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Designing Emergency Response Information System based on Axiomatic Design

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Abstract

An emergency response information system needs to assist decision makers to evaluate emergency plans and select an appropriate one during an emergency. An axiomatic design approach provides a systematic and scientific view of the structural design relating to emergency response information system. It gives deliberate method of decomposition and acceptable standard of information system design, therefore information system become clear and simple. Based on Axiomatic framework we can draw up a clear relation schema of these elements, furthermore assess the success probability of information system .

Keywords*: axiomatic design, emergency response, design matrix, Probability of Success*

1. Introduction

In recent years a variety of natural and manmade disasters such as earthquakes, volcanoes, floods, hurricanes, chemical spills, nuclear leaks, epidemics, crashes, explosions, landslide and urban fires, occur frequently around the world[1,2,3,4,5,6].Emergencies require coordinated and rapid responses[7].An emergency response information system is an important tool for authorities to enhance their emergency response capabilities. It is one of the key factors that determine whether emergency management will be successful [8]. In addition, it should provide differentiated services at each response phase to meet requirements [9,10].

In the past, many studies were conducted on emergency response information system (ERIS), but it has not been thoroughly examined how an effective ERIS can be designed and developed. The goal of this paper is to establish a new view to design ERIS based on axiomatic design.

This paper provides a systematic and scientific view to structurally design emergency response information system based on axiomatic design approach.

2. Axiomatic Design

Axiomatic design is a conceptual designing method of new product proposed by professor Nam Pyo Suh and his colleague of MIT in 1990s[11], but not until 2000s was this method minded widely day by day and popularized among enterprises. The design need interaction between “what should we want” and “how should we decide to gain the need”. Therefore a deliberate design method should certainly start with the definite express of “what should we want”, end up with the clear specification of “how should we decide to gain the need” [12]. Axiomatic design theory can be used throughout designing

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layer structure, clarifying design task, proposing and analyzing design plan, making design decision[13].

Axiomatic design method contains 5 important concepts: domain, hierarchical structure, mapping and two design axioms (independent axiom and informative axiom). We must determine minimum function requirements unit to meet customer requirements and conform to independent axiom. Informative axiom clarify that the design with highest probability success (minimum information content I) is the best[14].

Informative content I is determined by success probability P,

$$I = -\log 2\, P\,. \tag{1}$$

In practical design, success probability P is determined by design range and system range of candidate solution: P=Acr /system range. If FR is a continuously variable, success probability

$$P = \int_{dl}^{du} f(FR)dFR = A_{cr} \tag{2}$$

$f(FR)$ is pdf (probability density function) of FR, dl is lower limit of design range, du is upper limit of design range, Acr is the intersection area of system range and design range, shown in Figure1.

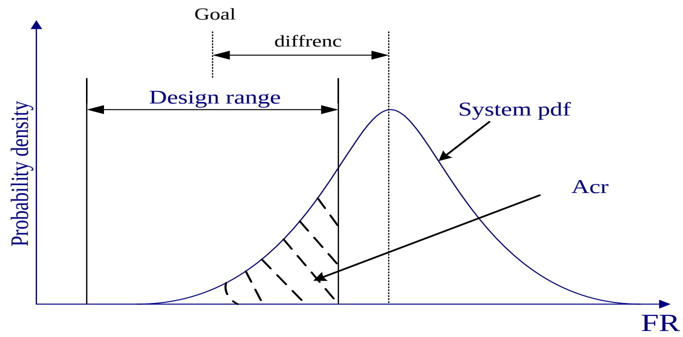

Fig1.relation of system pdf,design range and A_{CR}

● About no coupling design

All FRs are independent, so Information content I is simple and direct, it is the sum of information content of all FRs:

$$I = -\sum_{i=1}^{m} \log_2 p_i \tag{3}$$

● About decoupled design

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{pmatrix} A_{11} & 0 \\ A_{21} & A_{22} \end{pmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \end{Bmatrix} \tag{4}$$

Information content is：

$$\begin{aligned} I &= -\log_2[p_r(meet\,\mathrm{FR}_1 \text{and } \mathrm{FR}_2)] \\ &= -\log_2[p_r(meet\,\mathrm{FR}_1)] - \log_2[p_r(meet\,\mathrm{FR}_2 | \text{ meet } \mathrm{FR}_1)] \end{aligned} \tag{5}$$

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for FRs within design range, common difference of DPs must fulfill following conditions：

$$\Delta DP_1 \le \Delta FR_1 / A_{11}$$

$$\Delta DP_2 \le (\Delta FR_2 - A_{21}\Delta DP_1) / A_{22}$$

(6)

The most important factor of axiomatic design is that it gives deliberate method of decomposition and acceptable standard of information system design, therefore information system become clear and simple. Relevance is a key feature of information system design, nonzero and not diagonal elements of the design matrix represent interaction between different modules. Axiomatic design establishes an excellent framework for design matrix determining FR/DP relationship which need to be modeled. Axiomatic design supports reusability and scalability by concise way. Especially, some small-scale ERIS can properly reuse partial modules from large-scale integrated ERIS.

3. Analysis of DFRS based on Axiomatic Design

A studied project in the Derbyshire fire and Rescue Service (DFRS) has been selected as the case study to illustrate the application of the proposed axiomatic design. There are eight physically independent systems being used in the DFRS. The goal of the case study is to analyze interaction between these eight different systems and assess success probability of the integrated application through the axiomatic design[15,16].

These eight systems are :

●MOB provide functions: f11, f12, f13, f14, f15.
●MIS provide functions: f21, f22, f23.
●RISK provide functions: f31, f32, f33.
●GIS provide functions: f41, f42, f43.
●SAFETY provide functions:f51, f52.
●CRIME provide functions:f61, f62.
●HYDRANT provide function: f71
●OPTIM provide function: f81. [17,18,19,20]

Table 1. Functionality of Individual Components

Function	Description	Probability of Success (per year)
f11	Provide the current available resource information in the DFRS, including available fire engines and fire fighters	0.5
f12	Provide the fire incident information during the latest eight hours	0.75
f13	Provide the fire risk categorization for a particular building	0.5
f14	Provide an access plan for any particular higher risk premise	0.5
f15	Provide the location information of hydrant points	0.6
f21	Provide the access to the fire incident database	0.9
f22	Provide the access to the personnel database	0.75
f23	Provide the access to the relevant documents	0.75

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f31	Provide the fire risk categorization for a particular building	0.5
f32	Provide an access plan for a particular higher risk premise	0.5
f33	Provide the fire risk categorization for a particular area	0.5
f41	Provide the risk information of buildings	0.5
f42	Provide the risk information of areas	0.6
f43	Provide the location information of hydrant points	0.6
f51	Produce statistic reports	0.6
f52	Provide a forecasting function of the fire incident occurrence	0.5
f61	Provide various crime and disorder information such as hoax fire call, malicious call	0.4
f62	Identify the higher crime and disorder areas	0.7
f71	Provide the location and maintenance information of hydrant points	0.6
f81	Provide a computing environment for locating fire stations, fire fighters and fire engines	0.6

Table 2. Functionality of Integrated Application

Function	Description	Probability of Success (per year)
F1	Provide the available resource information in the DFRS, including available fire engines and fire fighters	0.5
F2	Provide the current fire incident information	0.75
F3	Provide the fire incident information during different periods of time	0.9
F4	Provide the fire risk categorization for a particular building	0.5
F5	Provide an access plan for any particular higher risk premise	0.55
F6	Provide the fire risk categorization for a particular area	0.55
F7	Provide a forecasting function of the fire incident occurrence	0.5
F8	Provide various crime and disorder information such as hoax fire call, malicious call	0.65
F9	Provide the location information of hydrant points	0.6
F10	Provide the maintenance information of hydrant points	0.75
F11	Provide a computing environment for locating fire stations, fire fighters and fire engines	0.6

We assume that we realize one function requirement with one design parameter (DP). The design matrix based on axiomatic design can be analyzed as bellow. Actually one FR can be realized by one or more DPs.

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Table 3. DFRS Design Matrix

FRs \ DPs			DP1					DP2			DP3			DP4			DP5		DP6		DP7	DP8
			DP11	DP12	DP13	DP14	DP15	DP21	DP22	DP23	DP31	DP32	DP33	DP41	DP42	DP43	DP51	DP52	DP61	DP62	DP7	DP8
FRs	FR1	FR11	1																			
		FR12		1																		
		FR13			1																	
		FR14				1						1			1							
		FR15					1									1					1	
	FR2	FR21						1											1			
		FR22							1													
		FR23								1												
	FR3	FR31									1			1								
		FR32				1						1			1							
		FR33											1		1							
	FR4	FR41									1			1								
		FR42				1						1	1		1							
		FR43					1									1					1	
	FR5	FR51															1					
		FR52																1				
	FR6	FR61						1											1			
		FR62																		1		
	FR7						1									1					1	
	FR8																					1

(white) no relevance; 1 some relevance
(dark grey) relevance between same branch's leafs
(light grey) relevance between different branch's leafs

All elements fuse into a seamless organic whole DFRS, their interaction is nonlinear[21]. We must analyze relationship among elements of DFRS based on independent axiom, distinguish between no coupling node, decoupled node and coupling node[22]. We must eliminate and refine the DFRS coupling. All elements must have independent functions, have no coupling (at least decoupling). Axiomatic framework can help us get a clear picture of these elements' relationship as table 3 (This table can be subdivided further). Table 3 shows clearly that DFRS include many coupling nodes, its information content is very high, and its success probability is low.

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Table 4. Integrated Application Design Matrix

FRs \ DPs		DPs										
		DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	DP9	DP10	DP11
FRs	FR1	1										
	FR2		1									
	FR3			1								
	FR4				1							
	FR5					1						
	FR6						1					
	FR7							1				
	FR8								1			
	FR9									1		
	FR10										1	
	FR11											1

no relevance | 1 some relevance
relevance between same branch's leafs
relevance between different branch's leafs

Table 4 shows clearly that integrated application include no coupling nodes, its information content is very low, and its success probability is high. After introducing parameters in table 2 into Eq(3), the information content I is figured out in a numerical value: 7.8025.

4. Conclusion and Future Research

This framework is an example for illustrating the application of axiomatic design in ERIS. Based on independent axiom, we can design more complicated ERIS using design matrix. Meanwhile we can assess success probability of ERIS based on informative axiom. And how to eliminate coupling among modules is an important topic for us to research in the future.

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References

[1] Huang G, Li L (2009) A mathematical model of infectious diseases. Ann Oper Res 168(1):41–80
[2] Li L, Xu L (1991) An integrated information system for the intervention and prevention of AIDS. Int J Biomed Comput 29(3–4):191–206
[3] Li L, Xu L (1992) Application of information systems to AIDS risk reduction. Med Inform 17(4):199–214
[4] Li L, Xu L, Jeng HA, Naik D, Allen T, Frontini M (2008)Creation of environmental health

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information system for public health service: a pilot study. Inf Syst Frontiers 10(5):531–543
[5] Luo J, Xu L, Jamont JP, Zeng L, Shi Z (2007) A flood decision support system on agent grid: method and implementation.Enterp Inf Syst 1(1):49–68
[6] Xie KF, Chen G, Wu Q, Liu Y, Wang P (2015) Research on the group decision-making about emergency event based on network technology. Inf Technol Manag 12(2):137–147
[7] Alexander D (2005) Towards the development of a standard in emergency planning. Disaster Prev Manag 14(2):158–175
[8] Peng Y, Zhang Y, Tang Y, Li SM(2014)An incident information management framework based on data integration, data mining, and multi-criteria decision making. Decis Support Syst 51(2):316–3
[9] Wang L, Xu L, Wang X, You WJ, Tan WN (2009) Knowledge portal construction and resources integration for a large scale hydropower dam. Syst Res Behav Sci 26(3):357–366
[10] Zhou Q, Huang WL, Zhang Y (2013) Identifying critical success factors in emergency management using a fuzzy DEMATEL method. Saf Sci 49(2):243–252
[11] Suh N P.The principles of design [M].NewYork: Oxford University Press,1990.
[12] Suh N P. Axiomatic design: advances and applications [M]. New York: Oxford University Press, 2001.
[13] Suh N P. Complexity :theory and applications[M]. New York: Oxford University Press, 2005.
[14] MIT Park Center for Complex System. Research [EB/OL]. [2007-04-18]. http://web.mit.edu/pccs.
[15] Abimbola A (2007) Information security incident response. New Secur 12:10-13
[16] Abrahamsson M, Hassel H,Tehler H (2010) Towards a system-oriented framework for analyzing and evaluating emergency response. J Counting Crisis Manag 18(1):14-25
[17] Alexander D(2005) Towards the development of a standard in emergency planning. Disaster Prev Manag 14(2):158-175
[18] Arora H, Raghu TS, Vinze A(2010) Resource allocation for demand surge mitigation during disaster response. Decis Sopport Syst 50(1):304-315
[19] Siqing Shan, Li Wang, Ling Li, Yong Chen(2012) An emergency response decision support system framework for application in e-government. Inf Technol Manag 13:411-427
[20] Amailef K, Lu J(2008) m-government: a framework of mobile-based emergency response systems. In:Li SZ, Li R, Ruan D(eds) Proceeding of 3rd international conference on intelligent system and knowledge engineering (ISKE 2008), Xiamen, China, 17-19 Nov, 2008,pp 1398-1403
[21] Yang L. *et al* (2006) Genetic algorithm based software integration with minimum software risk. Information and Software Technology 48:133–141.
[22] Yang Bin(2012) Research on trustworthy MIS based on Axiomatic design. J advancements in computing technology 4(23):57-65

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