).

The main focus of this application is on the painting system technology. Three electrostatic painting lines for pre-treatment and powder coating of iron and steel (2.5 million m²/year and 310 tons of powder paint/year) undertake two functions:

- (1) Zinc Phosphating: pre-treatment (8 stages) of outdoor products in Chemicals, Industrial zones and Coastal areas. The traditional spray pre-treatment in which the item passes through a tunnel and is sprayed with chemicals in a continuous process, operates with no water waste.
- (2) Powder Coating: with 70~100 micron pure electrostatic polyester powder coating for protection against corrosion and weather resistance. The maximum dimensions of parts that can be coated in the system are: length 2800 mm, width 1000 mm, and height 1400 mm.

Application Data Collection

This research requires two different types of data, expert-based judgments data (that have been collected through experts in the field of study) and archival data (the data exist in the records of the company). A detailed analysis of the computerized TT model processing is presented and discussed in later sections.

Expert-Based Judgments Data. These data were collected through data collection sheets. These sheets have three different parts, corresponding to the first three stages of the developed TT model. These data

were based on expert opinion in the field of painting technology and technology management. The questions were designed in the form of pairwise comparisons using a scale of 1 to 9 and their reciprocals (Saaty and Vargas 2001).

Archival Data. The archival data were obtained in technical reports and economic records of the company along with the source and the destination of the technology. Examples of these data are “actual production rate”, “expected production rate”, “time the organization uses the technology”, etc. Data collection sheets were also designed to collect this type of data. The data were required to evaluate, test, validate the developed TT model, and to determine those factors promoting effective and successful TT.

Processing of Stage 1

The TT program considers each application as a unique project. The first stage of the model starts with coding the project (i.e., entering a code and a description of the project). The program handles two types of data: data entered by the user of the program, and data generated randomly (limitations imposed to the random number generator to ensure an acceptable level to the data).

To measure the current technological situation

as a default in the program: productivity, quality level, flexibility, and unit production cost. The decision maker can select and/or add to the proposed measures as shown in Exhibit 1. In the ABB application, the decision maker selected three of the proposed measures and added two new measures. Flexibility of the existing technology is measured based on variety in size and color that can be used. Quality level is measured according to four different categories, pass, good, very good and excellent. Environmental impact has three levels which are: no, partially, and full treatment. Unit production cost is the only measure to be minimized.

For each selected performance measure (PM) the decision maker has to enter three values, the lower limit (LL), upper limit (UL), and the current value (CV). Next, the program calculates the utility (status) of each measure as shown in Exhibit 2.

Then the decision maker must make a pairwise comparison between the selected performance measures and assign a scale of 1 to 9 or the reciprocals as shown in Table 1. The spreadsheet is setup such that after the entries above and to the right of the diagonal are entered, the program automatically calculates the reciprocal preferences.

Exhibit 1. Performance Measures Selection For Stage 1.

The screenshot shows a software window titled "ABB ARAB PAINTING SYSTEM". At the top left, there is a "Project Code" field containing the number "10". Below this is a "Performance Measure" section with a list of five items, each with a checkbox:

- Quality Level
- Flexibility
- Unit Production Cost
- PRODUCTION RATE
- ENVIRONMENTAL IMPACT

 At the bottom of the window, there are two radio buttons: Max and Min.

and the percentage need for transfer of new technology, four critical proposed performance measures are kept

Exhibit 2. Estimating Quality Level Status.

The screenshot shows a software interface with the following components:

- Project Code:** 10
- Project Name:** ABB ARAB PAINTING SYSTEM
- Performance Measures:**
 - Quality Level
 - Flexibility
 - Unit Production Cost
 - PRODUCTION RATE
 - ENVIRONMENTAL IMPACT
- Quality Level Parameters:**
 - Max: (blank)
 - Lower Limit: 1
 - Upper Limit: 4
 - Current Value: 2
 - Status: 0.333
- Buttons:** Accept

Table 2. Current Technology Performance Measure Status and Need of Technology.

Performance Measure	Objective Level	Relative Weight	Unit Production	LL	UL	Current Value	Improvement Needed	Weighted Priority
Quality Level	MAX	0.309	1	4	2	0.333	0.667	0.206
Flexibility	MAX	0.062	1	3	1	1	2	0.0609
Unit Production Cost	MIN	0.188	10	33	15	0.2	0.4	0.152
Production Rate	MAX	0.309	20	40	23	0.50	0.15	0.238
Production Rate	MAX	0.31	0	2	1	1	0.5	0.0609
Environmental Impact	0.5	Need of Technology	0.5			0.5	1	0.101

Once all the relevant pairwise comparisons have been made, the matrix is normalized. This is done by totaling the numbers in each column. Each entry in the column is then divided by the column sum to yield its normalized score. The next step is to calculate the average score (priority) of each factor.

The final results of this stage are exhibited in Table 2. The table shows objective, relative

weight, LL, UL, CV, status, improvement needed, weighted status of each PM, and the need of technology. The needed improvement of a PM is the complementary of the current status for the measure such that current status plus improvement equal one unit for each measure.

Two main factors affected the need to transfer new painting technology, the relative weight and the status of the PM. If the status is low and the relative weight of the measure is high, there is a strong need to transfer new technology and vice versa. For the ABB Arab application, the results of stage 1 show that:

- (1) Quality level and production rate have the highest priority over all other measures. Flexibility of the existing technology had the lowest priority. For this reason, it does not affect the need of new painting technology.
- (2) The status of both flexibility and production rate have the lowest values.
- (3) Environmental impact ranked as the fourth measure. In addition, the environmental impact was reduced due to the treatment of waste water before releasing it to the environment.
- (4) Based on these results, ABB Arab Company has a need to transfer a new painting system technology (71%) due to its current poor quality level, low

production rate, and high unit production cost.

Processing of Stage 2

As a consequence of stage 1 results, ABB Arab Company decided to look for a new advanced technology for its painting process. There are five different electrostatic painting system technologies from five different technology suppliers that are candidate to be transferred (Technology 1, Technology 2 ... Technology 5). These technologies seem to meet the basic needs of the company (e.g. increase the production rate, improve the quality level and decrease unit production cost). The technical indicators selected by ABB Arab decision makers are depicted in Exhibit 3. The hierarchy has five levels: focus, aspects, performance measures, assessment criteria (indicators) and candidate technologies.

Performance measures, indicators and candidate technologies are entered to the program as a first step in the second stage of the model. For example, the form shown in Exhibit 4 is designed so the decision maker (user) can select the indicators and classify them as either quantitative or qualitative.

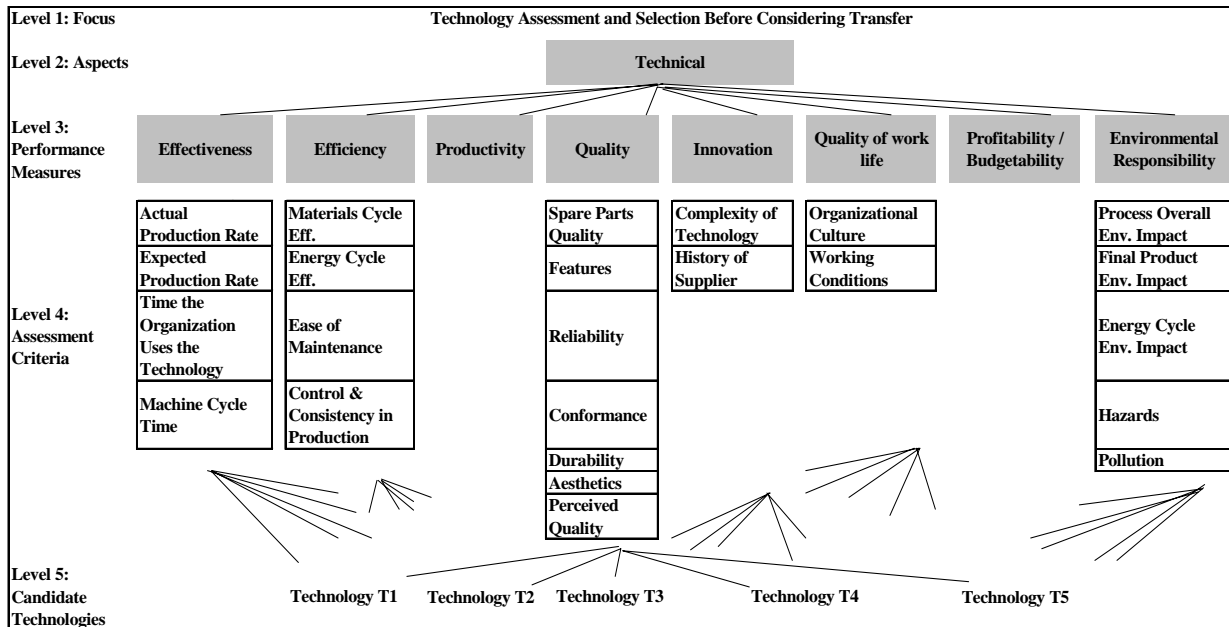


Exhibit 3 Hierarchy of Measures and Indicators for Selecting an Appropriate Technology (Technical Aspects).

Project Code: 10 ABB ARAB PAINTING SYSTEM

Performance Measures: Effectiveness

	Technical	Economic	Average
Technical	1	5	0.833
Economic	0.2	1	0.167
Sum	1.2	6	1

Technical: Actual Output, Expected Output, Length of the Time the Org. Uses the Technology, Machine Cycle Time

Economic: Percent (%) of Scrap, Work in Process Inventory

Quantitative Qualitative

Exhibit 4 Selecting the Technical and Economical Indicators of Effectiveness.

Regarding the feasibility analysis, pairwise comparison was performed to aid in determining the relative importance of the technical and economic factors. As expected from the feasibility study, the results show that technical aspects show highest priority (0.833) over economic aspects (0.167).

Level 2 results prioritize the selected measures from the eight proposed performance measures (e.g. effectiveness, efficiency, productivity, etc). In this level, comparisons are made between the performance measures. Based on the pairwise comparisons, quality of the technology gets the most weight (16.8%), followed by the profitability (16.6%). The measures with least priority are innovation (4.7%) and environmental responsibility (8.4%).

Level 3 results have eight subsections (one for each selected PM). This level assists in calculating the score (priority) of each assessment criterion (indicator) within each selected measure. The next step is to calculate the weighted average ratings of each indicator.

Table 3 summarizes the results at this level, which includes the technical and economic indicators that have highest priority for each selected measure.

For example, “Actual Production Rate” (36.7%) and “Percent of Scrap”(66.7%) are the promoting and facilitating factors in transferring painting technologies from developed to developing countries based on the effectiveness of the technology.

Level 4 is the most important level and it helps in the assessment of the candidate technologies through calculation of the technology’s TPI. The results of this level include qualitative indicators such as “Ease of Maintenance”, Perceived Quality, etc.

The last level (Level 5) in the data collection sheets is designed to collect data of quantitative indicators (e.g., machine cycle time, production rate, etc) for each candidate technology within each selected PM. Exhibit 5 is an example containing these types of indicators. The forms are designed such that the decision maker can define the optimization criteria for each quantitative indicator (maximization or minimization).

Exhibit 6 shows stage 2 final results for each candidate technology. From the Exhibit, technology T3 has the highest TPI followed by technology T2. Technology T5 has the lowest TPI.

Table 3 The Technical and Economical Indicators Affect the New Technology.

Performance Measures	Technical	Economic
Effectiveness	“Actual Production Rate”	“Percent of Scrap”
Efficiency	“Materials Cycle Efficiency”	“Materials Cycle Efficiency”
Productivity	-	“Total Productivity”
Quality	“Perceived Quality”	-
Innovation	“History of Supplier”	-
Quality of work life	“Organizational Culture”	-
Profitability	-	“Raw Materials Costs”
Environmental responsibility	“Hazards”	“Process Environmental Impacts”

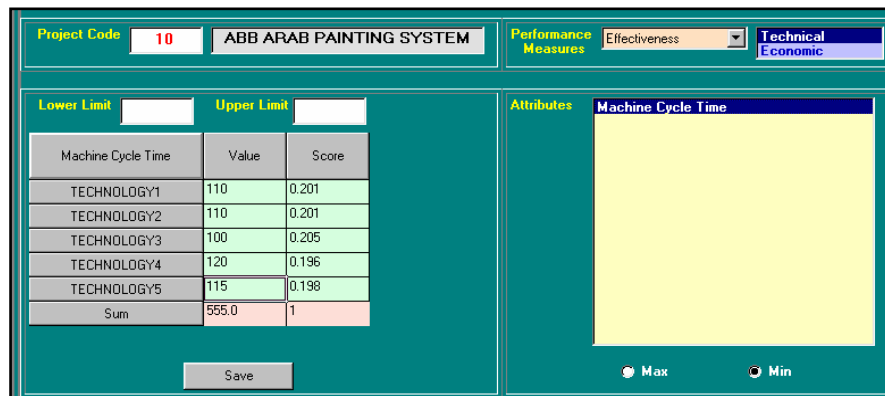


Exhibit 5. Data of “Machine Cycle Time” for Candidate Technologies.

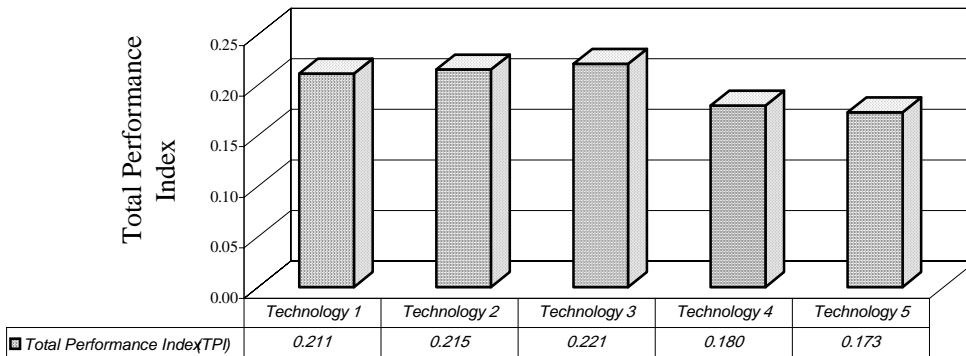


Exhibit 6 Final Results of Stage 2: Total Performance Index (TPI).

Processing of Stage 3

The literature shows that the most dominant measures which can be used to evaluate ATI of a new technology are: the percentage needed to be transferred, technology flexibility, availability of resources and the percent of local manufacturing. Additionally, the user needs to select a list of the required resources for the new technology. After selecting both the measures and needed resources for the new painting technology, the hierarchy of stage three is built as shown in Exhibit 7.

Next, the program is used to obtain the opinions of the decision makers in terms of pairwise comparisons between the measures in order to prioritize them. The judgments of the experts on the required resources are collected and hence, the relative importance of each resource and its overall weight are estimated. The results showed that “budget” available (0.479) is the most critical measure followed by “workers qualifications and quantity” (0.254). “Infrastructure” (0.106) and “spare parts” (0.162) have the lowest priority among available resource measures.

Decision makers are then asked to enter a number of subsystems under each new candidate

painting system technology and its level of need. After that the program assigns the suitable value of need by percent (0%, 25%, 50%, 75%, or 100%). The program provides the “Total percentage needed to be transferred” for each painting technology. These values are then normalized to get the score of each technology with respect to this measure. Technology 1, 2, and 3 satisfy this measure to a great extent with equal priorities (0.203).

To determine the flexibility of the new technology, two measures are needed: type of process model and type of product mix. The process model and product mix for all candidate painting technologies are fragmentary flow and high volume of some models, respectively. In ABB Arab application, the priorities of all candidate painting technologies were the same, and hence, this measure is not important in determining ATI.

All candidate painting technologies have the same priority for two resources (i.e., “Infrastructure” and “Workers Qualifications and Quantity”, (0.2)). Technology 3 and Technology 4 have the higher priority for the other two resources “Spare Parts” (0.26) and “Budget” (0.248). These results are shown in Table 4.

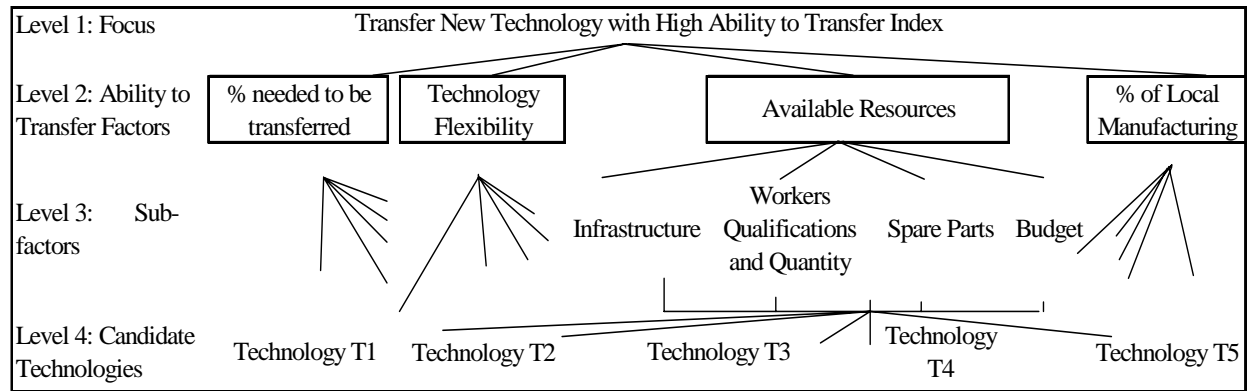


Exhibit 7 A Hierarchy of Ability to Transfer Factors.

Table 4 Partial Results of Priorities of Candidate Technologies for Availability of Resources.

Candidate Technology	Available Resources	Infrastructure (L.E.)	Workers Qualifications and Quantity (L.E.)	Spare Parts (\$)	Budget (\$)
Technology 1	Available (1000)	100	20	20	800
	Needed (1000)	100	20	35	1100
	Availability of Resources %	1.000	1.000	0.571	0.727
	Priorities	0.200	0.200	0.186	0.181

Local manufacturing percentage is 100% for all candidate painting technologies. As a result, the score is also 100%. Consequently, this measure is not crucial in determining the ATI for the new painting technology. The ranking of new painting technologies candidates after stage 3 based on ATI are: Technology 3, Technology 4, Technology 1, Technology 5, and Technology 2. The results are exhibited in Exhibit 8.

Processing of Stage 4

The selection of the suitable technology is based on both TPI and ATI determined during stages 2 and 3 respectively. Exhibit 9 provides the graph that is used to select the technology. According to the graph, some areas (with medium to high TPI and ATI) encourage the user to select technologies in these. According to both the guidelines in selecting a technology to transfer and the results from the graph, the following conclusions can be made:

- (1) Technology 3 is most highly recommended to be transferred as a new and appropriate technology to ABB Arab Company. It has

highest score in both indices, TPI (0.211) and ATI (0.219).

- (2) Technology 5 is not recommended to be transferred (low TPI, 0.173 and medium ATI, 0.196).
- (3) Technology 1 and Technology 2 have high TPI (0.211 and 0.215) but low ATI (0.194, 0.175). As a result, Technology 1 and Technology 2 were left to the decision maker to make further studies and decide between transferring such technologies or not.
- (4) Technology 4 has low TPI (0.180) and high ATI (0.217). The decision to accept or refuse the transfer of this technology was left to the decision maker.

The technology selection contingency table (Table 5) was used along with Exhibit 9. As shown in Table 5, the painting technologies are classified into different groups. The different technologies can be classified into one of three groups.

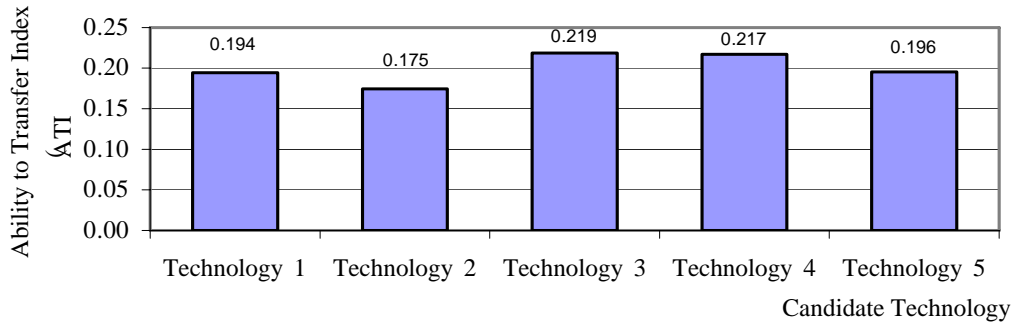


Exhibit 8 Ability to Transfer Index (ATI).

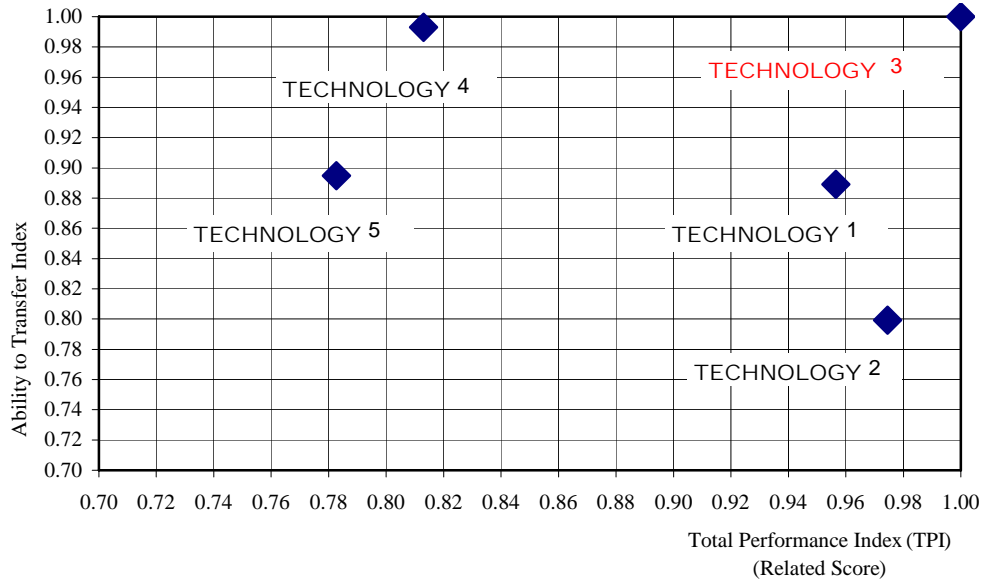


Exhibit 9 TPI and ATI of each Candidate Technology

Table 5 Painting Technology Selection Contingency Table.

ATI → TPI ↓	Low	Medium	High
Low		Technology 5	Technology 4
Medium			
High	Technology 1 & Technology 2		Technology 3

Technology most recommended to transfer
This technology needs further study to decide
Technology not recommended to transfer

Conclusions

Selection of appropriate technology to be transferred is not an easy decision. In particular, in developing nations like Egypt it requires a thorough analysis. The developed model is validated through its implementation at ABB Arab. The computerized model has the following characteristics:

- (1) It can be used in similar field studies to compare the total performance of relatively new technology with that of more advanced ones.
- (2) It can handle two types of data: data randomly generated and data entered by the user. Therefore, the model can be used to analyze both hypothetical case studies and existing applications.

- (3) It is flexible enough to include additional measures according to the type of technology to be transferred.

The implementation of the developed model at ABB Arab Company showed that: The company needs to transfer a new painting system technology (71%) due to the current poor quality level, low production rate, and high unit production cost.

Presence of complete information about the candidate new technologies is a crucial factor for the success of the evaluation and assessment of both current performance and ability to transfer the technology. Incomplete information may create problems due to the constraints on data collection, especially for hi-tech technologies. Additional

problems may arise due to incomplete information or constraints on data collection such as handling a qualitative measure as a qualitative measure. The developed model handles situations where there is missing or incomplete information.

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