Evaluation of Responsiveness of Health Systems Using Fuzzy-based Technique

Sukanya Phongsuphap, and Yongyuth Pongsupap

Abstract—This paper proposes a method for evaluating responsiveness of health systems. The method is based on a fuzzy model, which can tackle uncertainty of survey data, and perform corresponding to the way that human being makes decisions and adjustments. To measure responsiveness of health systems, we have defined five fuzzy sets for two input variables: score of direct experience of using health service and score of anchoring vignette, and five fuzzy sets for one output variable: responsiveness score which is defined as the difference between score of direct experience of using health service and score of vignette. The twenty-five fuzzy rules are derived from the analysis of input and output variables association. Mamdani style inference technique is used to compute a crisp value of average responsiveness score for each component of health systems, and the overall average responsiveness score is computed by using the weight average method. The data of seven components based on WHO framework were collected from 4,446 outpatients of three schemes of health care systems in Thailand consisting of Civil Servant Medical Benefit Scheme (CSMBS), Social Security Scheme (SSS), and Universal Coverage Scheme (UCS). Results showed that CSMBS got the highest average responsiveness score followed by SSS which got a slightly higher average responsiveness score than UCS, but there are some variations in each of seven components. The proposed method of responsiveness evaluation can provide concise information both in terms of quantitative and qualitative measures, which can be used as a policy implication to assist government and health system policy makers in improving and providing the more suitable heath care services.

I. INTRODUCTION

Health system responsiveness was introduced in a World Health Report 2000 by the World Health Organization

(WHO) [1]. This new framework for health system performance assessment has three goals: health, responsiveness, and fairness of financing. The concept of health system responsiveness was developed based on the human rights principle focusing on the non-medical aspect of health care which can be assessed by patients [2].

Responsiveness and satisfaction have some overlapping aspects. The main differences are as follows [3]:

- *Responsiveness* evaluates the health system as a whole, whereas *Satisfaction* evaluates the clinical interaction in specific health care settings.
- Responsiveness covers only the non-health enhancing

aspects of health system, whereas *Satisfaction* covers both medical and non-medical aspects of care.

• *Responsiveness* evaluates individual's perceptions of health system against legitimate universal expectations, whereas *Satisfaction* evaluates mixture of perceived need, individually determined expectations, and experience of care.

Responsiveness moves towards getting individuals to rate their health systems against objectively set standards, e.g., [4], rather than evaluate their satisfaction. However, much of work up-to-date has been on patient satisfaction [5], [6]. Usually, patient self-report measures are used, but the responses are subjective, and consequently, inconsistent and uncertainty are unavoidable. To cope with these problems, in this work, we introduce the use of survey questionnaires that include anchoring vignettes or standard settings, together with a new technique of health system responsiveness evaluation by adopting fuzzy-based techniques.

II. MATERIALS

This study was conducted in Thailand, which all Thai citizens were covered by three public health insurance schemes: Civil Servant Medical Benefit Scheme (CSMBS) for government employees, Social Security Scheme (SSS) for private sector employees, and Universal Coverage Scheme (UCS) for the rest of population [7]. A stratified three-stage sampling design was used to select subjects [8]. Patients aged not less than 18 years were selected if they used any of the three health insurance schemes. The number of subjects or respondents is summarized in Table I. This study was approved by the Institute for the Development of Human Research Protections (ref. no.175/2554 on 21 February 2011).

Our questionnaire was modified from WHO health system responsiveness questionnaire for outpatient [2], [9] and related researches [10]-[12]. It covers seven health system responsiveness components including 1) *Dignity*, 2) *Autonomy*, 3) *Confidentiality*, 4) *Communication*, 5) *Prompt attention*, 6) *Amenities*, and 7) *Choice*. Note that *Access to social support networks* was not included in this study because it applies for inpatient care [2]. Each component consisted of three to ten items and one vignette. The questionnaire was pre-tested in a pilot study and modified accordingly before being used in the main survey. Respondents were asked to rate their experience of care using

Sukanya Phongsuphap is with Faculty of Information and Communication Technology, Mahidol University, Bangkok 10400, Thailand (corresponding author to provide phone: +66-2-354-4333; fax: +66-2-354-7333; e-mail: sukanya.pho@mahidol.ac.th).

Yongyuth Pongsupap is a senior expert, National Health Security Office, the Government Complex, LakSi, Bangkok 10210, Thailand (e-mail: yongyuth.p@nhso.go.th).

a ten point scale ranging from 1 (lowest score) to 10 (highest score). Vignettes used the same scale as experience of care.

TABLE I Number of Respondents			
Health System	Number (%)		
Civil Servant Medical Benefit Scheme (CSMBS)	1,246 (28.0)		
Social Security Scheme (SSS)	1,507 (33.9)		
Universal Coverage Scheme (UCS)	1,693 (38.1)		
Total	4,446 (100)		

III. FUZZY TECHNIQUES FOR RESPONSIVENESS MEASURE

A. Fuzzy based Techniques

Zadeh initiated the fuzzy set theory [13], [14], which provides a framework for handling the uncertainties. The fuzzy theory can be applied to various decision-making processes in a fuzzy environment [15]. Because there exist uncertainty and imprecision in human perception, fuzzy techniques become a powerful and practical tool for solving human related problems. Fuzzy techniques have been successfully applied in many areas such as classification, evaluation and decision support in fields of industry, = economy, engineering, management, and medicine -[16]-[19].

In this paper, we use fuzzy techniques to calculate responsiveness scores of health systems. Our fuzzy model for responsiveness evaluation can be considered as a system with two inputs: score of direct experience of using health service, and score of anchoring vignette, and one output: responsiveness score for each of seven components of health system. The framework of the model is shown in Fig.1. The brief descriptions of the seven components of health system [2] are given in Table II. The responsiveness score is defined as the difference between score of direct experience of using health service, and score of anchoring vignette or reference standard setting as shown in Eq.(1) [8],

$$R_{ij} = D_{ij} - V_{ij} \tag{1}$$

where R_{ij} is a responsiveness score of a health system component *i* from a patient *j*, D_i is a score of direct experience of using health service, V_i is a score of vignette, i = 1, 2, ..., 7.

The basic ideas for evaluating responsiveness score are as follows. First, patients rate their experiences of care of the currently used health care systems, and rate the anchoring vignettes by using a ten point scale ranging from 1 (lowest score) to 10 (highest score). Second, the gap or difference between score of direct experience of using health service and score of vignette perceived by each patient for each component of health system (R_{ij}) is estimated by using fuzzy sets and fuzzy rules as explained in Sections III-B and III-C. Third, responsiveness score for each component of health system (R_i) is computed by aggregating R_{ij} using fuzzy

inference and composition operator as explained in Section III-D.



Fig.1. Fuzzy Model for Responsiveness Evaluation.

TABLE II			
COMPONENTS OF HEALTH SYSTEM			
Component	Description		
1) Dignity (Respectful treatment and communication)	The right of a care seeker to be treated as a person in their own right rather than merely as a patient.		
2) Autonomy (Involvement in decision)	Self-directing freedom including the right of an individual to information on his/her disease and alternative treatment opinions, the right to be consulted about treatment, Informed consent in the context of testing and treatment, and the right of patients of sound mind to refuse treatment.		
3) Confidential (Confidentiality of personal information)	Information relating to the patient and his/her illness should not be divulged during the course of care, except in specific contexts, without the prior permission of the patient. This is linked to the idea that patient's welfare is the supreme concern of the health care provider.		
4) Communication (Clarity of communication)	Clarity of communication, manner of information delivery, willingness to listen to the patient and to answer patient questions.		
5) Prompt Attention (Convenient travel and short waiting times)	Prompt attention consists of three characteristics: 1) Patients should be entitled to rapid care in emergencies, 2) Patients should be entitled to care within reasonable time periods even in the case of non-emergency health care problems or surgery so waiting lists should not cover long periods, 3) Patients seeking care at healthcare units should not face long waiting times for consultations and treatment.		
6) Amenities (Surrounding)	This aspect relates to the provision of physical infrastructure and a conductive care environment, e.g., clean surrounding, adequate furniture, sufficient ventilation, clean water, clean toilets.		
7) Choice (Choice of health provider)	The ability to choose between care providers.		

B. Fuzzy Sets for Input and Output Variables

We used trapezoidal functions to define membership functions of input and output variables as shown in Table III and Table IV, and graphical representations of the membership functions are shown in Fig.2 and Fig.3 respectively. Five fuzzy sets or linguistic terms are used to describe input variables: score of direct experience of care or using health service, and score of anchoring vignette. There are *Very Low* (*VL*), *Low* (*L*), *M* (*Medium*), *High* (*H*), and *Very High* (*VH*) for the range of value [1, 10]. For the output variable: responsiveness score, the range of value is [-9, +9]. It represents the direct experience of using health service response relative to the anchoring vignette response. We defined the following linguistic terms to describe the responsiveness: *Very Lower* (*VL*), *Lower* (*L*), *Same* (*S*), *Higher* (*H*), and *Very Higher* (*VH*) relative to the vignette.



Fig.2. Fuzzy Membership Function for Input variable.



Fig.3. Fuzzy Membership Function for Output variable.

	TABLE III				
	Membership Functions (μ) for Input Variables (D, V)				
No	Fuzzy Set	Notation	Fit Vector		
1	Very Low	VL	(1/1, 1/2, 0/3)		
2	Low	L	(0/2, 1/3, 1/4, 0/5)		
3	Medium	М	(0/4, 1/5, 1/6, 0/7)		
4	High	Н	(0/6, 1/7, 1/8, 0/9)		
5	Very High	VH	(0/8, 1/9, 1/10)		

TABLE IV

MEMBERSHIP FUNCTIONS (μ) FOR OUTPUT VARIABLE (R)

No	Fuzzy Set	Notation	Fit Vector
1	Very Lower	VL	(1/-9, 1/-8, 0/-5)
2	Lower	L	(0/-8, 1/-6, 1/-4, 0/-1)
3	Same	S	(0/-4, 1/-2, 1/2, 0/4)
4	Higher	Н	(0/1, 1/4, 1/6, 0/8)
5	Very Higher	VH	(0/5, 1/8, 1/9)

C. Fuzzy Rules

To construct fuzzy rules, we asked opinions from experts and used the definition of responsiveness in Eq.(1) to derive the input-output association by analyzing the output: Responsiveness score (R) on a plane of two inputs: Direct experience of using health service score (D) versus Vignette score (V). Consequently, we got a DV-Fuzzy Associative Memory representation as shown in Fig. 4. Finally, we obtained 25 fuzzy rules as shown in Table V to find a responsiveness score.

	VH	VL	L	L	S	S
tte	Н	L	L	S	S	S
Vigne	М	L	S	S	S	Н
7	L	S	S	S	Н	Н
	VL	S	S	Н	Н	VH
		VL	L	Μ	Н	VH
	D -Direct experience of care					

Fig.4. DV - Fuzzy Associative Memory Representation.

TABLE V					
Fuzzy	FUZZY RULES FOR RESPONSIVENESS EVALUATION				
Rule	IF (D A	THEN (R)			
#	D	V	R=D-V		
1	VL	VL	S		
2	VL	L	S		
3	VL	М	L		
4	VL	Н	L		
5	VL	VH	VL		
6	L	VL	S		
7	L	L	S		
8	L	М	S		
9	L	Н	L		
10	L	VH	L		
11	М	VL	Н		
12	М	L	S		
13	М	М	S		
14	М	Н	S		
15	М	VH	L		
16	Н	VL	Н		
17	Н	L	Н		
18	Н	М	S		
19	Н	Н	S		
20	Н	VH	S		
21	VH	VL	VH		
22	VH	L	Н		
23	VH	М	Н		
24	VH	Н	S		
25	VH	VH	S		

D. Fuzzy Inference for Responsiveness Evaluation

To compute a responsiveness score for each of seven components and the overall average responsiveness score of a health system, we performed the following steps:

Step 1: *Fuzzification*. The inputs which are scores of direct experience of using health service from seven domains of the used health system and the corresponding anchoring vignette scores obtained from each respondent are fuzzified by using the defined fuzzy sets as shown in Fig.2.

Step 2: *Inference*. The inference is performed based on the defined twenty-five rules shown in Table V. The Mamdani's max-min inference technique [19], [20] is used to produce a fuzzy output for each component of health system. The membership function of the output is defined as shown in Fig.3.

Step 3: *Defuzzification*. Fuzzy output values are converted into a single crisp value as an average responsiveness score of each component of health system by using the center of gravity method.

Step 4: *Overall Responsiveness Evaluation*. The overall average responsiveness score (R_a) is computed by using the weight average method as defined in Eq. (2):

$$R_a = \sum W_i R_i / \sum W_i \tag{2}$$

where W_i is weight coefficients for each of the seven components (i = 1, 2, 3, ..., 7), which values are 0.125, 0.125, 0.125, 0.125, 0.20, 0.10, and 0.05 for R_1 to R_7 , corresponding to dignity, autonomy, confidential, communication, prompt attention, amenities, and choice respectively [1], [4].

IV. RESULTS

Table VI shows responsiveness scores of seven components of three health systems evaluated by using fuzzy-based technique. On average, the overall responsiveness of CSMBS, SSS, and UCS are on the same level as vignettes or standard settings. It indicates that CSMBS, SSS, and UCS can provide the health services that meet the standard settings. However, when considering the details of responsiveness scores, CSBMS (2.35; $\mu_s=0.55$, $\mu_{\rm H}$ =0.45; same level) performed better than other schemes. SSS (2.14; $\mu_s = 0.62$, $\mu_H = 0.38$; same level) performed slightly better than UCS (2.13; $\mu_s = 0.62$, $\mu_H = 0.38$; same level). For each of the seven components of health system we can conclude as follows. The responsiveness of the following components: Dignity, Communication, Amenities are quite higher than the vignettes or standard settings (score > 3.0, $\mu_{\rm H}$ > 0.5). The responsiveness of *Confidentiality* is somewhat

higher than the vignettes or standard settings (2.5 < score < 3.0, $\mu_{\rm H}$ > 0.5). The responsiveness of *Autonomy* is about the same level as/slightly higher than the vignettes or standard settings (2.0 < score < 2.5, $\mu_{\rm S}$ > 0.5). The responsiveness of *Choice* is at the same level as the vignettes or standard settings (0.0 < score < 1.0, $\mu_{\rm S}$ =1.0). Finally, the responsiveness of *Prompt Attention* is also about the same level as the vignettes or standard settings (-1.0 < score < 0.0, $\mu_{\rm S}$ =1.0). The results indicate that among the seven components, *Prompt Attention* and *Choice* need more considerations for improvements than the other components for all of three health systems (CSMBS, SSS, and UCS).

No	Component	Health System		
		CSMBS	SSS	UCS
1	Dignity	3.53	3.11	3.22
		(μ _s =0.16,	$(\mu_{s}=0.30,$	$(\mu_s=0.26,$
		$\mu_{\rm H} = 0.84$)	$\mu_{\rm H} = 0.70)$	$\mu_{\rm H} = 0.74)$
		higher	higher	higher
2	Autonomy	2.25	2.14	2.07
		(μ _s =0.58,	(μ _s =0.62,	(µ =0.64,
		$\mu_{\rm H} = 0.42$)	$\mu_{\rm H} = 0.38$)	$\mu_{\rm H} = 0.36$)
		same	same	same
3	Confidentiality	2.98	2.65	2.57
		(μ _s =0.34,	(μ _s =0.45,	$(\mu_{\rm S}=0.48,$
		$\mu_{\rm H} = 0.66$	μ _H =0.55)	μ _H =0.52)
		higher	higher	higher
4	Communication	3.42	3.08	3.05
		(μ _s =0.19,	(μ _s =0.31,	(μ _s =0.32,
		$\mu_{\rm H} = 0.81$)	$\mu_{\rm H} = 0.69$	$\mu_{\rm H} = 0.68)$
		higher	higher	higher
5	Prompt	-0.12	-0.07	-0.04
	Attention	$(\mu_s = 1.0)$	$(\mu_{s} = 1.0)$	$(\mu_{s} = 1.0)$
		same	same	same
6	Amenities	3.25	3.20	3.26
		(μ _s =0.25,	(μ _s =0.27,	(μ _s =0.25,
		$\mu_{\rm H}=0.75)$	$\mu_{\rm H}=0.73)$	$\mu_{\rm H}$ =0.75)
		higher	higher	higher
7	Choice	0.79	0.67	0.61
		$(\mu_s = 1.0)$	$(\mu_{s} = 1.0)$	$(\mu_{s} = 1.0)$
		same	same	same
	Overall	2.35	2.14	2.13
	Responsiveness	(μ _s =0.55,	(μ _s =0.62,	(μ _s =0.62,
		$\mu_{\rm H}=0.45)$	$\mu_{\rm H}=0.38)$	μ _H =0.38)
		same	same	same

Table VII shows the average scores of direct experience of using health service classified by components of health system. In contrast to responsiveness, UCS got the highest score followed by SSS and CSMBS respectively. However, all three health systems got the scores at the high level. It means that all three health systems: UCS, SSS, and CSMBS can provide the health services that meet patient expectations. There were some differences among seven components of health system. The *Dignity* got the highest score (greater than 8 out of 10, high level) whereas the *Choice* got the lowest score (less than 6 out of 10, medium level) for all health schemes. UCS patients rated the direct experience of using health service higher compared to SSS and CSMBS patients for all components of health system. It indicated that USC patients are more satisfied with the provided health services than SSS and CSMB patients.

Table VIII shows the average vignette scores or standard settings classified by components of health system, which on average, SSS patients and UCS patients rated at a medium level, but CSMBS patients rated at a low level. It reflects that vignettes or standard settings meet SSS and UCS patient expectations, except CSMBS patients may have the higher expectation. There were some differences among seven components of health system. For all three health systems, the Prompt Attention got the highest scores (greater than 7 out of 10, high level) followed by the Autonomy (greater than 5 out of 10, medium level) whereas the rest components got the lower scores, and the Amenities got the lowest score. The results indicated that the vignette or standard settings of the Prompt attention approached to the idealized expectation of patients at a satisfactory high degree whereas those of the other components did not.

TABLE VII Score of Direct Experience of Using Health Service with Membership Degree (μ) and *Linguistic Label* for each Component of Health System and Overall System

No	Component	Health System		
	-	CSMBS	SSS	UCS
1	Dignity	8.20	8.13	8.28
		$(\mu_{\rm H} = 0.80,$	(μ _H =0.87,	$(\mu_{\rm H} = 0.72,$
		$\mu_{VH} = 0.20)$	$\mu_{VH}=0.13$)	$\mu_{VH}=0.28)$
		high	high	high
2	Autonomy	8.01	8.08	8.14
		(μ _H =0.99,	(μ _H =0.92,	$(\mu_{\rm H} = 0.86,$
		$\mu_{VH}=0.01$)	μ _{VH} =0.08)	$\mu_{VH}=0.14)$
		high	high	high
3	Confidentiality	7.57	7.61	7.79
		$(\mu_{\rm H}=1.0)$	$(\mu_{\rm H}=1.0)$	$(\mu_{\rm H}=1.0)$
		high	high	high
4	Communication	8.09	8.11	8.26
		$(\mu_{\rm H} = 0.91,$	(μ _H =0.89,	(μ _H =0.74,
		μ _{VH} =0.09)	$\mu_{VH}=0.11$)	μ _{VH} =0.26)
		high	high	high
5	Prompt Attention	7.27	7.31	7.53
		$(\mu_{\rm H}=1.0)$	$(\mu_{\rm H}=1.0)$	$(\mu_{\rm H} = 1.0)$
		high	high	high
6	Amenities	7.09	7.35	7.57
		$(\mu_{\rm H} = 1.0)$	$(\mu_{\rm H} = 1.0)$	$(\mu_{\rm H} = 1.0)$
		high	high	high
7	Choice	5.69	5.67	5.74
		$(\mu_{M}=1.0)$	$(\mu_{M}=1.0)$	$(\mu_{\rm M}=1.0)$
		medium	medium	medium
	Average Score of	7.29	7.32	7.46
	Direct Exp.	$(\mu_{\rm H} = 1.0)$	$(\mu_{\rm H} = 1.0)$	$(\mu_{\rm H} = 1.0)$
		high	high	high

V. CONCLUSIONS

This paper presents how fuzzy inference system can be used to evaluate responsiveness of health system on real data. Using fuzzy-based techniques enabled us to handle uncertainty in survey data in a more appropriate way, and consequently can increase the credibility of the evaluation results. The membership functions and fuzzy rule bases were developed based on input-output associations and logical reasoning incorporated with experts' opinions. It worked in a more flexible and intelligent manners. It evaluated that in what degree a health system responded appropriately relative to the universally legitimate expectations of individuals defined as vignettes or standard settings. The results obtained reflect that the proposed method can give rich and useful information for assisting government and health system policy makers in judgmental purpose in order to make proper decisions related to health system improvement.

TABLE VIII
SCORE OF VIGNETTES WITH MEMBERSHIP DEGREE (μ) and <i>Linguistic</i>
LABEL FOR EACH COMPONENT OF HEALTH SYSTEM AND OVERALL SYSTEM

No	Component	Health System		
	-	CSMBS	SSS	UCS
1	Dignity	3.96	4.29	4.38
		$(\mu_{\rm L} = 1.0)$	(μ _L =0.71,	(μ _L =0.62,
			μ _M =0.29)	$\mu_{M}=0.38)$
		low	low	low
2	Autonomy	5.22	5.42	5.52
		$(\mu_{\rm M} = 1.0)$	$(\mu_{\rm M} = 1.0)$	$(\mu_{\rm M} = 1.0)$
		medium	medium	medium
3	Confidentiality	3.88	4.29	4.56
		$(\mu_{\rm L} = 1.0)$	(μ _L =0.71,	$(\mu_L = 0.46,$
			µ _M =0.29)	μ _M =0.54)
		low	low	medium
4	Communication	3.92	4.33	4.54
		$(\mu_L = 1.0)$	(μ _L =0.67,	(μ _L =0.46,
			µ _M =0.33)	μ _M =0.54)
		low	low	medium
5	Prompt Attention	7.59	7.52	7.64
		$(\mu_{\rm H} = 1.0)$	$(\mu_{\rm H} = 1.0)$	$(\mu_{\rm H} = 1.0)$
		high	high	high
6	Amenities	3.23	3.51	3.70
		$(\mu_{\rm L} = 1.0)$	$(\mu_L = 1.0)$	$(\mu_L = 1.0)$
		low	low	low
7	Choice	4.83	4.82	5.03
		$(\mu_L = 0.17,$	$(\mu_L = 0.18,$	
		$\mu_{\rm M} = 0.83$)	$\mu_{M}=0.82)$	$(\mu_{M}=1.0)$
		medium	medium	medium
	Average Score of	4.46	4.69	4.86
	Vignette	(μ _L =0.54,	(μ _L =0.31,	$(\mu_L = 0.14,$
		$\mu_{\rm M} = 0.46)$	$\mu_{M} = 0.69)$	$(\mu_{M}=0.86)$
		low	medium	medium

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