行政院國家科學委員會專題研究計畫 成果報告

整合多準則決策與失效模式於液晶顯示器之製程研究
研究成果報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 100-2410-H-009-004-
執 行 期 間 ：100 年 08 月 01 日至 101 年 07 月 31 日
執 行 單 位 ：國立交通大學工業工程與管理學系（所）

計 畫 主 持 人 ：王志軒

報 告 附 件 ：出席國際會議研究心得報告及發表論文

公 開 資 訊 ：本計畫可公開查詢

中 華 民 國 101 年 09 月 13 日

中文摘要： 失效模式分析(FMEA: failure mode and effects analysis)已被廣泛地應用在許多領域，包括航空、軍事、汽車、電子、機械與半導體產業等，用來辨識及消除潛在的劣化因子或風險因素等。一般來說，傳統的失效模式會依據所謂的風險優先指標(RPN: risk priority number)對失誤事件(failure events)進行排序，而風險優先指標即由三項因素的簡單乘積來計算，包括發生率(occurrence)、可測度(detection)與嚴重性(severity)。很明顯地，傳統失效模式分析並未考慮三項風險因素的相對重要性，致使區辨不同風險組合所造成的相同風險優先指標之失誤事件變得非常困難；縱使其背後所隱藏的物理意義可能完全不同，而且追蹤失誤事件的根本成因(root cause))在實務上也變得極不可行。因此，本研究提出一個統合的多準則決策(MCDM: multi-criteria decision making)模型，以模糊尺度的語意量表；將層級分析法(AHP: analytical hierarchy process)、灰關聯法(GRA: grey relational analysis)、與決策實驗分析法(DEMATEL: decision making and trial laboratory)彙整以克服傳統失效模式的困境，同時以液晶顯示器的製程實證資料來印證所提架構之有效性。

中文關鍵詞： 失效模式、風險優先值、層級分析法、灰關聯法、決策實驗分析法

英文摘要： Failure mode and effects analysis (FMEA) has been widely applied to many domains (i.e. aerospace, military, automobile, electronic, mechanical, and semiconductor industries) for identifying and/or eliminating potential deteriorated factors, risks, and problems. Generally, the conventional FMEA prioritizes specific failure events based on a so-called risk priority number (RPN), which is a multiplicative product of the three risk factors: occurrence (O), detection (D), and severity (S). Obviously, the conventional FMEA is deficient in considering the relative importance among occurrence, detection and severity and incapable to distinguish different combinations of three risk factors resulting in the same RPN value. Hence, linking specific failure events to corresponding causal factors becomes very difficult and infeasible in practice. As a result, a fuzzy MCDM (multi-criteria decision making) based approach that incorporates AHP (analytical hierarchy analysis), GRA (grey relational analysis), and DEMATEL (decision making trial and evaluation laboratory) is presented to overcome the above-mentioned shortcomings. An industrial example regarding the fabrication process for TFT-LCD (thin film transistor-liquid crystal display) is demonstrated to validate the proposed approach.

英文關鍵詞： FMEA, RPN, AHP, GRA, DEMATEL, TFT-LCD

整合多準則決策與失效模式於液晶顯示器之製程研究結案報告

(NSC 000-2410-H-009-004)

目前已發表成果

Journal paper:

Wang, C.H.; Chen, J.N. (2012), Using quality function deployment for collaborative product design and optimal selection of module mix, in press, Computers & Industrial Engineering (SCI, IF=1.826).

Conference paper:

C.H. Wang (2011), A Novel Approach to Construct an Intelligent System for Product Configuration and Prototype Selection, published in APIEMS conference, Beijing.

其他衍生效益

1. 目前正思考將 FMEA 或 QFD 結合多準則決策等方法，運用至專案管理與產品組合等相關風險問題的研究上，以期能擴大其研究範圍與能量。另外，除了液晶顯示器外，DRAM 及 PCB，亦可以納入探討的主力產品，以增加對 FMEA 的了解。
2. 另外，亦正與竹科太陽能大廠洽談，從既有的工業資料分析方法，包括多變量分析或資料採礦；進而提升太陽能產品的高效組合，降低其破片綠與增加其產出。

尚在進行當中的研究：

列出英文摘要與與研究成果於隨後幾頁內容，以供參考；另外，本人參與(2011)Beijing APIEMS 與(2012)Hong Kong IEEM 亦分別受邀擔任大會分項會議主持人，與參加會議之學者廣泛針對研究議題交換意見。

Conducting Effective Risk Evaluation for Failure Mode and Effects Analysis: An Example for the Fabrication Process of TFT-LCD

Abstract

Failure mode and effects analysis (FMEA) has been widely applied to many industries for identifying and/or eliminating potential deteriorated factors, risks, and problems. Generally, the conventional FMEA prioritizes specific failure events based on a so-called risk priority number (RPN), which is a multiplicative product of the three risk factors: occurrence (O), detection (D), and severity (S). Obviously, the conventional FMEA is deficient in considering the importance degrees of three risk factors. Moreover, it is very difficult to distinguish various combinations of three risk factors caused by the same RPN value although their hidden causes might be totally different. Hence, linking specific failure events to corresponding causal factors becomes quite infeasible in practice. As a result, a fuzzy MCDM (multi-criteria decision making) based FMEA that incorporates AHP (*Analytical Hierarchy Process*), GRA (*Grey Relational Analysis*), and DEMATEL (*Decision Making Trial and Evaluation Laboratory*) is developed to overcome the above-mentioned shortcomings. An industrial example regarding improving the fabrication process for TFT-LCD (thin film transistor-liquid crystal display) products is demonstrated to validate the proposed approach.

Keywords: fuzzy FMEA, RPN, AHP, GRA, DEMATEL, TFT-LCD.

Conclusions

FMEA has been widely used to enhance product reliability and process stability over several decades through ranking a so-called RPN for specific causal factors or failure events. However, traditional FMEA fails to consider the importance degrees of three risk factors when applied to different industries. Besides, various combinations of three risk factors are possible to generate the same RPN although their hidden root causes may be vastly different in practice. In this study, a hybrid MCDM based fuzzy FMEA that integrates AHP, GRA, and DEMATEL offers a flexible framework to overcome frequently-encountered deficiencies in the conventional FMEA. The proposed approach cannot only accommodate the importance degrees of three risk factors, but also construct a composite RPN index based on three factors concurrently rather than using a simple mathematical product. Furthermore, by identifying the complex interrelationships between resulting “failure events” and corresponding “causal factors”, quality engineers or reliability practitioners are able to visualize and to understand the urgency of crucial factors more effectively and to allocate their corrective resources more efficiently. To illustrate the applicability and validity of the proposed method, an industrial example regarding the fabrication process for TFT-LCD products is demonstrated in this study.

Table 1. A crisp rating scale used for the conventional FMEA

Rating	Possibility of "*Occurrence*"	Impact	Probability of "*Detection*" (%)	Impact	Effect of "*Severity*"
1	<1/20,000	Almost never	86-100	Almost certain	None
2	1/20,000	Remote	76-85	Very high	Very minor
3	1/10,000	Very slight	66-75	High	Minor
4	1/2,000	Slight	56-65	Moderately high	Very low
5	1/1,000	Low	46-55	Medium	Low
6	1/200	Medium	36-45	Low	Moderate
7	1/100	Moderately high	26-35	Slight	High
8	1/20	High	16-25	Very slight	Very high
9	1/10	Very high	6-15	Remote	Hazardous with warning
10	1/2	Almost certain	0-5	Almost impossible	Hazardous without warning

Table 2. A linguistic rating scale used for proposed fuzzy FMEA

TFN	Symbol	AHP	Symbol	DEMATEL
(1, 1, 3)	E	Equally	VL	Very low
(2, 3, 4)	S	Slightly	L	Low
(3, 4.5, 6)	M	Moderately	ML	Moderate low
(4, 5.5, 7)	T	Strongly	M	Moderate
(5, 6.5, 8)	G	Greatly	MH	Moderate high
(7, 8, 9)	A	Absolutely	H	High
(8, 10, 10)	X	Extremely	VH	Very high

Table 3. Random index used by fuzzy AHP

	Order of matrix						
n	2	3	4	5	6	7	8
RI	0	0.58	0.90	1.12	1.24	1.32	1.41

Table 4. Simplified symbols denoting the fabrication process of TFT-LCD products

CFs	Causal factors (mechanisms)	*FEs*	Failure events (results)
CF1	Poor gamma curve design	FE1	Grayscale display defect
CF2	Different edge and interior delta	FE2	Uneven splotches at edges and corners of LCD
CF3	Disable conductive material	FE3	Flickering display
CF4	Conductivity reduction owing to moisture	FE4	No displays
CF5	Low LCD resistance	FE5	Missing pixels
CF6	Scratch	FE6	Missing lines
CF7	Particles remain on LCD internal	FE7	Contrast ratio
CF8	Poor operations	FE8	Crosstalk
CF9	Too large bias level	FE9	Slow LCD response time
CF10	Cell gap setting error	FE10	Poor high-temperature constant
CF11	Spacer leaking light		

Table 5. A ranking comparison of CFs among different RPN schemes

CFs	(O, D, S)	Conventional RPN	Rank	Unweighted RPN	Rank	Weighted RPN	Rank
CF1	(VL, ML, MH)	48.75	5	0.54	5	0.571	5
CF2	(VL, L, M)	27.5	8	0.424	9	0.431	8
CF3	(L, VL, ML)	22.5	10	0.416	10	0.371	10
CF4	(L, VL, M)	27.5	8	0.443	8	0.42	9
CF5	(L, L, MH)	58.5	4	0.519	6	0.525	6
CF6	(VL, L, H)	40	6	0.612	4	0.776	1
CF7	(VL, M, MH)	59.58	3	0.655	3	0.667	2
CF8	(L, M, M)	90.75	2	0.665	2	0.606	3
CF9	(ML, ML, M)	111.37	1	0.697	1	0.559	4
CF10	(L, VL, ML)	22.5	10	0.416	10	0.371	10
CF11	(VL, L, MH)	32.5	7	0.466	7	0.509	7

Table 6. A sample of initial interdependence matrix between *CF*s and *FE*s

	FE1	FE2	FE3	FE4	FE5	FE6	FE7	FE8	FE9	FE10
CF1	M									
CF2		L								
CF3		L								
CF4			ML							
CF5			M							
CF6				M						
CF7					MH	MH				
CF8							VH			
CF9								H		
CF10									L	
CF11										ML

Table 7. Final interdependence between *CF*s and *FE*s through fuzzy DEMATEL

	FE1	FE2	FE3	FE4	FE5	FE6	FE7	FE8	FE9	FE10
CF1	0.423	0	0	0	0	0	0	0	0	0
CF2	0	0.269	0	0	0	0	0	0	0	0
CF3	0	0.192	0	0	0	0	0	0	0	0
CF4	0	0	0.308	0	0	0	0	0	0	0
CF5	0	0	0.385	0	0	0	0	0	0	0
CF6	0	0	0	0.462	0	0	0	0	0	0
CF7	0	0	0	0	0.5	0.5	0	0	0	0
CF8	0	0	0	0	0	0	0.718	0	0	0
CF9	0	0	0	0	0	0	0	0.615	0	0
CF10	0	0	0	0	0	0	0	0	0.231	0
CF11	0	0	0	0	0	0	0	0	0	0.346

Table 8. Conducted priority of failure events

FEs	Weights	Priority
FE1	0.242	7
FE2	0.187	8
FE3	0.331	6
FE4	0.358	2
FE5	0.3335	4
FE6	0.3335	4
FE7	0.435	1
FE8	0.344	3
FE9	0.086	10
FE10	0.176	9

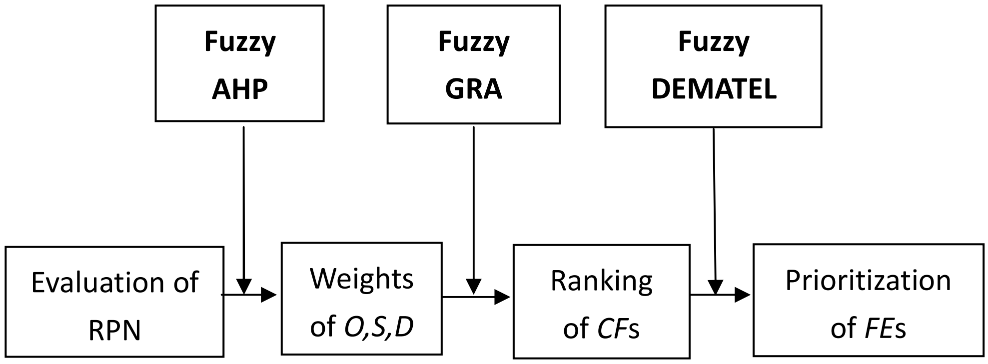

Figure 1. A proposed fuzzy FMEA to construct a RPN for TFT-LCD products

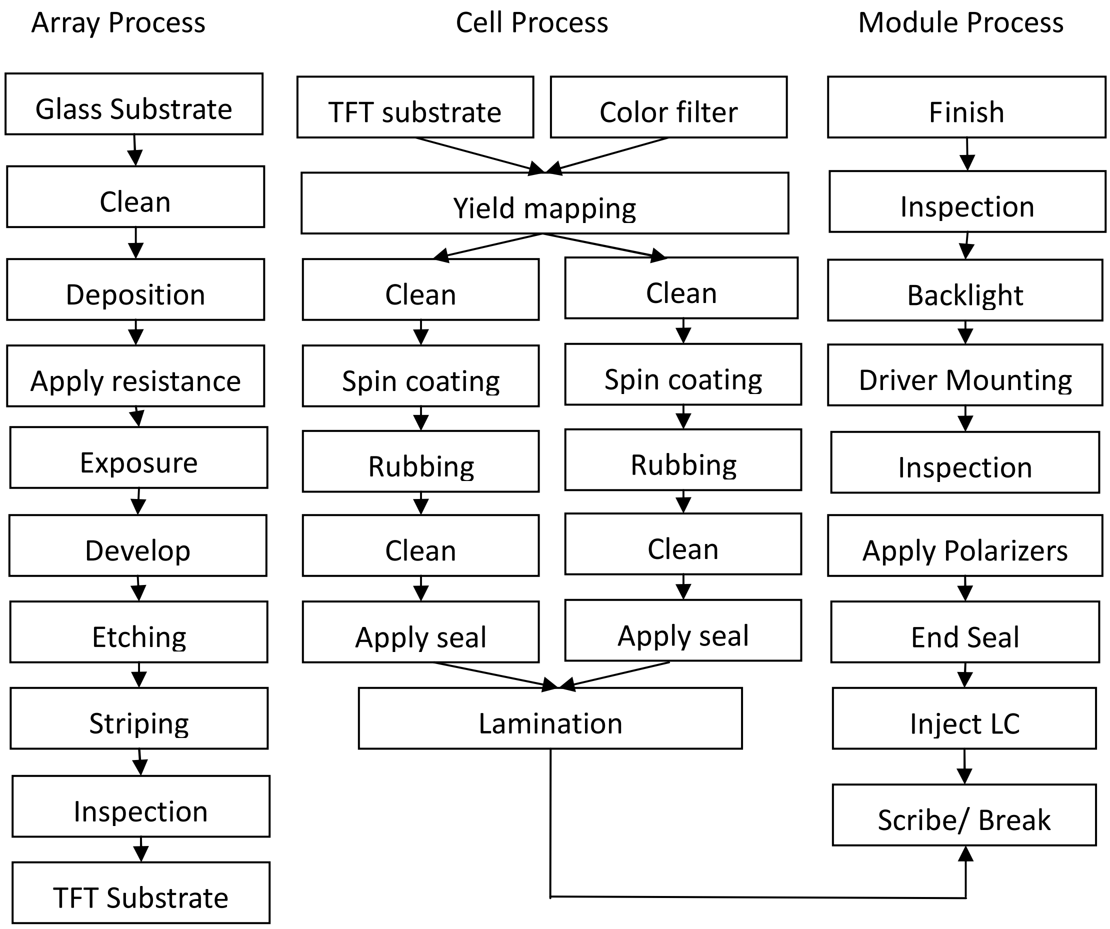

Figure 2. Typical manufacturing processes of TFT-LCD products

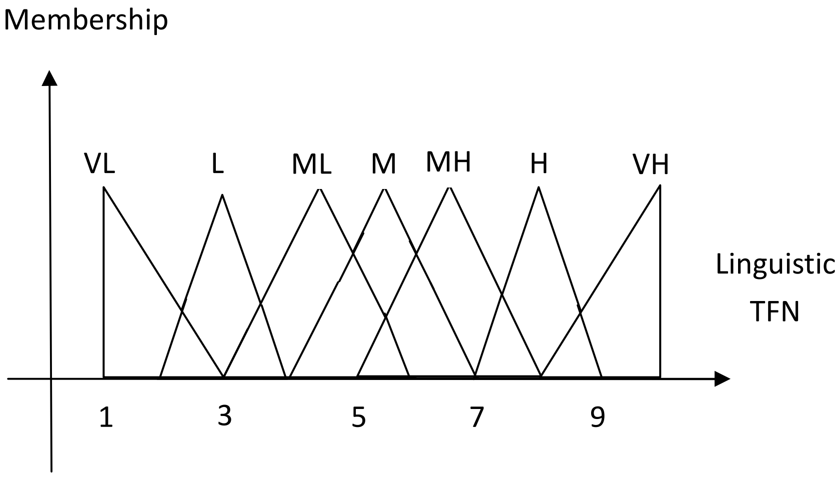

Figure 3. Triangular fuzzy numbers and membership functions used for fuzzy FMEA

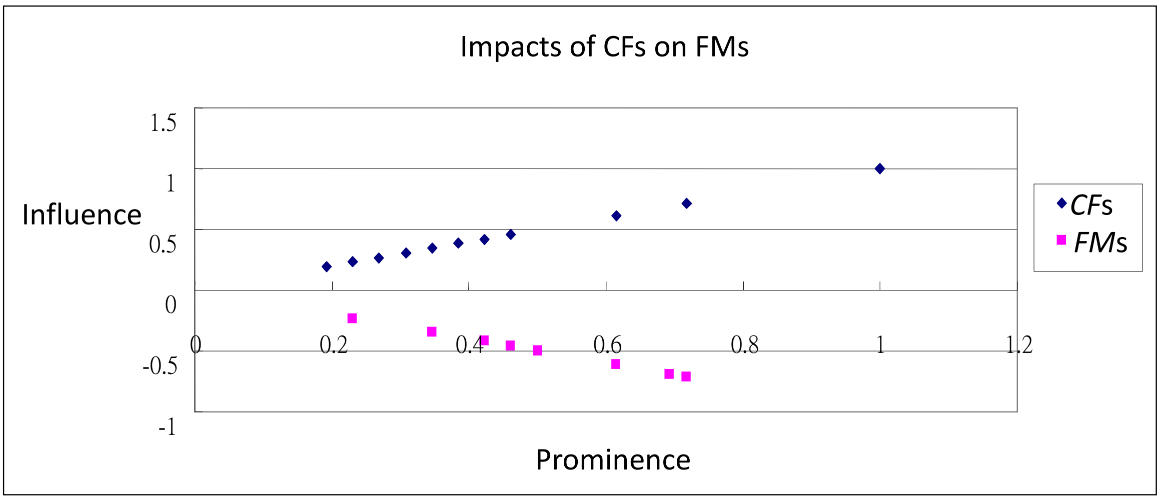

Figure 4. A causal diagram generated between CFs and FEs through fuzzy DEMATEL

出席國際學術會議心得報告

計畫編號	**NSC 000-2410-H-009-004**
計畫名稱	整合多準則決策與失效模式於液晶顯示器之製程研究結案報告
出國人員姓名 服務機關及職稱	王志軒/ 交通大學工業工程與管理學系/ 助理教授
會議時間地點	2011/12 / Beijing, China
會議名稱	Asia Pacific Industrial Engineering & Management Systems
發表論文題目	A Novel Approach to Construct an Intelligent System for Product Configuration and Prototype Selection

一、參加會議經過

APIEMS 是國際上有關工業工程及管理系統的重要會議，本人參與了該會相當多個主題單元，包括 Tutorial, Workshop, and keynote speech。大會安排了許多知名學者來進行專題演講，同時在閉幕前還舉出了各領域中的優秀著作，著實令我印象深刻。

二、與會心得

本人受邀擔任大會分項會議主持人(session chair)，能與國際學者同聚一堂，彼此交換名片、並作研究心得的交流；不禁讓我覺得受益匪淺，由衷地感激國科會對國內學者在學術研究上的幫助。另外，透過與期刊領域主編及聆聽大會 keynote speaker 的演講，亦讓我對研究領域的啟發產生相當程度的助益。

三、研討會論文摘要 (如後所附)

發表人:

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Abstract: A collaborative QFD (quality function deployment) based platform is widely applied to many industries because it is flexible to gather diverse opinions among cross-functional team members. Besides, it helps product practitioners interpret marketing "*customer requirements*" (*CR*s) into technical "*engineering characteristics*" (*EC*s) when configuring an intangible design concept. However, the conventional QFD generates the priorities of *CR*s and *EC*s independently without considering the inter-dependences and/ or the inner-dependences among themselves. In addition, most existing schemes for selecting "*design alternatives*" (*DA*s) are heavily reliant on experts' domain experiences and subjective human judgments. In practice, this may be harmful to the performance of achieving successful NPD (new product development) for modern firms. To overcome the above-mentioned shortcomings, a hybrid QFD that combines DEMATEL (*DEcision MAking and Trial Evaluation Laboratory*) and GRA (*Grey Relational Analysis*) is presented in this study. In particular, a real case relevant to developing an underwater digital camera is illustrated lastly.

Keywords: QFD, NPD, DEMATEL, GRA.

國科會補助計畫衍生研發成果推廣資料表

日期:2012/09/13

國科會補助計畫	計畫名稱: 整合多準則決策與失效模式於液晶顯示器之製程研究
	計畫主持人: 王志軒
	計畫編號: 100-2410-H-009-004- 學門領域: 生產及作業管理
無研發成果推廣資料	

100 年度專題研究計畫研究成果彙整表

計畫主持人：王志軒							計畫編號：100-2410-H-009-004-
計畫名稱：整合多準則決策與失效模式於液晶顯示器之製程研究							
成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	1	1	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	1	1	100%	篇	2012 Computers and Industrial Engineering (SCI)
		研究報告/技術報告	0	0	100%		
		研討會論文	1	1	100%		2011 Asia Pacific Industrial Engineering & Management Systems (APIEMS)
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	1	1	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	目前正與竹科公司洽談產學合作計畫，以既有的工業資料分析方法(包括多變量分析與資料採礦)為基礎，擴大研究範圍至太陽能產業!

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

Journal paper:

Wang, C.H.； Chen, J.N. (2012), Using quality function deployment for collaborative product design and optimal selection of module mix, in press, Computers & Industrial Engineering.

Conference paper:

C.H. Wang (2011), A Novel Approach to Construct an Intelligent System for Product Configuration and Prototype Selection, published in APIEMS conference, Beijing.

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

目前正思考將 FMEA 或 QFD 結合 MCDM 等方法，運用至專案管理與產品組合等相關風險問題的研究上，以期能擴大其研究範圍與能量。另外，除了液晶顯示器外，DRAM 及 PCB，亦可以納入探討的主力產品，以增加對 FMEA 的了解。