

Integrating Production Assessment with PPAP – A QFD Approach

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Abstract

All organizational activities, especially production activities, have to be consolidated in new premises for a supply chain of particular products to be competitive in a globalization market. Production Part Approval Process (PPAP) is a second-party approval process, as well as a part of the consolidating mechanism, conducted by a manufacturing company on its suppliers to ensure quality of parts from these suppliers. On the other hand, Production Assessment such as Total Productivity Management (TPM) is a third-party approval process, also a part of the consolidating mechanism, to endorse the production and process capacity of the suppliers. To avoid repetitive resource investment of the suppliers on these approval processes, this study proposes a three-phase approach called PPAP-QFD in an attempt to integrate requirements from both PPAP and Production Assessment, and then outline necessary improvement methods to meet these requirements via Quality Function Deployment (QFD). A real-world case study utilizing PPAP-QFD is presented to demonstrate how this approach can continuously improve production capacity and ensure product quality.

Keywords

Production assessment, Production part approval process (PPAP), Quality function deployment (QFD), Real-world case study.

1. Introduction

In global competition era, product quality is a key factor for the success of a manufacturing company and its suppliers. Production Part Approval Process (PPAP) is an approval process conducted by a manufacturing company on its suppliers to ensure quality of parts from these suppliers. Not until suppliers meet PPAP requirements can they supply parts to the manufacturing company. In the meantime, with continuous improvement, suppliers may also seek external assessment on their production management systems. PPAP requirements are classified by 5 levels (AIAG 2006), unless requested by customers, the default level is 3 for all suppliers, that is, Part Submission Warrant (PSW) with product samples and complete supporting data. It is a suitable tool and have many positive side effects too from better documentation and communication to cooperation with suppliers in developing new product (Hermans and Liu 2013). Effective implementation of PPAP will help the supply chain to improve the quality of the product, reduce the cost by optimal use of resources and maintain on time delivery at competitive cost (Khanna 2005). For PPAP, a process with inter-correlated activities, to be effective, Rewilak and Tokaj (2012) proposed four concepts based on the Taguchi loss function. They suggested guidelines based on observed correlations between PPAP effectiveness indicators and manufacturing process performance indices should be developed. Meanwhile, Dai and Blackhurst (2012) proposed a

four-phase approach that integrated Analytical Hierarchy Process (AHP) with QFD, the so-called AHP-QFD, for supplier assessment in terms of sustainability.

QFD was developed in Japan in the late 1960s by professors Akao and Mizuno (Akao 1994). The Professors aimed at developing a quality assurance method that would design customer satisfaction into a product before it was manufactured. Prior quality control methods like Ishikawa were primarily aimed at fixing a problem during or after manufacturing. It is a system for translating customer requirements into appropriate company requirements at each stage from research and product development to engineering and manufacturing to marketing/sales and distribution (Bossert 1991). Due to its systematic approach to describe the cause and effect relationships between the competitive priorities, significant measures of performance, the best practices and the associated variables, QFD is applied to detailing capacity planning of manufacturing systems (Kochhar and Eguia 1998). It is also served as a benchmarking tool for building envelop design solutions in market (Cho *et al.* 2015). On the other hand, Devrim Ictenbas and Eryilmaz (2011) implemented QFD in strategy planning and shown that the customer-driven strategy can systematically translate vision into action, target opportunities, and create innovative strategies. In addition, a framework based on QFD can be used to analyze the process of new product development (NPD) (Murata 2017). Aniyani and Pramod (2018) moved further by develop DCOR-QFD model to improve process performance and product quality for situations when product refreshing, NPD, and new technology introduction.

Third party production assessment such as TPM (Total Productivity Management) can significantly improve system performances. Schuh *et al.* (2011) integrated assessment and configuration of production systems that aligned overall elements of the product and production system to eliminate complexity- related bottlenecks and over capabilities to increase the global competitiveness of the company. As far as the suppliers are concerned, PPAP and other external assessment, a second-party approach versus third-party approach, are both meant for improving production management effectiveness and upgrading manufacturing levels. However, resources dedicated to both approaches are highly overlapped. To avoid wasting resource, conflicting management procedures, as well as confusing employee's comprehensions, this study proposes a three-phase approach called PPAP-QFD in an attempt to integrate requirements from both PPAP and external assessment on production management.

2. Methodology

The PPAP-QFD outlines necessary improvement methods to meet these requirements from both PPAP and external assessment on production management via Quality Function Deployment (QFD). As illustrated in Figure 1, the first phase is transferring PPAP requirements into assessment items on production management system. The eighteen requirements in PPAP are weighted according to their relative importance, as well as the ability of the supplier to fulfill each requirement. The second phase of PPAP-QFD focuses on transfer assessment items into performance indices on production, quality, cost, due date, safety, and morale. The last phase then seeks improvement methods on improving these performance indices via relationship matrix. After PPAP-QFD, an action plan can be outlined to implement in systematic order all improvement methods. It is important to mention that PPAP-QFD is a continuous process. Companies adopt PPAP-QFD have to setup a review period for their suppliers. Each review for any supplier goes through these three phases and generate an action plan for the period with a list of KPIs to be improved and potential improvement methods to be conducted. The three phases of PPAP-QFD are outlined in the following sections.

2.1 Phase I - PPAP Deployment

The first phase in the PPAP-QFD approach is the PPAP deployment. The eighteen requirements in the PPAP describe customer's demand for supplier, that is equivalent to customer's voice in the QFD. Both PPAP and QFD are customer demand oriented. In this phase, customer's demand in PPAP is transformed to assessment items of the production management.

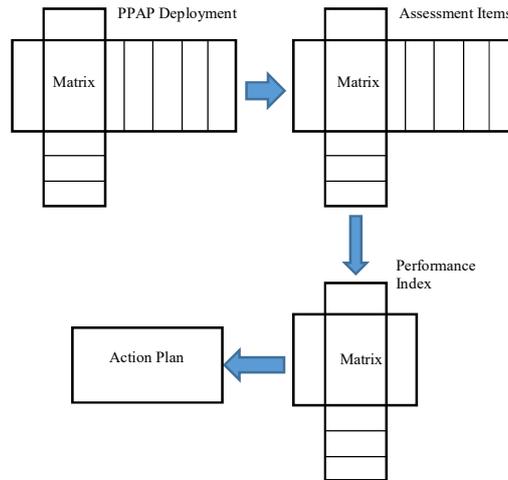


Figure 1. The PPAP-QFD approach

Stage 1 of PPAP deployment is to capture customer's demand in term of supplier's fulfillment on the eighteen PPAP requirements. As illustrated in Figure 2, relative importance (Ia_1) to each other of the eighteen requirement in PPAP are tabulated and rated by the procurement manager or other managers of the company. The supplier's ability to carry on these requirements are then evaluated by the customer before they write down their expectations and percentage of improvement for each of the requirements about the supplier, where

$$\% \text{ of Improvement } (Ia_4) = \text{Expectation } (Ia_3) / \text{Ability to Carry on } (Ia_2).$$

Finally, the importance weighting of each requirement in PPAP can be derived by multiplying relative importance by % of improvement, i.e.,

$$\text{Importance Weighting } (Ia_5) = \text{Relative Importance } (Ia_1) \times \% \text{ of Improvement } (Ia_4)$$

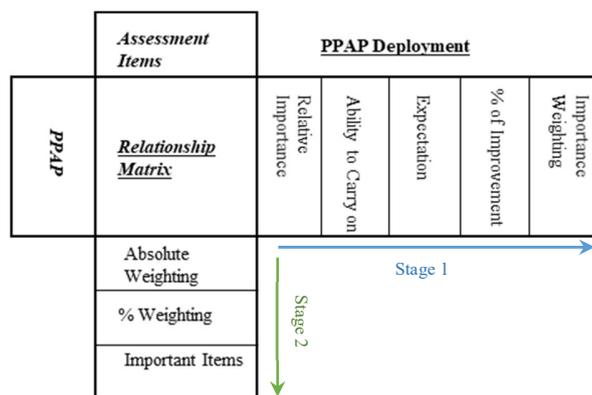


Figure 2. PPAP Deployment

Stage 2 of PPAP deployment is to decide assessment items and their contents. In 2002, Corporate Synergy Development Center (CSD) issued a list of assessment items on evaluating a corporate synergy system in five categories – financial, marketing, management, technical, and manufacturing process functions (CSD 2002). All but financial and marketing functions are related to the eighteen requirements of PPAP. This study adopts a total of 60

potential assessment items from categories of management, technical, and manufacturing process functions. A relationship matrix (M_1) is designed to be filled out by managers or experts of the company to indicate the degree of relationship between any requirement of PPAP and any assessment item. Absolute weighting (Ib_1) of an assessment item is the summation of degree of relationship times importance weighting (Ia_5) of the requirement of PPAP. Additionally, percentage of weighting (Ib_2) of an assessment item is the proportion of its absolute weighting to the sum of absolute weighting of all assessment items. At last, important items (Ib_3) are those assessment items whose % of weighting ranking on top 20% (80/20 rule), i.e., the first 15 items.

2.2 Phase II - Assessment Item Deployment

The second phase in the PPAP-QFD approach is the assessment item deployment. Same as in phase I, Phase II takes two similar stages. But in this phase, important assessment items of the production management are transformed to performance indices.

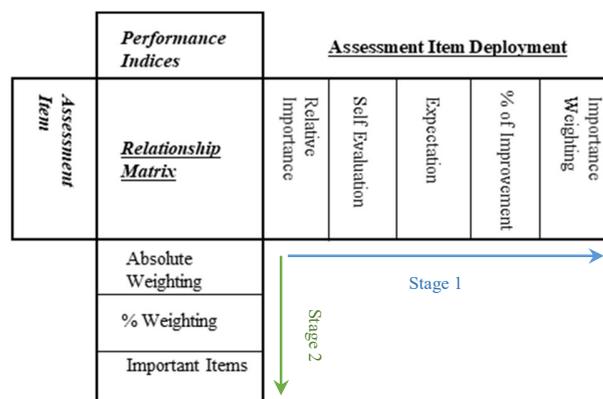


Figure 3. Assessment Item Deployment

Stage 1 of assessment item deployment is to capture importance weightings of important assessment items extracted in phase I. As illustrated in Figure 3, relative importance (IIa_1) to each other of the important assessment items are calculated from its % of weighting (Ib_2) divided by the summation of % of weighting of all of these important assessment items. The procurement manager or other managers of the company conduct self-evaluation before they write down their expectations and percentage of improvement for each of the important assessment items about the supplier, where

$$\% \text{ of Improvement } (IIa_4) = \text{Expectation } (IIa_3) / \text{Self Evaluation } (IIa_2).$$

Finally, the importance weighting of each important assessment items can be derived by multiplying relative importance by % of improvement, i.e.,

$$\text{Importance Weighting } (IIa_5) = \text{Relative Importance } (IIa_1) \times \% \text{ of Improvement } (IIa_4)$$

Stage 2 of assessment item deployment is to decide performance indices and their contents. In 1999, Corporate Synergy Development Center (CSD) published a book containing a full set of classic forms in TPM activity (Productivity Press 1999), in which production management indices are classified into six categories, i.e., productivity (P), quality (Q), cost (C), delivery (D), safety (S), and morale (M). This study adopts a total of 22 performance indices from these six category. A relationship matrix (M_2) is designed to be filled out by managers or experts of the company to indicate the degree of relationship between any important assessment item and any performance index.

Absolute weighting (IIb_1) of a performance index is the summation of degree of relationship times importance weighting (IIa_5) of the assessment item. Additionally, percentage of weighting (IIb_2) of a performance index is the proportion of its absolute weighting to the sum of absolute weighting of all performance indices. At last, important item (IIb_3) of any performance index is its rankings in terms of % of weighting. The company, then, can pick several performance indices for the current period to improve based on available resources on hand.

2.3 Phase III - Performance Index Deployment

The last phase in the PPAP-QFD approach is the performance index deployment. Same as in phase II, Phase III takes two similar stages. But in this phase, key performance indices of the production management are transformed into methods of improvement.

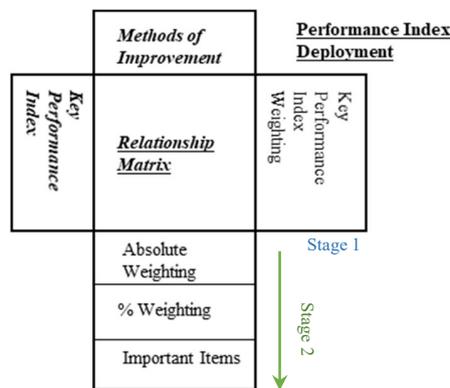


Figure 4. Performance Index Deployment

Stage 1 of performance index deployment is to capture importance weightings of key performance indices extracted in phase II. As illustrated in Figure 4, importance weightings ($IIIa_5$) to each other of the key performance index are calculated from its % of weighting (IIb_2) divided by the summation of % of weighting of all of these key performance indices.

Stage 2 of performance index deployment is to decide methods of improvement and their contents. There are a lot of methods for improvement. As far as production management is concerned, IE (Industrial Engineering) methods and QC (Quality Control) methods are most commonly used. This study adopts a total of 32 methods of improvement from IE and QC domains. A relationship matrix (M_3) is designed to be filled out by managers or experts of the company to indicate the degree of relationship between any key performance index and any method of improvement. Absolute weighting ($IIIb_1$) of a method of improvement is the summation of degree of relationship times importance weighting ($IIIa_5$) of the key performance index. Additionally, percentage of weighting ($IIIb_2$) of a method of improvement is the proportion of its absolute weighting to the sum of absolute weighting of all methods of improvement. At last, important item ($IIIb_3$) of any method of improvement is its rankings in terms of % of weighting. The company, then, can demand the supplier to conduct several methods of improvement from the ranking list for the current review period to improve key performance indices, and thus improve its fulfillment on the eighteen requirements of PPAP.

2.4 Action Plan

The final product of conducting the PPAP-QFD approach is to generate an action plan for the period of time (usually a year). This action plan outlines PPAP requirements and theirs corresponding assessment items, key performance indices, and selected methods of improvement for the period. In addition, who and what department should be

responsible to execute this action plan, as well as who conducts the assessment afterward and what are the scores for each item. PPAP-QFD is a continuous improvement approach, therefore, action plans for different periods are certainly different.

3. The Real-world Application

Established in year 2010, T company focuses on researching and manufacturing medical and rehabilitation equipment to be sold worldwide. With many certifications such as ISO 13485 and TUV on hand, T company implement PPAP in 2017 in seeking for another certification. Managers of T company agreed to participate in this study by implementing PPAP-QFD, and assigned an assistant director from procurement department and the leader of quality assurance department to assist this study. The case study run throughout the entire year of 2017. The entire process of this PPAP-QFD application is outlined below.

3.1 Phase I - PPAP Deployment

Stage 1 of PPAP deployment is to capture customer's demand in term of supplier's fulfillment on the eighteen PPAP requirements. As illustrated in Table 1, requirement on the left of the table is compared to that on the top. Relative importance (I_{a1}) is weighted by divided total points of the requirement to grand total of all requirements. Continuing in Table 2 is a series of calculations to get importance weightings (I_{a5}) of all requirements of PPAP for the review period.

Table 1. Relative Importance of the Eighteen Requirement of PPAP

The 18 Requirements of PPAP	1. Design Record	2. Authorized Engineering Change Document	3. Customer Engineering Approval	.....	.....	16. Checking Aids	17. Special Requirement by Customer	18. Part Submission Warrant	Total points	Relative Importance Weighting
1. Design Record	-	⊗	⊗	.....	.....	□	O	Δ	38	5.86
2. Authorized Engineering Change Document	□	-	⊗	□	O	Δ	19	2.93
3. Customer Engineering Approval	□	□	-	□	□	Δ	7	1.08
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16. Checking Aids	⊗	⊗	⊗	-	O	O	61	9.41
17. Special Requirement by Customer	Δ	Δ	⊗	Δ	-	O	43	6.64
18. Part Submission Warrant	O	O	O	Δ	Δ	-	39	6.02
* ⊗ very important, 5 points; O important, 3 points; Δ less important, 1 point; □ much less important, 0 point.									648	100

Table 2. Importance Weightings of the Eighteen Requirement of PPAP

<u>The 18 Requirements of PPAP</u>	Relative Important Weighting	Ability to Carry on	Expectation	% of Improvement	Importance Weighting
1. Design Record	5.86	3	5	1.67	9.77
2. Authorized Engineering Change Document	2.93	1	4	4.00	11.73
3. Customer Engineering Approval	1.08	1	4	4.00	4.32
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16. Checking Aids	9.41	3	4	1.33	12.55
17. Special Requirement by Customer	6.64	2	5	2.50	16.59
18. Part Submission Warrant	6.02	2	5	2.50	15.05

Stage 2 of PPAP deployment is to decide assessment items and their contents. As illustrated in Table 3, potential assessment items are rated with regard to its relation with each of the eighteen requirement of PPAP. The absolute weighting (I_b) of each assessment item is the summation of rating times importance weighting of every requirement of PPAP. Based on 80/20 rule, twelve assessment items (ranking on top 20%) are listed in Table 4 for the review period which account for 65.35% total weightings.

Table 3. Weighting and Ranking of the Assessment Items

<u>Assessment Items</u> <u>18 Requirements of PPAP</u>	R&D_New Product Development	R&D_Reliability	R&D_Budget	.....	.....	QM_Inspection	QM_OSA & Inspection Free	QM_QCC	QM_Education & Training	Importance Weighting
1. Design Record	⊗	O	□	: :	: :	□	Δ	□	Δ	9.77
2. Authorized Engineering Change Document	□	□	□	Δ	Δ	□	Δ	11.73
3. Customer Engineering Approval	Δ	□	□	: :	: :	□	□	□	□	4.32
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16. Checking Aids	Δ	⊗	□	: :	: :	O	Δ	□	Δ	12.55
17. Special Requirement by Customer	O	□	□	: :	: :	O	Δ	□	Δ	16.59
18. Part Submission Warrant	⊗	O	□	: :	: :	O	O	□	Δ	15.05
Absolute Weighting	514.2	452.8	124.19	: :	: :	467.28	209.44	12.963	185.37	
% of Weighting	6.98%	6.15%	1.69%	: :	: :	6.35%	2.84%	0.18%	2.52%	
Important Items (Ranking)	2	4	21	: :	: :	3	14	35	17	
* ⊗ strong related, 5 points; O related, 3 points; Δ weak related 1 point; □ not related, 0 point..										

Table 4. Selected Assessment Items for the Review Period

Ranking	Assessment Item	Absolute Weighting	% of Weighting
1	S_QC Standard	590.1	8.01%
2	R&D_New Product Development	514.2	6.98%
3	QM_Inspection	467.3	6.35%
4	R&D_Reliability	356.6	4.84%
5	S_SOP	431.1	5.85%
6	S_Fixture & Tools	402.5	5.47%
7	PT_Mold & Fixture Development	399.4	5.42%
8	TS_Process Capability	362.9	4.93%
9	PT_Equipment	361.1	4.90%
10	R&D_PD Survey	356.6	4.84%
11	S_Material Usage	290.6	3.95%
12	TS_PDM	280.7	3.81%
Total % of Weighting			65.35%

3.2 Phase II – Assessment Item Deployment

The second phase in the PPAP-QFD approach is the assessment item deployment. Selected (relatively important) assessment items of the production management are transformed to performance indices. As listed in Table 5, the selected assessment items only related to production (P), Quality (Q), Cost (C), and Delivery (D), therefore Safety (S) and Moral (M) are not considered for the current review period. After the transformation, key performance indices for the review period is selected based on their important items ranking (I1b₃) and listed in Table 6 which account for 58.20% of total weightings.

3.3 Phase III – Performance Indices Deployment

The last phase in the PPAP-QFD approach is the performance index deployment. In this phase, key performance indices of the production management are transformed into methods of improvement. Of a total of 21 methods of improvement, the top seven methods, i.e., SPC, Visual Management, Jidoka, MSA, Cause-and-effects Diagram, Plato Analysis, and Autonomous Maintenance, account for 49.97% of total weightings as listed in Table 7. Therefore, for the current review period, the company should encourage the supplier to implement these methods of improvement so that key performance indices of the supplier can be improved effectively. The supplier, on the other hand, shall outline a detailed action plan to implement these methods of improvement so as to be more compliant with the eighteen requirements of PPAP.

Table 5. Transformation of Selected Assessment Items into Production Performance Indices

Performance Indices Assessment Items	Labor Productivity	OEE	Utilization	Operation Rate	Yield	.....	.....	Lead Time	Stock Level	% of Weighting
S_QC Standard	□	O	□	□	⊗	⋮	⋮	□	□	8.01
R&D_New Product Development	□	□	□	□	□	⋮	⋮	□	□	6.98
QM_Inspection	□	⊗	□	⊗	⊗	⋮	⋮	□	□	6.35
.....			⋮	⋮
.....			⋮	⋮
R&D_PD Survey	□	□	□	□	□	⋮	⋮	□	□	4.84
S_Material Usage	□	O	□	O	⊗	⋮	⋮	O	⊗	3.95
TS_PDM	□	□	□	□	□	⋮	⋮	□	□	3.81
Absolute Weighting	10.78	171.66	53.87	190.97	148.72	⋮	⋮	94.97	19.75	
% of Weighting	0.69%	11%	3.45%	12.24%	9.53%	⋮	⋮	6.08%	1.27%	
Important Items (Ranking)	16	3	13	1	4	⋮	⋮	6	15	

* ⊗ strong related, 5 points; O related, 3 points; Δ weak related, 1 point; □ not related, 0 point..

Table 6. Key Production Performance Indices for the Review Period

Ranking	Key Performance Indices	Absolute Weighting	% of Weighting
1	Operation rate	190.97	12.24%
2	Proportion of Defects	189.75	12.16%
3	OEE	171.66	11%
4	Yield	148.72	9.53%
5	Customer Complaint	112.26	7.19%
6	Lead Time	94.97	6.08%
Total % of Weighting			58.20%

Table 7. Transformation of Key Production Performance Indices into Methods of Improvement

Key Performance Indices \ Methods of Improvement	2S	Visual Management	Autonomous Maintenance	Why-Why Analysis	PM Analysis	.....	.....	SPC	Cause & Effects Diagram	% of Weighting
Operation Rate	O	⊗	O	Δ	Δ	· · ·	· · ·	⊗	O	12.24
Proportion of Defects	O	⊗	O	Δ	Δ	· · ·	· · ·	⊗	⊗	12.16
OEE	O	⊗	⊗	Δ	⊗	· · ·	· · ·	⊗	O	11.00
Yield	O	⊗	O	Δ	Δ	· · ·	· · ·	⊗	O	9.53
Customer Complaint	Δ	Δ	Δ	⊗	O	· · ·	· · ·	⊗	⊗	7.19
Lead Time	O	⊗	O	Δ	O	· · ·	· · ·	⊗	O	6.08
Absolute Weighting	160.2	262.2	182.2	86.96	128.74	· · ·	· · ·	291	213.3	
% of Weighting	5.09%	8.32%	5.78%	2.76%	4.09%	· · ·	· · ·	9.24%	6.77%	
Important Items (Ranking)	11	2	7	17	14	· · ·	· · ·	1	5	
* ⊗ strong related, 5 points; O related, 3 points; Δ weak related, 1 point; □ not related, 0 point..										

4. Conclusions and Recommendations

All organizational activities, especially production activities, have to be consolidated in new premises for a supply chain of particular products to be competitive in a globalization market. Both PPAP and Production Assessment are part of the consolidating mechanism. However, repetitive resource investment on these approval processes would hinder the progress of the supplier toward global competitiveness. This study proposes a three-phase approach called PPAP-QFD in an attempt to integrate requirements from both PPAP and Production Assessment, and then outline necessary improvement methods to meet the eighteen requirements of PPAP via QFD. A real-world case study utilizing PPAP-QFD is presented to demonstrate how a company can apply this approach to continuously improve production capacity and guarantee product quality delivered by the supplier. It is recommended that a simplified version of this PPAP-QFD approach and a software program, such as the approach adopted by Moubachir and Bouami (2015), can be developed in the future for its more successful implementation.

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Biography / Biographies

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Hornng-Chyi Horng was born in Taichung, Taiwan in 1966. He came to USA in 1991 and got his M.S.E and Ph.D. degrees from the department of I&MSE at Arizona State University, in 1992 and 1996, respectively. His major field of study is systems simulation. He used to work as a systems engineer at KEEKOR Environmental Product, Inc. from 1994 to 1996. After graduated from ASU in 1996, he returned to Taiwan and got an Associate Professor faculty position at Chaoyang University of Technology. He currently serves as the chairperson for the department of Industrial Engineering and Management. His research interests include systems simulation, quality control, and decision sciences. He is a member of IIE, CIIE, CTPM, and IEET