Evaluation of performance in introducing CE marking on the European market to the machinery industry in Taiwan

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Abstract

Purpose – Aims to assess the effect of European Union performance directives related to CE marking on the machinery industry of Taiwan.

Design/methodology/approach – This paper adopts a questionnaire to collect information. By means of a statistical scheme, performance indices of importance and difficulty, which meet the directives requirement, are designated. The performance evaluation matrix presented by Lambert and Sharma is modified using an introduced standardized system.

Findings – Management in the industry needs simply to locate the difficulty and importance of the directive on a performance matrix. Performance levels can be assessed and the strategy for improving the performance of CE marking established.

Originality/value – Provides information on the best countermeasure that can be obtained to serve as a reference for the industry to introduce CE marking.

Keywords Quality function deployment, European Union, Taiwan, Product management

Paper type Research paper

Introduction

The European Union (EU) includes 15 member countries. The languages, currencies and laws vary greatly among these member countries, so unification and integration are important in promoting the economic development of the region. The EU Headquarters issues different CE directives to ensure that products that circulate among member countries meet basic safety standards. Simply, the CE marking passes products to be offered in EU markets. Among 20 EU Directives already issued, some already apply to toys, machines and electromagnetic devices and others. Upon passing the evaluation procedures, a product is verified as meeting CE marking requirements; the marking indicates that the product does not endanger the health and safety of the user (Essential Health & Safety Requirements), but that it satisfies environmental protection requirements. Then, the product can be freely marketed among member countries of the EU. However, if the product does not meet these requirements, a notice will be given to all member countries either to restrict or reject its entry into the market,

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or they will be asked to recall the product and fine the responsible party up to ten million Deutschmarks or five million pounds (EEC, 1985).

The EU's Directives can be divided into Regulations (REG), Directives (DIR), Resolutions (RES), Commissions (COM) and Suggestions (SUG) according to their legal status effectiveness. Directives can be further divided into Generally Applicable Directives, General Directives and Product Specific Directives (European Community, 1957). CE safety markings for machinery were first used in June 1989 (EEC, 1989)). General directives that apply to electrical machinery include the Machines Directive, the Electromagnetic Compatibility Directive and the Low Voltage Electrical Products Directive. Manufacturers must consider dimensions to be certified for CE markings. They include technical documents, product verification and introduction management, which are covered by 27 directive items (EC, 1998). According to Colletti (1987), service quality of an enterprise can satisfy customer's requirements and expectations effectively. Accordingly, emphasis on directive items placed by the assistance specialists has to be realized and the inclination of performing directive items by the industry needs to be assessed for effective introduction of CE marking system.

In principle, CE marking is a compulsory product certifying system, a pass for the markets of EU. Products without CE marking cannot be marketed in Europe. However, ISO 9000 is an international system of quality standards and a voluntary quality management system. Its related articles are not correlated to most of the CE directives announced by EU directly. Therefore, the ISO 9000 system is optional and products that are not ISO 9000 certified can have CE marking. Importance of directives related to CE marking will vary with different timing, places, backgrounds and industries. Besides, difficulties in implementing essential items of various directives will be variant due to divergent properties, backgrounds and technologies of the companies. As a successful introduction of CE marking is closely related to business opportunities of the companies themselves as well as user safety and environmental protection, a performance evaluation model of CE marking introduction will be presented in this paper.

First, importance and difficulty indices will be specified for 27 directive items. Researchers should assess importance indices and difficulty indices according to the ability of companies to implement directives. Generally, if a company is highly capable of meeting a certain directive requirement, the difficulty associated with that directive item is low, and vice versa. The performance evaluation matrix of Lambert and Sharma (1990) is modified herein: the importance of the directive's introduction and the difficulty of implementing it replace emphasis on the customer and satisfaction with service, respectively. In general, when the importance of an item is high and the difficulty is low, the effectiveness of the directive will be high. On the contrary, when the importance of an item is high and the difficulty is extremely high, the effectiveness of the directive will not be high. Consequently, the effectiveness can be assessed easily from the positions of importance of the introduction of the directive and the difficulty of implementing it in the evaluation matrix. However, the cost and timeliness of the introduction must also be considered. Therefore, the priority of the items in the critical directives must be determined from the importance and difficulty to determine strategies for improvement and to modify the evaluation matrix accordingly. Quality function development (QFD), a method initiated by a Japanese Zi Mizuno in 1972, was applied in this paper to define critical product functional items. QFD is used for

product development and design highlighting incorporation of "consumers' wishes" on every production stage and conversion them to product design and manufacturing flow. Implementation of QFD improves the efficiency of product design and development process significantly, including shortening time phase required for product development, improving product quality, enhancing realization of customers' requirements and real time solving of crucial problems on the production line (Fariborz and Rafael, 2002). According to house of quality (HOQ) this must be adhered to while implementing QFD, the elements of HOQ consist of customers' demands, engineering technology, evaluation of competitive products, correlated matrixes, weight of importance and absolute weight, etc. Then, critical directives of low importance and high easiness and of high importance and low easiness will be targeted. Finally, critical product function items will be specified using the method presented by Shen *et al.* (2001) and using quality function deployment (QFD) directives of low importance and low difficulty and those of high importance with great difficulty. Accordingly, the best countermeasures can be sought to overcome the difficulty of introducing such Directives, and such information is useful as a reference for industry's beginning to respond to the CE marking system.

System-introduced performance evaluation model

As stated above, the ease of implementing and the importance of each directive item, varies with the industry and the company. Thus, the random variable I is used to represent importance and E easiness. The ease of introducing the system changes with the manpower and resources of the company. Generally, when a company has plenty of talent or abundant resources, the ease of implementation will be higher.

Next, the ideas of Parasuraman *et al.* (1985, 1991) are referred to define one performance index assessing each directive. A k-point scale is used to evaluate the importance and easiness of implementation for each directive item. The indices of importance and ease of implementation are defined as follows.

$$P_{\mathrm{I}} = \frac{\mu_{\mathrm{I}} - \min}{R} \text{ (index of importance)}$$

$$P_{\mathrm{E}} = \frac{\mu_{\mathrm{E}} - \min}{R} \text{ (index of easiness)}$$

The terms μ_{I} and μ_{E} are the means of importance (I) and ease of implementation (E), respectively. $\min = 1$ represents the minimum of the k scale and $R = k - 1$ is the full range of the k scale. A lower value corresponds to a directive that is less important or less easy to implement. Clearly, these two indices are within (0, 1). For example, on a five-point scale ($k = 5$) with $R = k - 1 = 4$, when the mean importance (or easiness) exceeds 3 (medium), the corresponding index will exceed 0.5 and the integral average importance (or easiness) will be positive. On the contrary, when the average importance (or easiness) is below 3 (medium), indices will be below 0.5 and the integral average importance (or easiness) will be negative. Consequently, through the values of the indices, which represent a convenient and efficient tool with which company management can evaluate the effectiveness of the introduction of CE marking.

The index of importance is plotted as a Y-coordinate and that of easiness as the X-coordinate. A performance matrix is redefined based on various strategic requirements

of companies, as a tool for use in the performance analysis of, and the improvement of a newly introduced system. Since indices $\hat{P}_{\mathrm{I}}$ and $\hat{P}_{\mathrm{E}}$ are within the range [0, 1], four thresholds [0.0, 1/3, 2/3, 1.0] are adopted to define three levels of ease of implementation – least easy [0.0, 1/3], moderately easy [1/3, 2/3] and most easy [2/3, 1.0] and three levels of importance – least important, moderately important and most important. $(P_{\mathrm{E}}, P_{\mathrm{I}}) = [0.0, 0.0]$ means least easy and least important; $(P_E, P_{\mathrm{I}}) = [1.0, 1.0]$ means the easiest and the most important. Indices $(P_{\mathrm{E}}, P_{\mathrm{I}})$ between [1/3, 1/3] and [2/3, 2/3] mean moderately easy and moderately important. The dotted line parallel to the y-axis in Figure 1 ($P_{\mathrm{E}} = 0.5$) indicates medium easiness. The area to the right of the dotted line represents a high average higher than average easiness and that to the left of the dotted line represents a lower than easiness. The dotted line parallel to the x-axis ($P_{\mathrm{I}} = 0.5$) stands for medium importance. The area above the dotted line represents higher than zero importance and the area below the dotted line represents a low average importance.

As stated above, the system-introduced performance matrix is divided into nine performance zones that represent the effectiveness of various system – introduced directive items. $B_{ij}(i = 1, 2, 3;\ j = 1, 2, 3)$ is used to represent the performance zones, where B_{31}, for example, is the directive with the least ease of implementation and the most importance – it is thus the zone that demands most improvement. B_{13} is the directive item with the highest ease of implementation and the least importance, corresponding to greatest effectiveness. With $i = 3$, the three performance zones B_{31}, B_{32} and B_{33} represent the greatest importance and are called the "most important zones". With $i = 2$, the three performance zones B_{21}, B_{22} and B_{23} represent medium importance and are called the "medium important zones". With $i = 1$, the three performance zones B_{11}, B_{12} and B_{13} are called the "least important zones". With $j = 3$, the three performance zones B_{13}, B_{23} and B_{33} represent the easiest implementation and are called the "easiest zones". With $j = 2$, the three performance zones B_{12}, B_{22} and B_{32}

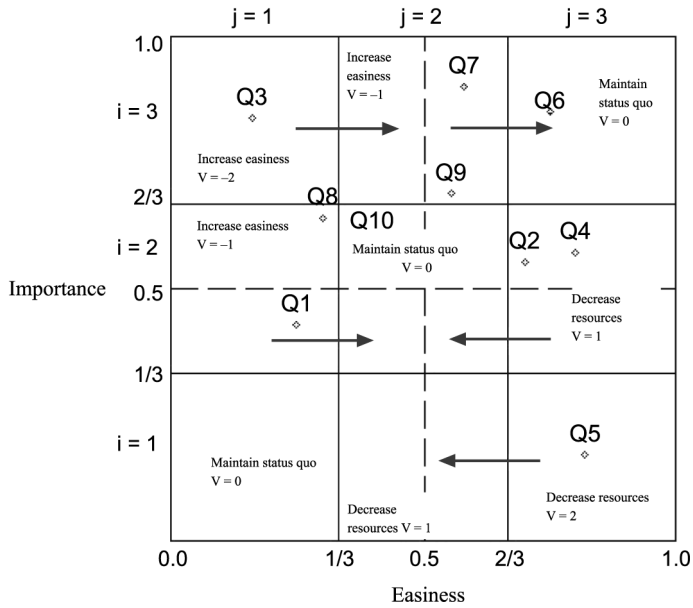

Figure 1.
Appropriate performance zone

represent moderate ease of implementation and are called the "moderately easy zones". With $j = 1$, three performance zones B_{11}, B_{21} and B_{31} represent the least easy implementation and are called the "least easy zones". With $i = j$, the importance of three performance zones B_{11}, B_{22} and B_{33} the importance equals the ease of implementation and the zones are called the appropriate performance zones. Although certification is important for the sustainable success of a company, critical directive items must be identified and requirements met with regard to cost. Therefore, if a company adopts the management strategy of obtaining an "appropriate performance level", a certain performance level can be maintained and the cost of introducing a system will be reduced. Consequently, an enterprise must set the priorities of directive items (as shown in Figure 1). The "target zone" is the "appropriate performance zone" in which the importance equals the easiness – ($i = j$) (B_{11}, B_{22} and B_{33}). The easiness exceeds the importance ($i<j$) in zones B_{12}, B_{13} and B_{23}. Applied resources should then be decreased to reduce the cost of meeting the directives. Easiness is lower than importance ($i > j$) in zones B_{31}, B_{32} and B_{21}. Applied resources then should be increased to enhance performance. The performance should be improved in the "target zones", in the direction of the arrow in Figure 1. The strategies for improvement in each performance zone are of three types – increase resources to enhance effectiveness, decrease resources to reduce the cost of introducing the directive, and maintain the present situation. For example, performance study of CE marking certification includes ten directive items, distributed as in Figure 1 (Q1-Q10). Clearly, Q1, Q3, Q9 and Q7 are four directive items critically important to obtain certification, which are more important than they are easy to implement ($i > j$). Located in zones B_{31}, B_{32} and B_{21}, which means extremely low easiness, applied resources must be increased to increase performance. The three directive items Q2, Q4 and Q5 fall in zones B_{12}, B_{13} and B_{23}, in which importance is lower than ease of implementation ($i < j$), so resources need to be reallocated so that surplus resources can be applied to implement four directive items Q1, Q3, Q9 and Q7 with greater importance and easiness. Accordingly, the CE marking can be promoted without increasing the cost, and perhaps even reducing it. When analyzing the performance matrix of the introduction CE marking, management needs only determine the type of the performance matrix from the position (P_E,P_I) of the indices of importance and easiness of implementation of the directive items of interest. Accordingly, the performance level of each directive item can be assessed and projects and strategies for improvement formulated. Thus, the performance matrix is a simple and easy-to-use graphic analysis tool and, which is quite helpful in evaluating the performance of introduction of CE marking.

Improved weighted indices and QFD

An improved weighted index, V_i, is defined here. It is designed that the differences between the coordinate values of importance and easiness in Figure 1 are as follows.

$$V_i = j - i; \quad i = 1, 2, 3; \quad j = 1, 2, 3; \quad -2 \leq V_i \leq 2$$

The terms i, j are the coordinates of importance (I) and easiness of implementation, respectively, and range from 1 to 3. Clearly, V_i will be between -2 and 2. When $V_i = 0$, importance equals easiness ($i = j$), and the coordinates are in the most suitable "target zones", B_{11}, B_{22} and B_{33}, implying not only that requirements are met, but also that costs are saved. When $V_i > 0$, importance exceeds easiness ($i < j$), and

coordinates lie in zones B_{13}, B_{12} and B_{23}, implying that the directive items less important and can be performed more easily. Therefore, resources must be reduced to reduce the cost of implementing the directive. When $V_i < 0$, the importance is less than the easiness ($i < j$), and the coordinates are in zones B_{31}, B_{21} and B_{32}, implying that the directives are more important and more difficult to implement. Thus, more resources must be assigned to increase effectiveness.

Next, V_i values of abnormal directive items are entered into the QFD table and experts brainstorm the weightings W_{ij} of directive items and product function items in QFD. The approach is to add the improved weighted indices V_i of abnormal directive items. The total weighted T_j values of function items of product can be obtained as follows. Table I is a QFD table.

$$T_j = \sum_{i=1}^{n} \sum_{j=1}^{m} V_i W_{ij}, \quad i = 1, \ldots, n; \quad j = 1, \ldots, m$$

Finally, the total weighted T_j values are sorted in ascending or descending order and critical product function items are determined for improvement. When the total weighted value is negative, investment in resources must be increased to improve the effectiveness until the optimum value $T_j = 0$ is reached. However, when the total weighted value is positive, the resources must be reduced to yield $T_j = 0$ to reduce the cost of implementing the directive. Table II facilitates a strategy for improving the abnormal total weighted T_j values. Therefore, the introduction of CE marking can be systematically evaluated and improved using assessment model developed in this paper.

A set of simple evaluation procedures is provided to facilitate the assessment of the effectiveness of the introduction of CE marking and perform a systematic QFD evaluation of all directive items. This process includes five major steps in Figure 2:

(1) Conduct a survey of the importance and easiness of 27 introduced directive items by using a questionnaire. Experts will judge the indices of importance, and a certified company will evaluate the indices of easiness. P_E and P_I are calculated from the importance and ease of implementation indices defined in this paper.

(2) Input the importance index P_I and the ease of implementation index P_E of each directive item into the system introduction performance matrix defined in this paper.

Product function item Abnormal directive item	Coordinate indices	1	…	j	…	M
1	V_1	W_{11}	…	W_{ij}	…	W_{1m}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
i	V_i	W_{i1}	…	W_{ij}	…	W_{im}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
N	V_n	W_{n1}	…	W_{nj}	…	W_{nm}
Total weighted value		T_1	…	T_j	…	T_m

Table I.
QFD table of V_i values for abnormal directive items

(3) Use the formula provided to calculate the improved weighted index V_i, the coordinates of indices P_E and P_I in the system introduction performance matrix. If $V_i \neq 0$, it refers to an abnormal directive item.

(4) Input the improved weighted index V_i of abnormal directive items into the QFD table and discuss to establish the weighted W_{ij} for each product function item through the development of QFD. Add the improved weighted indices V_i and weighted to determine the total weighted T_j of an individual product function item. If $T_j \neq 0$, it refers to a critical product function item.

(5) Priorities for improvement will be determined by the total weighted T_j values for critical product function items. When the negative value is smaller or the

Type of index	Coordinate weighted index T_j	Matrix coordinates	Improvement order	Improvement strategy
Easiness lower than importance	Negative	B_{31}, B_{21} & B_{32}	Higher priority for smaller negative	Increase resources to promote easiness until optimum value $T_j = 0$ is reached
Easiness higher than importance	Positive	B_{13}, B_{12} & B_{23}	Higher priority for bigger positive	Decrease resources to reduce costs of implementing the directive until optimum value $T_j = 0$ is reached

Table II.
Table of strategies for improving abnormal total weighted T_j values

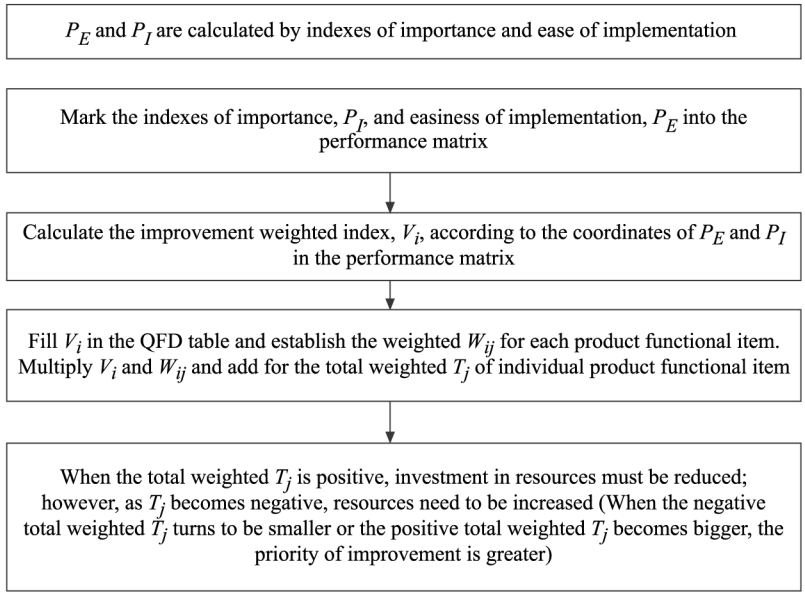

Figure 2.
Flow chart of five major steps

positive value is larger, the priority of the item is higher. Refer to the suggestions in Table II for strategies for improvement. When the total weighted T_j is negative, resources must be increased to increase the effectiveness to yield the optimum value $T_j = 0$. However, when the total weighted T_j is positive, investment in resources must be reduced to reduce the costs of implementing the directive, to obtain the optimum value $T_j = 0$.

Discussion of actual example

The machinery industry in Taiwan is headquartered in the central region. Manufacturers are working hard to become CE certified to win more orders for their machine tools. Twenty-seven directive items, related to CE certification, are addressed in the questionnaire (Table I). The five-point Likert scale is used to measure various variables: 1 implies very uneasy or very unimportant; 2 implies uneasy or unimportant; 3 implies average easiness or average importance; 4 implies easy or important; and 5 implies extremely easy or extremely important. The questionnaire is divided into two parts. The first part is for domestic consulting experts in CE certification. The main purpose is to evaluate the importance of the 27 directive items. The second part is for CE certified manufacturers to assess the ease of implementation of directive items for CE certification for the machinery industry in Taiwan. Random sampling is used to conduct the questionnaire survey of 50 experts and scholars and 100 manufacturers. The evaluation procedure is as follows:

(1) First, the means and indices P_{I} and P_{E} for the importance and ease of implementation of directive items are calculated. Table III presents the results.

(2) The importance index P_{I} and the ease of implementation index P_{E} of each directive item are input into the system introduction performance matrix. Figure 3 presents the results.

(3) The improved weighted index V_i is calculated from the coordinates of indices P_{E} and P_{I} in the system introduction performance matrix. If $V_i \neq 0$, then it refers to an abnormal directive item. The actual example includes seven abnormal directive items, including item 1 (translation of technical documents from source languages into official EU languages), item 6 (full machine drawings), item 12 (instructions for implementing risk-minimizing strategies), item 16 (maintenance manuals), item 18 (selection of certifying agencies), item 23 (incomplete implementation plans) and item 24 (lack of recognition to certification in the whole company). Table III presents the improved weighted index V_i.

(4) Fill the improved weighted index V_i of abnormal directive items into the QFD table and experts discuss to establish the weighted W_{ij} for each product function item through QFD development. Add improved weighted indices V_i and weighted W_{ij} values of all product function items after multiplying, which results in the total weighted T_j of individual product function item. If $T_j \neq 0$, it belongs to a critical product function item, shown as Figure 4.

(5) Priorities and strategies for improvement will be determined from the total weighted T_j values of critical product function items. When the negative value is smaller or the positive value is bigger, the priority of an item is higher. Next, the critical product function items for improvement are identified. When the

Directive items	Importance	Easiness	P_I	P_E	V_i
I. Technical documents					
1. Translating technical documents from source languages to EU official languages	*4.3333*	*2.4655*	*0.833325*	*0.366375*	*1*
2. Presentation of documents to be consistent with technical documents	4.2	3.675	0.8	0.66875	0
3. Questions that used to be ignored	3.5333	3.7647	0.633325	0.691175	0
4. Product specifications (nomenclature, model, required standards)	3.7	4.2647	0.675	0.816175	0
5. Instruction manuals (operation and maintenance instructions)	3.8	4.1176	0.7	0.7794	0
6. Machine full view drawings	*1.8545*	*3.4567*	*0.213625*	*0.614175*	*−1*
7. Control lines	3.8667	4.2647	0.716675	0.816175	0
8. Lists of component parts	3.7667	4.3824	0.691675	0.8456	0
9. Part drawings	3.8	4.2059	0.7	0.801475	0
10. Calculation data	4.1333	3.9118	0.783325	0.72795	0
11. Test reports	4.1333	3.9704	0.783325	0.7426	0
12. Instruction manuals about risk strategies	*4.4667*	*2.7617*	*0.866675*	*0.440425*	*1*
13. Installation instructions	4.4667	4.3235	0.866675	0.830875	0
14. Safety instructions	4.3667	4.3235	0.841675	0.830875	0
15. Specified uses	4.1	4.2059	0.775	0.801475	0
16. Maintenance manuals	*2.6754*	*4.3235*	*0.41885*	*0.830875*	*1*
II. Product certification					
17. Establishment of quality system	3.6	3.6765	0.65	0.669125	0
18. Selection of product certifying agency	*2.1356*	*4.5675*	*0.2839*	*0.891875*	*−2*
19. Products cannot meet specifications of directives	3.6333	3.6765	0.658325	0.669125	0
20. Product features cannot meet directive requirements	4	3.8824	0.75	0.7206	0
21. Insufficient experience of assistance organizations	3.9	4.2059	0.725	0.801475	0
22. Difficulty of putting CE articles into practice	3.8	3.5967	0.7	0.64917	0
III. Management					
23. Incomplete implementation plans	*3.8667*	*2.0145*	*0.716675*	*0.253625*	*2*
24. Lack of recognition	*2.8954*	*1.7565*	*0.47385*	*0.189125*	*1*
25. Management does not provide sufficient support	3.9	4.0882	0.725	0.77205	0
26. Relevant personnel do not actively participate in participation	3.9	3.8824	0.725	0.7206	0
27. Difficulty in acquiring talent, technology and equipment to meet CE directives	3.9	3.7353	0.725	0.683825	0

Table III.
Means and performance values of importance and easiness of implementing CE marking-related directives

total weighted value is positive, resources must be reduced until the optimum value $T_j = 0$ is achieved. Priority for improvement, measured on a points system is 20 for item 48 (warning indicators), 19 for item 51 (instruction manuals), 18 for item 42 (mechanical maintenance) and 15 for item 7 (actuation system control). When the total weighted value is negative, investment in

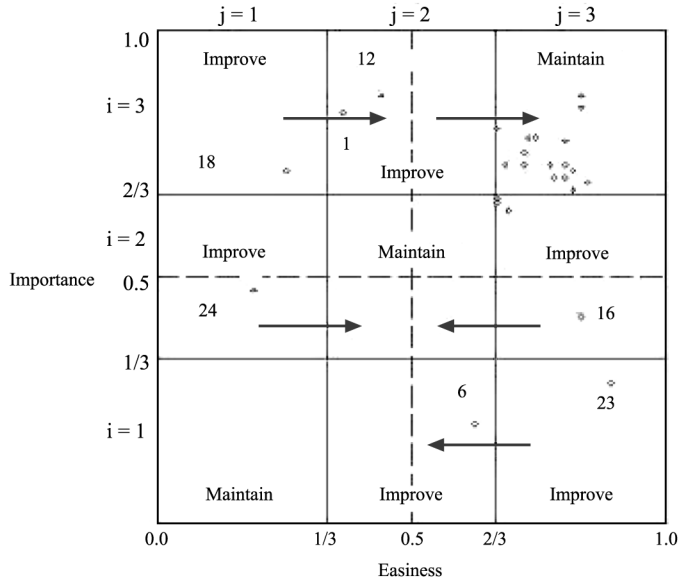

Figure 3.
System introduction performance matrix

resources should be increased to reduce the costs of implementing the directive and obtaining the optimum value $T_j = 0$. Improvement priority for item 48 (warning indicator), -17 points for item 13 (stability hazard prevention), -15 points for item 51 (instruction manuals), -14 points for item 5 (control system safety), -12 points for item 39 (gas leakage prevention) and -10 points for item 27 (power protection measures). Finally, Table IV presents strategies for improving against abnormal T_j. The effectiveness of introducing CE marking can be systematically evaluated and improved efficiently using the assessment model developed in this paper (See also Tables V and VI).

Conclusion

The government of Taiwan is actively assisting manufacturers to develop markets in European to reduce over-dependence on trade with America. However, Europe uses CE marking to specify manufacturers' responsibilities and ensure the quality of the products that circulate in such a large market. The government must be more positive in assisting manufacturers to have their good certified and increase industrial competitiveness in the European market, thereby overcoming trade barriers and grabbing a share of the European market. Therefore, the promotion and introduction of CE marking has become an important issue and a challenge for the operation of all industries nowadays. Generally speaking, as the members of the European Communities established a unified market in Europe, product safety standards and requirements have been imposed since 1995 to ensure the quality of products and services circulating on the European market. Safety design and manufacturing along with related documents and papers have to be prepared and verifications and inspections of the products need to meet pertinent directives and specifications

Abnormal Directive Item	Product Function Item / W_{ij} / V_i Value	≈	5. Control System Safety	≈	7. Actuation System Control	≈	13. Stability Hazard Prevention	≈	27. Power Protection Measures	≈	39. Gas Leakage Protection	≈	42. Mechanical Maintenance	≈	48. Warning Indicator	≈	51. Instruction Manual
Item1	+1	≈		≈	3	≈		≈		≈		≈	3	≈	3	≈	4
Item12	+1	≈		≈	5	≈		≈		≈		≈	4	≈	3	≈	5
Item16	+1	≈		≈	3	≈		≈		≈		≈	3	≈	4	≈	4
Item23	+1	≈		≈	2	≈		≈		≈		≈	4	≈	5	≈	3
Total Positive Weighted Value		≈		≈	**15**	≈		≈		≈		≈	**18**	≈	20	≈	19
Item26	–1	≈	3	≈		≈	4	≈	3	≈	3	≈		≈	2	≈	2
Item24	–1	≈	3	≈		≈	5	≈	3	≈	3	≈		≈	4	≈	3
Item18	–2	≈	4	≈		≈	4	≈	2	≈	3	≈		≈	6	≈	5
Total Negative Weighted Value		≈	**–14**	≈		≈	**–17**	≈	**–10**	≈	**–12**	≈		≈	–18	≈	–15

Notes: On abnormal directive items: Item 1: Translation of technical documents from source languages into official EU languages; Item 6: full-view drawings of machinery; Item 12: instructions of risk strategies; Item 16: maintenance manuals; Item 18: selection of certifying agencies; Item 23: incomplete implementation plans; Item 24: lack of recognition to certification in the whole company

Figure 4.
QFD table of directive items

required by the European market prior to launching the products unto the market with CE markings. On the other hand, promoting CE marking not only helps to market the products on the European common market from the perspectives of management and development, but also contributes to expansion of the global market, development of more competitive products, enhancement of productivity and significant increase in business volumes and market shares. Consequently, it is obvious to know that satisfaction of various services will be increased after introducing CE.

However, as properties of relevant directives are different, implementation easiness and importance vary. Therefore, evaluation of performance on the difficulty and importance of related directives to be introduced should be conducted and an effective improvement model needs to be presented for applying the CE marking efficiently.

A questionnaire method is adopted in this paper to collect information on the effect of performing directives related to CE marking in the machinery industry of Taiwan. First, calculate means of the importance level of directive items and P_I values as well as means of implementation easiness and P_E values. Then, mark the importance index P_I and the implementation easiness index P_E of each directive item into the system introduction performance matrix. Finally, calculate the improvement weighted index V_i in compliance with the coordinate locations of indices P_E and P_I of individual directive item. If $V_i \neq 0$, it belongs to an abnormal directive item. Next, the total

Table IV.
Table of strategies for improving critical product function items

Critical product function item	Coordinate weighted index T_j	Type of index	Coordinates in matrix	Priority (for OR of) improvement	(Strategy for improvement OR improvement strategy)
Item 48	−18	Negative T_j values (easiness lower than importance)	B_{31}, B_{21} & B_{32}	Smaller negative values for higher priority	Increase investment in resources to enhance ease of implementation until optimum T_j=0
Item 13	−17 points				
Item 51	−15 points				
Item 5	−14 points				
Item 39	−12 points				
Item 27	−10 points				
Item 48	20 points	Positive T_j values (easiness higher than importance)	B_1, B_{12} & B_{23}	Bigger positive values for higher priority	Decrease investment in resources to reduce costs of meeting directive until $T_j = 0$
Item 51	19 points				
Item 42	18 points				
Item 7	15 points				

Notes: Names of critical product function items – item 5: control system safety; item 7: actuation system control; item 13: stability hazard prevention; item 27: power protection measures; item 39: gas leakage prevention; item 42: mechanical maintenance; item 48: warning indicator; item 51: instruction manuals

Critical product functional item	Measures of improving erroneous directives by increasing resources
Item 48 – warning indicator	Increase warning indications marked on the full-view drawing of the machine List the functions of warning indicators in the maintenance manual
Item 13 – stability hazard prevention	Increase stability hazard prevention indications on the full-view drawing of the machine Add papers of stability hazard prevention in the maintenance manual Carefully select the product certifying agencies that can provide technology on stability danger prevention
Item 51 – instruction manual	Add an instruction manual that displays the full-view drawing of the machine Record the instruction manual in the maintenance manual
Item 5 – safety of control system	Increase control system safety indications on the full-view drawing of the machine Put down the functions of control system safety in writing in the maintenance manual Carefully select the product certifying agencies that can provide technology on control system safety
Item 39 – gas leakage prevention	Increase gas leakage prevention indications marked on the full-view drawing of the machine Record the functions of gas leakage prevention in the maintenance manual Carefully select the product certifying agencies that can provide technology on gas leakage prevention
Item 27 – power protection measures	Add power protection measures marked on the full-view drawing of the machine Record the functions of power protection measures in the maintenance manual Carefully select the product certifying agencies that can provide technology of power protection measures

Table V.
Table of improving directive errors after increasing resources

weighted T_j of respective product functional items is obtained via applying V_i values of these abnormal directive items to the QFD model. As $T_j \neq 0$, it is one critical product functional item. Finally, the total weighted T_j of critical product functional items will determine improvement priority and strategies. In the actual example in this paper, there are four abnormal directive items, including item 1 (translation of technical documents from source languages to EU official languages), item 12 (instructions of risk strategies), item 23 (no complete implementation plans) and item 24 (lack of recognition to certification in the whole company). The total weighted value is positive through the QFD model indicating easiness is greater than importance. As the cost is wasted resulted from excess investment in resources, resources have to be decreased to enhance easiness for implementation with the optimum value $T_j = 0$. Improvement priority based on the maximum is 20 points for item 48 (warning indicator), 19 points for item 51 (instruction manuals), 18 points for item 42 (mechanical maintenance) and

Critical product functional item	Measures of improving erroneous directives by decreasing resources
Item 48 – warning indicator	Translate the technical documents on warning indicators into EU official languages
	Reduce the warning indications marked in instructions of risk strategies
	Cut down resources of plans for implementing warning indications
Item 51 – instruction manual	Translate the technical documents of instruction manuals into EU official languages
	Cut down resources of plans for implementing instruction manuals
Item 42 – mechanical maintenance	Translate the technical documents on mechanical maintenance into EU official languages
	Reduce mechanical maintenance indications marked in instructions of risk strategies
	Cut down resources of plans for implementing mechanical maintenance
Item 7 – control of actuation system	Translate the technical documents on actuation system control into EU official languages
	Reduce actuation system control items marked in instructions of risk strategies
	Cut down resources of plans for implementing actuation system control

Table VI.
Table of improving directive errors after decreasing resources

15 points for item 7 (actuation system control). Besides, there are three abnormal directive items with negative values, which are item 6 (machine full-view drawings), item 16 (maintenance manuals) and item 18 (selection of certifying agencies). The total weighted value is negative through the QFD model revealing easiness is lower than importance. Therefore, investment in resources needs to be increased so that costs of introducing the system might be reduced and the optimum value $T_j = 0$ could be obtained. Improvement priority based on the minimum is -18 points for item 48 (warning indicator), -17 points for item 13 (stability hazard prevention), -15 points for item 51 (instruction manuals), -14 points for item 5 (control system safety), -12 points for item 39 (gas leakage prevention) and -10 points for item 27 (power protection measures). A systematic evaluation and improvement on the performance of introducing CE marking can be conducted efficiently through this assessment model.

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Further reading

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