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Research Article

Inclusion of Management Desirability and Risk in Service FMEA-Based Corrective Action Selection Methodology

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When selecting competing corrective actions on FMEA, decision makers may have a different desirability to target a certain improvement goal. Besides, once the corrective actions have been implemented, there may exist a considerable degree of risk due to the possible uncertainties of the outcome. This paper attempts to present FMEA-based corrective action prioritization, incorporating both management desirability and implementation relevant risk into the model. To reflect team desirability and risk attitude in estimating the attractiveness of corrective actions, the Derringer desirability and risk aversion factor are used. An illustrative example is provided to demonstrate the applicability of the proposed model.

1. Introduction

The service FMEA can be effectively used as means for analyzing the risk due to unfavorable business situation. Following Seyedhoseini and Hatefi [1], within risk management framework, corrective action provision is as important as risk quantification. Nevertheless, previous references on improving capability of FMEA in service operation such as [2–6] do not address the issue. Furthermore, improvement of FMEA-based corrective action methodologies such as [7–12] seems to be still applied to nonservice sectors. Moreover, as Groso et al. [13] stated, it is also very important to consider possibility of risk occurrence during improvement efforts. But the previous studies ignore the degree of uncertainty on outcome of strategy implementation, without mentioning the importance on articulation of management desirability.

This paper presents a conceptual model on ranking corrective action priority, which considers the uncertainty of improvement effort and the strategic function of managing risk in service quality improvement efforts. The model is formulated so that the preference score can be determined on the basis of team desirability, efforts, impacts, and relevant risk for each competing corrective action.

The remaining part of the paper is presented according to the following sections. In Section 2, the desirability function and other key concepts are presented. Section 3 constructs a new model to estimate attractiveness index of competing corrective actions based on team desirability, effort, and risk of implementing corrective action (CA). In Section 4, research methodology and a step by step implementation procedure are provided with an illustrative example. In Section 5, some discussions are provided with managerial implications followed by Section 6 conclusion.

2. Desirability Function of Selecting Corrective Action

In actual application, in attempt to improve, FMEA team usually has certain desirability as manifestation in selecting certain corrective action. To articulate such desirability, the use of various classes of Derringer desirability function can be utilized to accommodate the situation mentioned above. Along with performance-related desirability, FMEA team intends to reduce the failure occurrence rate. Now denote that $DPCA_{ij}$ represents performance-related desirability index of corrective action j for failure mode i, for $i = 1, 2, 3, \ldots, k$ and $j = 1, 2, \ldots, r_i$. And ΔFM_i represents reduction in failure occurrence rate of failure mode i. Assuming the management desirability and reducing the failure occurrence rate are of the same importance, and the composite desirability function $CDCA_{ij}$ which covers both mentioned above in selecting specific corrective action is formulated as follows:

$$CDCA_{ij} = DPCA_{ij}\Delta FM_i. \quad (1)$$

Note that the factor ΔFM_i also represents an improvement factor to indicate the effectiveness of a corrective action. In attempt to classify various classes of quality-related desirability index, references such as [14] can be consulted.

2.1. Quantifying Impact and Effort of Corrective Action. In attempt to achieve specific goal, FMEA team used resources to implement specific CA. From this point of view, all necessary inputs to accomplish specific improvement activity are called *efforts*. To simplify the calculation, all above effort variables are usually quantified by monetary metric, the implementation cost. The component of implementing corrective action costs (IC_{ij}) and how to estimate them can be referred to [15, 16]. The impact of an effort can be defined as the amount of benefit from which a certain corrective action task will be implemented and represented by using monetary metric such as *the net present value* (NPV). However, since the outcome of implementing corrective actions still remains unknown until being implemented, pairwise comparison among some measures of commercial benefits with the AHP (Analytic Hierarchy Process) can be used. Let WCA_{ij} represent the weight of estimated benefit of each corrective action and $ICCA_{ij}$ denote the corresponding estimated implementing cost; then by deleting assumption of tangible and intangible benefits, the efficiency of each corrective action is formulated as in the following:

$$AICA_{ij} = \frac{W_{CA_{ij}}}{ICCA_{ij}}. \quad (2)$$

Next, since company expects to reach the goal in a limited implementing time span, a "lead time" success factors should be considered to appraise competing corrective action. In this study, the lead time of success of corrective action is defined as the estimated time span from initial implementation of a corrective action until an expected benefit can be observed. If TCA_{ij} represents lead time success factor from implementing specific CA, then (2) is rewritten as in the following:

$$AICA_{ij} = \frac{W_{CA_{ij}}}{ICCA_{ij}TCA_{ij}}. \quad (3)$$

2.2. Quantifying the Risk of Selecting Corrective Action. In addition to considering the impact and effort components, decision makers should also take the risks that may occur in selecting corrective action candidates into consideration [17]. The risk will be considered since uncertainty is an unavoidable factor to implementing strategy [18]. According to Söderholm and Karim (2010 [19]), the risk in implementing corrective action may be defined as "the effect of uncertainty on achieving goal." The modes of effect might be either the positive or negative types [20] and their typologies can be consulted to [21]. In this study, the payoff factors $\rho_{CA_{ij}}$ is used to represent the surrogate of the benefits or losses gain due to the existence of risk factor corresponding to CA and it can be estimated as follows:

$$\rho_{CA_{ij}} = P(R)\,CA^{+}_{ij}LCA^{+}_{ij} - P(R)\,CA^{-}_{ij}LCA^{-}_{ij}. \quad (4)$$

$P(R)CA^{+/-}_{ij}$ and $LCA^{+/-}_{ij}$ represent the probability of risk event occurrence when selecting a corrective action and related estimated economic consequences.

Indeed, determining probability of risk event occurrence is not easy. Assuming that the explanatory risk variable is available, it can be accomplished by using logistic regression methodology. However, if it is not available, a dimensionless ordinal scale will become the value of risk impact and occurrence of risk events. For simplicity in practical application, the use of 1–10 Likert-like scale can be used to represent the magnitude of risk impact and its corresponding occurrence score. If no historical data available, the basis to determine the scale can be based on decision makers' judgment. The estimated economic losses due to risk event occurrences can be consulted to [22, 23]. In reverse, some measures to estimate the indication of positive outcomes of expected benefit value can be referred to [24]. Next, considering the risk attitude of FMEA team, the risk aversion factor (RA) should be taken into consideration and its score can be estimated based on [25].

3. Estimating Preference Score of Corrective Action

Assuming that each competing CA is timely feasible for implementation, formulation of a preference score to rank competing corrective actions is based on idea that decision maker will choose the corrective action with the largest failure risk, benefit impact, payoff, the least efforts, and shortest lead time success. Therefore, by considering FMEA team's desirability, impact, effort, and risk and neglecting interdependency among CAs, the attractiveness index (AI) as surrogate of decision makers' preference score in choosing each competing corrective action can be represented as in the following:

$$AICA_{ij} = \frac{W_{CA_{ij}}RPNFM_i CDCA_{ij}\rho_{CA_{ij}}}{ICCA_{ij}TCA_{ij}RACA_{ij}}. \quad (5)$$

The nominator of (5) is the benefit impact components of CA; meanwhile the denominator is the effort component of CA. Larger $AICA_{ij}$ index represents larger attractiveness of corresponding CA, and in reverse, lower $AICA_{ij}$ indicated lower attractiveness of certain CA.

Table 1: Root cause and effect analysis of critical failures from case example (excerpted partly from [28]).

Criticality priority	Failure mode	Effects	Possible causes
1	Unreliable supply of goods/merchandise (RPN = 27.29)	Shortage of goods	Poor supplier evaluation and selection
		Unreliable supply of goods/merchandise	Inappropriate supplier relationship management
		Lost sales	Insufficient inventory of suppliers
		Decrease customer loyalty	Inadequate marketing research
		Customer complaint	Lack of upward communication
		Complicated job allocation and replenishment activity	Insufficient customer relationship focus
		Customer leave	Failure to match demand and supply
2	Air conditioning malfunction (RPN = 25.38)	Foods deteriorate	Poor electrical power design
		Customer complaint	Aged air conditioning
		Customer leave	Fail to adjust the sales floor temperatures

4. Research Methodology

In attempt to demonstrate the applicability of our theoretical model, a case study is presented. According to Yin (1994 [26]), the typical case study chosen as this study is aimed at demonstrating application of the new theory, answering the "why" and "how" research questions, and noticing that the researchers have no control over the object of study.

4.1. Illustrative Example. In this study, a case study adopted partly from [27] which pertains to hypermarket consumers' good selling service is presented as case example. The hypothetical goal is to appraise competing CAs by considering amount of efforts and estimated impact and uncertainty on implementing CA. Note that all figures used here are hypothetical and are used for illustrative purpose only.

4.2. Implementing Procedure. The implementing procedure to apply our proposed model is described in the following sections.

4.2.1. Determine Criticality of Service Failure Modes. Referring to Table 1, based on the RPN estimation of partial failure modes from [27], the first rank of critical failure modes is "Unreliable supply of goods/merchandise" and the second rank is assigned to "Air conditioning malfunction." Every failure mode has multiple causes and effects. Depending on the familiarity of FMEA team and deep analysis, various arrays of Root Cause Analysis as represented by [28] can be used in this stage.

4.2.2. Determine Desirability Index of Potential Corrective Actions. Upon probable root causes are identifiable, based on brainstorming, targeted goal and resource capability; desired performance specification is then determined. In line with the goal in implementing CA, qualitative and quantitative goals should exist. For example, effort of "increase supplier frequency contact" has qualitative goal to "improve emotional relationship with suppliers" and "perform supplier evaluation." This is also proposed to achieve the goal of "reduction in the lead time span of purchased goods/merchandise." To simplify the calculation, the use of Likert like 1–5 scale is used to facilitate in quantifying qualitative attributes. The composite desirability index of every potential CA is calculated between desirability against failure occurrence rate reduction and service performance specification attributes by using (1). The results are then depicted in Table 2. Among competing CAs, the effort of "Increase frequency of supplier contacts (CA_{12})" and "Fostering inter-personal relationships with outdoor activities (CA_{15})" has the largest desirability index related to the first critical failure mode and "Investing staff to AC maintenance training (CA_{21})" has the largest desirability related second critical service failure mode.

4.2.3. Estimate the Benefit Score of Potential Corrective Actions. In attempt to estimate the benefit of specific CA by using the AHP, some criteria are used as basis for calculation. The first criterion is the weight of failure attributes from which service dimension came from. Then, the second criterion is related to the categories of goal to which the CA will be targeted. In this study, it was supposed that the company of case example owned its own criteria based on the Likert like 1–3–5–7 scoring model. Using such scale as scoring basis, any CAs which aimed to improve sustainability are given score 7, product/service quality is scored 5, profitability is scored 3, and 1 is assigned to staff internal growth. The score of composite benefit weight is then obtainable by multiplying the weight of SERVQUAL dimensions and goal of targeted goal as described above. The overall result of applying composite scoring model mentioned above is then given as in Table 3.

4.2.4. Estimate the Payoff Score of Competing CAs. In attempt to estimate the payoff factor, (4) is used and the score on probability of risk event occurrence is supposed to be based on the FMEA team judgment. The decision tree diagram was used to model the potential outcome of risk events. All theoretical risk factors pertaining to this study are determined upon breaking down the CAs and then the results are depicted in Table 4.

4.2.5. Estimate Effort Components of Each Corrective Action. Estimation of implementing cost and lead time of success of a corrective action is based on assumption that

Table 2: Desirability index of potential CAs of case example.

Root cause of failure mode	Potential corrective action	Goal (benefit)	Current occurrence score/targeted failure occurrence score	Current performance/targeted performance	Limit: Minimum	Limit: Target	Limit: Maximum	Weight	Composite corrective action desirability index
Unreliable supply of goods/merchandise (FM_1)			5/3						
Poor supplier evaluation and selection	Perform supplier evaluation (CA_{11})	Reduce the lead time of purchased goods		2 days/0.5 day	0.5 day	2	7 days	3	0.728
Inappropriate supplier relationship management	Increase frequency of supplier contacts (CA_{12})	Improve physiological relationship with suppliers		1/4	2	4	5	4	2
Insufficient inventory of suppliers	Finding new creditors (CA_{13})	Increase financial capability to add new suppliers		2/3	1	3	4	8	0.000304
Inadequate marketing research	Hiring market consultant (CA_{14})	Increase understanding on market dynamics		70%/90%	80%	90%	100%	8	0.0000305
Lack of upward communication	Fostering interpersonal relationships with outdoor activities (CA_{15})	Increase flow of inner and outer company communication		70%/100%	70%	100%	100%	5	2
Insufficient customer relationship focus	Delegate marketing staff visiting to customers (CA_{16})	Increase pleasant communication quality with suppliers		70%/80%	70%	80%	100%	5	0.00823
Air conditioning Malfunction (FM_2)			3/1						
Poor electrical power design	Investing staff to AC training (CA_{21})	Increase preparedness staff against sudden AC malfunction in future		2/5	2	4	5	5	1
Aged air conditioning	Purchasing new AC units (CA_{22})	Increase convenience in shopping		2/5	2	3	5	8	0.000304
Fail to adjust the sales floor temperatures	Improve empowerment of operation staff on the sales floor (CA_{23})	Increase responsiveness against sudden inconvenience at shop floor		1/5	1	5	5	8	0.20

Table 3: Benefit score of corrective action.

Failure mode	Corrective action (CA)	Category of targeted goal/score	Dimensions of SERVQUAL/score	Composite weight of benefit
Unreliable supply of goods/merchandise (FM_1)	Performing supplier evaluation (CA_{11})	Product/service quality/5	Reliability/1.50	7.5
	Improve supplier relationship (CA_{12})	Sustainability/7	Reliability/1.50	10
	Add adequacy of suppliers (CA_{13})	Sustainability/7	Reliability/1.50	10
	Improve technique of marketing research (CA_{14})	Profitability/3	Reliability/1.50	4.5
	Facilitate internal upward communication (CA_{15})	Internal growth/1	Reliability/1.50	1.50
	Improve focus on customer relationship communication (CA_{16})	Sustainability/7	Reliability/1.50	10
Air conditioning malfunction (FM_2)	Train engineering staff on air conditioning machine maintenance (CA_{21})	Service quality/3	Tangible/0.80	2.40
	Purchase new AC units (CA_{22})	Service quality/3	Tangible/0.80	2.40
	Improve empowerment of operation staff on the sales floor (CA_{23})	Staff internal growth/1	Tangible/0.80	0.80

the aforementioned factors are deterministic in terms of their value, and those were assumed obtainable from previous experience. To simplify the calculation, a Likert-like 1–10 scale is used to represent the magnitude of implementing cost and lead time score where 1 is assigned to "the least/smallest" categories and 10 is assigned to the "longest/largest" score categories. The scale of lead time score can be based on team discretion. The results in estimating the abovementioned components are depicted in Table 5.

4.2.6. Estimate Attractiveness Index of Each Corrective Action. After performing some calculus as described in brief in Section 2, by using (5), the attractiveness index of each corrective action in case example is then depicted as in Table 6.

5. Discussions

Driven by observable gaps on improving quality of risk-based strategy selection in previous FMEA references, a model for appraising competing improvement strategies is presented. The model gives a theoretical procedure to select corrective actions by considering FMEA team desirability, amount of efforts needed, and the risk on implementing corrective actions. Illustrative example from hypermarket consumer service is provided to demonstrate the proposed model. By using the proposed model, instead of relying only on the failure risk dimension as represented by the risk priority number (RPN) measures as commonly used by earlier FMEA references, management desirability and uncertainty outcome of implementing improvement initiative are considered at the same time.

Considering time-based competition paradigm, the success lead time of implementing strategy is incorporated as complimentary basis to measure time efficiency in appraising competing improvement efforts. Embodiment of lead time success of strategy implementation will provide supplemental basis to appraise competing CAs instead of relying on their financial dimension only. Thus, it enables to appraise competing corrective action from both two important dimensions, financial and time efficiency. Within risk response study, inclusion of time dimension is justified as described by [29].

FMEA takes the risks naturally found in real situation into consideration, and the risk aversion factor is incorporated in the model. In brief, for managerial purpose, the paper provides a theoretical exemplary step in incorporating team desirability and how to deal with uncertainty outcomes when decision makers attempted to rectify their business problems based on competing strategy options. In line with growing studies on utilizing FMEA in service operations, indeed, there are many earlier techniques that have been used to overcome the limitation of using the RPN solely as basis to ranking improvement efforts. For example, grey relational analysis-based failure risk prioritization has been proposed by [5] to deal with interrelationship of various service dimensions in a hospital service. Moon et al. (2013) [30] presented the integration of fuzzy logic and grey theory for ranking critical failure modes at a car dealership service. Some other methods for ranking the risk of failures as basis for selection improvement efforts using FMEA methodology can be referred to [31]. What is observed from the previous works has become the novelty of our approach compared to earlier studies on incorporating the FMEA team desirability and possibility on risk occurrence when selecting a corrective action within framework of impact and effort analysis. Moreover, we also provide an exemplar on how to appraise the weight of corrective action by using the AHP tool. To the best of our knowledge, there are no previous FMEA-based improvement strategy selection references which include all the aspects above.

Despite the benefits for both of theoretical and practical purposes, the proposed model is certainly not free from limitations. Since this is still based on conceptual idea, the model proposed lacks strong reliability, validity, and generalization to other service settings. The proven advantage(s) against conventional FMEA-based CA reprioritization shall be tested in real application followed by appropriate statistical testing. Next, performance-related specification targets are usually probabilistic in nature and those are not accommodated in the proposed model. In addition, regarding that the goal of

Table 4: Estimation on the payoff score of corrective actions of case example.

Corrective action	Payoff components: Potential positive consequences	Probability of success in achieving goal	Benefit category score	Estimated gain score	Potential negative outcome	Probability of failure in achieving goal	Loss category score	Estimated loss score	End effect category	Payoff score
Performing supplier evaluation (CA_{11})	Reduction in unreliable delivery schedule	0.8	10	8	Resistance from suppliers	0.2	8	1.6	Direct and opportunity financial loss for company	7.4
Improve supplier relationship (CA_{12})	Possibility on increase in economic transaction	0.4	7	2.8	Limited knowledge to reveal real suppliers' desire	0.6	8	4.8	Financial opportunity loss	−2
Add adequacy of suppliers (CA_{13})	Increase in financial opportunity gain	0.4	4	1.6	Financial hardship moment to obtain banking loan	0.6	7	4.2	Opportunity and sale loss	−2.2
Improve technique of marketing research (CA_{14})	Opportunity gain due to widening market share	0.5	3	1.5	Nonapproval from top management	0.5	3	1.5	Loss sale (revenue risk), degrading staff moral	0
Facilitate upward communication (CA_{15})	Increase in working productivity	0.7	3	2.1	Unfavorable company culture	0.5	5	2.5	Staff productivity loss	−0.4
Improve focus on customer relationship communication (CA_{16})	Increase in customers' order	0.4	5	2.0	Nonapproval from company owner	0.6	1	1.6	Sale opportunity loss	0.4
Air conditioning malfunction (FM_2)										
Invest staff on AC Training (CA_{21})	Speed in alleviating AC problems	0.8	8	3.6	Unresolved AC malfunction problem	0.2	8	1.6	Opportunity loss sale	2
Purchase new AC units (CA_{22})	Ensuring store convenience	0.2	8	1.6	Nonapproval from top management	0.8	8	6.4	Opportunity loss sale	−5.8
Empower available crew (CA_{23})	Improve empathy against aggravated customers	0.7	8	5.6	Resistance to change from staff	0.3	8	2.1	Staff productivity loss	3.5

Table 5: Estimation on the score of effort components of each corrective action.

Failure mode	Corrective action	Implementing cost score	Success lead time score	Risk aversion factor
Unreliable supply of good/merchandise (FM_1)	Performing supplier evaluation (CA_{11})	7	3	0.3
	Improve supplier relationship (CA_{12})	5	5	0.3
	Add adequacy of suppliers (CA_{13})	8	5	0.5
	Improve technique of marketing research (CA_{14})	10	2	0.3
	Facilitate intercompany upward communication (CA_{15})	2	4	0.1
	Improve focus on customer relationship communication (CA_{16})	4	2	0.3
Air conditioning malfunction (FM_2)	Invest staff on attending AC training (CA_{21})	5	3	0.2
	Purchase new AC equipments (CA_{22})	6	1	0.1
	Empower available crew (CA_{23})	2	4	0.3

improvement effort may not be fully reached, team tolerability in achieving improvement goals should be also taken into consideration. Another limitation is that since SERVQUAL's dimension is the basis of this study, following [32], the characteristics of SERVQUAL dimensions which are static over time shall be considered carefully in implementing the model in practical situation. Ignoring the change of SERVQUAL attribution over time is inappropriate since that will increase the possibility of strategy obsolescence. Another gap that must be taken into consideration for practical purposes is that in real application setting, various competing corrective actions may have interdependency and such situation is not covered within the model.

Realizing that FMEA session is a kind of team-oriented activity, where different persons may have different risk attitudes, and assigning risk aversion score into a single numerical value as demonstrated by this study are not appropriate. However, such situation is beyond coverage of this study. Lastly, the fuzziness of the scale used in the model as basis to score the effort variables is not considered in formulating the attractiveness index.

5.1. Managerial Implications

5.1.1. Utilization of Derringer Desirability Index in Articulating FMEA Team Desirability. In this study, the Derringer desirability index along with failure occurrence rate reduction ratio is used to represent FMEA team desirability in alleviating critical failure modes. Utilization of such index can facilitate FMEA team to synchronize the targeted improvement effort. Specific class of desirability index can be used with the targeted improvement effort. For instance, for corrective action which is intended to reach larger the better service performance specification, the corresponding larger the better (LTB) Derringer desirability class can facilitate such targeted goal. By using the Derringer desirability index, FMEA management team can indicate which failure mode and corresponding corrective action's specification target is going to be achieved.

5.1.2. Management of Corrective Action. In practical business situation, selection of competing improvement efforts to curb the root cause of failure mode is usually based on cost-benefit criteria as company is a kind of profit seeker body and not solely based on the risk dimension of failure mode (the RPN of failure). In this regard, inclusion of impact and effort analysis proposed in this study can facilitate company management with more realistic improvement from economic perspective. Moreover, using the composite weight in appraising competing improvement initiative, inclusion on payoff score, and risk aversion factor, more real improvements are in sight. It is because in real world application, selecting improvement initiative is a risky process and the actor who implements such initiative is a human being and the level of risk is thus increased.

6. Conclusion

Despite the importance in risk-based improvement effort, inclusion on team desirability and risks in selecting corrective actions are omitted from previous FMEA references. In this paper, a new theoretical model to select competing improvement strategies based on management desirability and risk of strategy selection is proposed. Application of the theoretical model is demonstrated with case example and merits and demerits of the model are also discussed.

The proposed model advances service FMEA knowledge to both academicians and practitioners in the following ways:

(1) providing means on how to integrate FMEA team desirability and risks in achieving specific performance goal when alleviating critical failure mode(s);

(2) providing an easy example on how to determine the potential corrective actions upon obtaining information on the critical failure modes, their potential negative impacts, and the probable root causes;

(3) presenting an approach on how to consider impact and effort aspect to select competing risk-based improvement initiative. In addition, the model provides exemplary on how to appraise the weight of corrective action by using certain criterion as facilitated by the use of decision tool, the AHP;

(4) providing illustrative example on how to identify strategic corrective action option which corresponds to critical failure modes in the vital service quality dimensions;

Table 6: Attractiveness index of CA of case example.

Failure mode	Corrective action	Risk priority number	Impact component: Desirability index	Impact component: Weight of CA goal	Impact component: Payoff score of CA	Effort component: Implementing cost	Effort component: Lead time success of CA	Risk aversion factor	Attractiveness index
Unreliable supply of goods/merchandise (FM_1)	Perform supplier evaluation (CA_{11})	27.29	0.728	7.5	7.4	7	3	0.3	175.01
	Improve supplier relationship (CA_{12})		2	10	−2	5	5	0.3	145.54
	Add adequacy of suppliers (CA_{13})		0.000304	10	−2.2	8	5	0.5	0.009125
	Improve technique of marketing research (CA_{14})		0.0000305	4	0	10	2	0.3	0
	Facilitate intercompany upward communication (CA_{15})		2	1.50	−0.4	2	4	0.1	13.64
	Improve focus on customer relationship communication (CA_{16})		0.00823	10	0.4	4	2	0.3	0.748
Air conditioning malfunction (FM_2)	Invest staff on attending AC training (CA_{21})	25.38	1	2.40	2	5	3	0.2	140.60
	Purchase new AC units (CA_{22})		0.000304	2.40	−5.8	6	1	0.1	−0.178
	Empower available crew (CA_{23})		0.20	0.80	3.5	2	4	0.3	5.922

(5) showing a simple, step-by-step, and risk-based improvement effort selection model which not only considers the risk dimension due to failure modes occurrence, but also at the same time considers management desirability, risk of implementing specific corrective action, cost and benefit of corrective action, and also risk attitude of FMEA team.

Regarding that this study is still in theoretical stage, some extendable research directions are viable as avenue for further investigations. First and foremost, applying the conceptual model in real situation and comparing the actual benefit between conventional FMEA and the proposed model shall be accomplished by future study. Second, inclusion of the value analysis, customers and competitors' reaction, and strategy flexibility in appraising competing improvement efforts are still unknown in the literature. Considering robustness in appraising competing improvement efforts becomes a challenging issue for further investigation.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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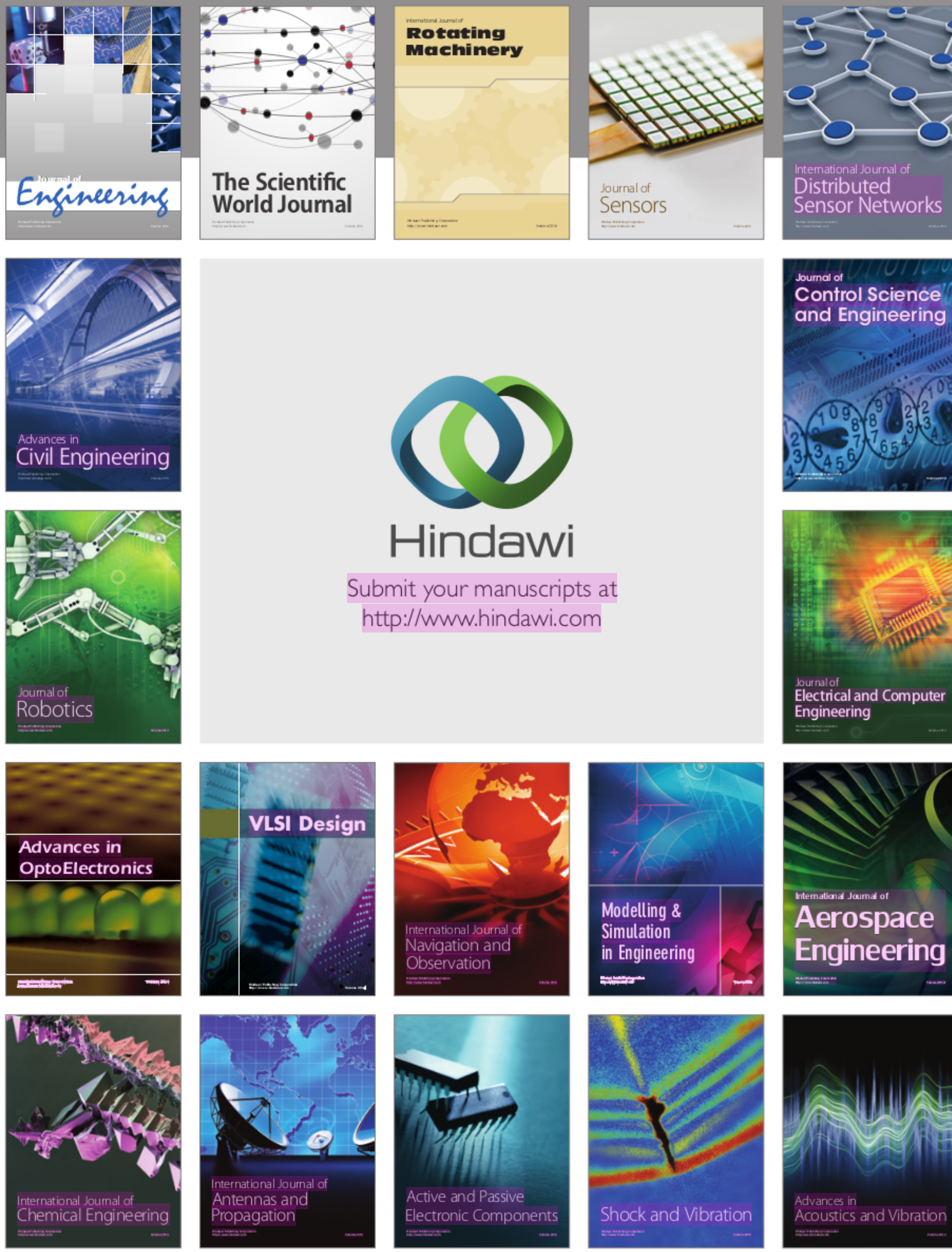
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