IT Services Evaluation Model Based on Fuzzylogic

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Abstract—*In IT Service Management (ITSM) environment, current performance measurements approaches usually use technical metrics as they are easy to be understood by IT staff and generally directly measured. Business experience is not reflected into the picture. Also, uncertainty related to importance of an IT service usually unconsidered while it is more applicable when we think of value of IT service or business experience than the certain knowledge and rigid values.*

In this work we proposed an evaluation model that address the end to end service hence beside the technical metrics accommodates subjective measures and vague uncertainty to quantify true service delivery in a time period. The model is based on the use of triangle fuzzy numbers (TFN) and an equivalent linguistic term. A simple method for aggregating quality metrics is introduced. A case study is presented to illustrate how the proposed model works.

Keywords—*IT Service Management,Service Measurement, ITIL, Continual Service Improvement, Fuzzy Logic, fusion by priority.*

I. Introduction

One of the goals of Information Technology Infrastructure Library (ITIL) implementation is creating value and being aligned to business. Service Measurement Process is an essential step in being able to manage services, processes and report value to customer [1][2].Three types of metrics are introduced in Service Measurement Process [3]:

1. Technology metrics: related to component and application

2. Process metrics: critical success factors (CSFs) and key performance indicators (KPIs)

3. Service metrics: the end to end service which reflect a true service delivery and customer experience.

Although, ITIL provides a great list of potential metrics there are still difficulties in practice. Most organization uses technical metrics (for instant; number of incidents handled and closed, time to complete a flight booking in airline website) to measure performance as they are easy to be understood by IT staff and usually directly measured.

In addition, non-technical or subjective metrics are not reflected or poorly addressed (subjective metrics could be; IT specialist tone or behavior, well organized web interface or business experience in general) [4],[5] which led to difficulties in benefit realization and lack of quantifiable evidence of these predicted benefits from adopted organizations. [6], [7]Another important aspect that usually unconsidered in the measuring process is uncertainty (vague) related to importance or business value of an IT service. [4], [8].for instant; which IT service is more valuable for an airline a web based booking system vs. a mobile application booking system? Estimating the valuable IT service to business can alter and enhance IT service management and as a result improve the overall IT value to business.

Unlike human, computer is based on binary logic (0, 1), thus human aspects such as subjectivity and uncertainty can't be represented or processed efficiently. Fuzzy logic is a human thinking approach to computing based on degree of truth and uses linguistic terms to define and model Fuzzy solution to solve a wider range of problems.

Another challenge with capturing subjectivity and uncertainty beside the technical metrics is metric aggregation, hence each measure can have different unit (times, duration, percentage and etc.) and type (numerical, categorical and etc.) In general, the key task in aggregating information is identifying the fusion problem [9]as not all aggregation techniques (operators) make sense in any context.

In the next section, we review prior literature on ITIL evaluation initiatives. Next we analyze the elected model that addresses our arguments, after which we present our proposalwhich usefusion by priority for parent KPIs incapturing IT service quality. Finally case study is presented to illustrate our proposal.

II. Literature Review

A systematic literature review was conducted to aggregate ITIL evaluation initiatives and empirical evidence achieved using variety of techniques from several disciplines.

Rresearchstarted by looking for ITSM measurements/frameworks then narrowed down to measuring ITIL using Fuzzy logic. In general, few frameworks found in literature:

- Only one of them addressed subjectivity and uncertainty.
- One study followed a technology approach
- Others focused on applicable measurement for ITSM and ITIL.

Lahtela , J¨antti and Kaukola[10]believe that measuring ITSM processes especially service support processes is a difficult task because of four reasons:

1. Lack of structured approach for measuring ITSM processes and services in IT organizations.

2. Tools used by service support teams often offer a weak measurement and reporting functions which maximize the manual work and affects improvement efforts.

3. Luck of practical examples in ITSM frameworks illustrates how to measure support processes. Instead they provide a list of potential metrics (for example ITIL has 15 potential measures for incident management).

4. There are several measurement perspectives and targets for an IT organization to choose.

To overcome these difficulties, they used a technology-oriented approach as they developed a real-time tool that measures incident and problem process with several adjustable criteria. Hence process, product or project managers can monitor the process performance and take proactive decisions to avoid disasters. There were several limitations but since tool development is out of the research scopecritic is skipped.

Gacenga[7] conducted a survey and qualitative analysis on ITSM performance measurement to investigate the practice and existed challenges. They focused on two aspects on their research:

1. Identifying performance metrics that can be used to measure ITSM benefits.
2. Exploring the challenges of measuring and reporting ITSM benefits.

They used the Balance Score Card (BSC) perspective to classify the metrics used, measuring challenges and reporting challenges. The reason behind that is that BSC is the most used framework to measure the performance of ITSM as per the survey result. Furthermore, managers around the world are familiar with its concept.

Table 1: Percentage of used metrics for incident, change and problem management processes presented in BSC concept[7]

BSC perspective	Customer	Internal Business	Innovation & learning	Financial
Incident management metrics	12%	82%	6%	0%
Change management metrics	30%	44%	26%	0%
Problem management metrics	2.5%	90%	7.5%,	0%

As shown in (Table 1) 30% of the respondent uses BSC or IT BSC while 45% doesn't use any performance measurement frameworks. This could explain the challenges in measuring and reporting the benefits. Most of the metrics used are in Internal Business perspective which shows a gap between business and IT as the reported performance or benefit are from IT perspective. In addition, it indicates that IT functions are still IT focused rather than customer focused. The results show that IT service organizations mostly adopt ITIL Service Operation processes, in addition performance measurement and reporting efforts also concentrated on these processes.

Gacenga [11]argued that beside the difficult in quantifying benefits, there are also difficulties in linking operational and financial benefits.

Gacenga suggested that ITSM performance should be measured on three levels: IT service demand, IT service resources and IT service offering since the ITSM frameworks provide guidance on how to manage these areas.

Gacenga proposed a multidimensional ITSM framework consist of three components:

- **Organization level performance measurement**: focus on the efficiency and effectiveness of IT capabilities and the use of IT resources in term of productivity, profitability and quality.
- **Metrics selection model**: provide guidance on metrics selection based on Contingency theory.
- **Process constituent's model**: provide guidance on categorizing metrics on five constituents (identified from survey[11] by qualitative analysis) for each process.

These three components work together to provide a guide to measure the performance of ITSM at different levels of an organization.

Performance measurement and reporting layers					
Layer 1	Business Environment				
Factors influencing selection of metrics	External		Internal (Parent and IS organisation)		
Layer 2	Service - defined in the business and service catalogue				
Service components	People	Process	Resources	Product	
Layer 3	Performance metrics - defined in the metrics catalogue				
Process metric constituents	Outcome	Stage	Type	Conduct	Measures

Figure 1: Gacenga's ITIL performance measurement framework[11]

McNaughton, Ray and Lewis [6]designed a holistic evaluation framework for ITIL evaluation, improvement efforts and benefit realization. Ninepotential evaluation frameworks were analyzed including:itSMF/OGC ITIL Assessment Tool, SLA comparisons, IT Service Capability Maturity Model, Criteria Catalogue method, Stakeholder Process approach, IS Adapted SERV-QUAL, IT Balanced Scorecard and etc.

Conclusion was that existing evaluation frameworks were generally weak as they did not consider the contribution of ITIL best practices to key business processes. On the other hand, SLA Comparisons is the most applicable evaluation but it doesn't have a well-defined best practices and measures.

Their framework consists of four perspectives of evaluation: management, technology, users, and IT employees (which used to determine the benefit and value of ITIL); in two levels of evaluation:

- Corporate (generic): to capture the overall benefits, IS adapted SERVQUAL and IS adapted Reverse SERVQUAL were used.
- Process (detailed): to capture the benefit of a specific process, a range of drafted metrics and survey questions for each process were defined.

Finally, a scoring/weighting system was developed to summarize each perspective value into a single value for easy comparison overtime.

Unfortunately the framework was not validated on real world case rather verified using contextual inquiry interviews with academia and industry experts.

Lima and Sauvé [4]with several researchers argue that current ITIL evaluation frameworks suffer from four drawbacks:

1. Subjective elements or business feedback usually unaddressed.
2. Uncertainty is not covered whither it is random or vague
   a. Random: related to random nature of physical process
   b. Vague: related to value of measurement used
3. Metrics aggregation: is an important issue as different measurement (quantative or quantative) give different type or unit of data.
4. Lack of strategic level information as service quality metrics usually implemented on operational level only.

Lima and Sauvé [4] developed a model to enhance the check phase of Plan-Do-Check-Act (PDCA) cycle of the Continual Service Improvement. A design change on traditional KPI and key quality indicator (KQI) was also proposed to allow fuzzy inference to essential IT service quality percent using linguistic terms (Table2).

Table 2: Triangular fuzzy numbers and linguistic terms [4]

Triangular Fuzzy Numbers				Linguistic Terms
Ň	a	m	b	
Ň1	0	0	1	Insufficient
Ň2	0	1	2	Low
Ň3	1	2	3	Regular
Ň4	2	3	4	Good
Ň5	3	4	4	Excellent

Later, Lima and Sauvé [12]published the complete model with validation case study. They have used Fuzzy Logic type1 for uncertainty and used expertise estimation to quantify service's business value. In addition, the model follows a bottom-up approach where:

- Set of experts *S*estimates business value of services under evaluation, service grouping is used whenever applicable. Grouping rule used was accepting greatest business value given with or without the grouping. Result is

$$\mathbf{V(g)} = \sum_{j=1}^{|E|} \boldsymbol{vij},\ g \in P \text{ where P is partition of} S \quad \mathbf{(1)}$$

- Set of users Uevaluate the quality of each service metric (using linguistic terms mentioned in Table 3), then subjective metrics are aggregated in one triangle fuzzy number based on degree of concordance between the users and users importance. KPIs aggregation follows a similar approach where all child metrics including technicalones are aggregated to end up with one value representing the overall quality for an objective. KPIs aggregationis based on degree of concordance between KPIs and KPI weight:

- Evaluator concordance matrix (ECM): which represent concordance between evaluators in one to one matrix

ECM (m) = C(Ňi(m),Ňj(m)) where i,j =1,….U**(2)**

- Mean concordance : represent evaluator e concordance with all evaluators

$$\mathbf{Ecdj(m)} = \sqrt{\frac{1}{|U|-1}\sum_{\substack{i=1\\ j\neq i}}^{|U|} ec^2\,(m)} \quad \mathbf{(3)}$$

- Relative degree of concordance (normalization):

$$\mathbf{Ercdj(m)} = \frac{ecdj(m)}{\sum_{i=1}^{|U|} ecdi(m)} \quad \mathbf{(4)}$$

- Evaluator consensus coefficient(evaluator weight):

$$\mathbf{Eccj(m)} = \frac{ercdj(m)\cdot evj}{\sum_{i=1}^{|U|} ercdi(m)\cdot evi}$$ where ev evaluator importance**(5)**

$$\textbf{Result is } \check{N}(m) = \sum_{i=1}^{|U|} eccj(m)\cdot \check{N}j(m) \quad \mathbf{(6)}$$

- Reference Quality Standard is also calculated as previous step but with desired quality instead of actual. Then, quality values go throughde-fuzzificationprocess to result in a quality index q(m) for each metric m. Equation (6) calculates how much current quality for metric m fits in the desired quality for metric m. Hence, q(m) result∈ (0,1)

$$\mathbf{q(m)} = \frac{\int_x \min(\mu\,\bar{Q}(m)(X), \mu\,\check{N}(m)\,(X)\,)dx}{\int_x \mu\check{N}(m)(x)dx} \quad \mathbf{(7)}$$

- Delivered business value is the result of multiplication of business value and quality index.

$$\mathbf{dv(g) = V(g)\cdot q(m)} \quad \mathbf{(8)}$$

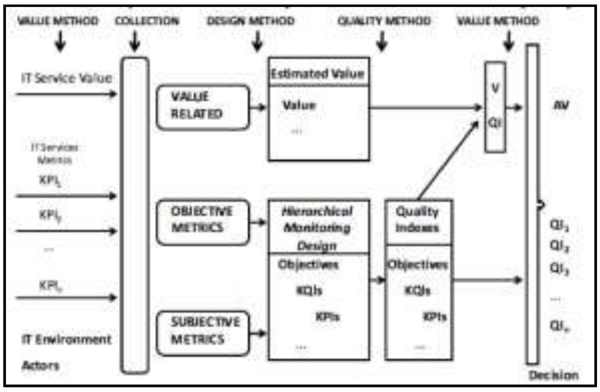

Figure 2: Lima's CSI model[12]

As shown in Figure 3, there are two input IT service value estimations provided by experts (crisp)and IT service Mercies or KPIs (which include subjective and objective metrics).Reference quality is estimated too.Quality (actual and desired) only follows fuzzy aggregation method. Delivered business value is the result of multiplication of business value (crisp) and quality index (ratio). Input and output are crisp values.

The model was validated by conducting a case study on service desk of Bank of Northeast of Brazil (BNB) [8],[12]. Results were promising as the model showed that service quality was well defined and valued. In addition, subjectivity and vague uncertainty were captured. On the other hand, managers stated that the model lack completeness and has some complexity. Automation has been suggested to minimize the complexity and achieve effective results.

We followed Lima & Sauvé model [12] since it covers most of our objectives. Although, two main drawbacks were identified:

1. Business value estimation doesn't cover vague uncertainty.

Some drawbacks were found inherited from squeezing the detailed business value quantification approach mentioned in [13]. Crisp expert's bids were used instead of weighted value interval WV suggested in [13]. Uncertainty related to value estimation and expert's risk behavior was ignored. In both [12],[13] evaluator's consensus was addressed using bids rounds and reasoning sessions, thus, not arithmetically measured. Finally, the total business value of services is simply the sums of all evaluator's bids.

2. Parent KPI aggregation weighted by child KPI concordance and normalized mean.

$$w(hi) = \frac{mrcdi(m)\cdot mi(hi)}{\sum_{hj\in H(m)} mrcdj(m)\cdot mi(hj)} \quad \mathbf{(9)}$$

Where:

- mrcdi(m) is the normalized metric relative concordance degree
- mi(hi) is the normalized mean value of the fuzzy number $\check{N}$(hi)

Capturing an IT service quality by aggregating several measures submitted by heterogeneous or homogenous sources is named **merging uncertain observationproblem**.

Dubois and Prade [9] defined the problem as follow: *"Given a set of sources of information, generally heterogeneous ones, supplying data about the value of some parameter or the description of a situation, Find the most plausible values of the observed parameter or the most credible description of the situation, trying to discard erroneous pieces of information, while remaining faithful to the available information."*

For such problem logical combination typically used depend on sources reliability; conjunctive fusion is suitable for cases where all sources are reliable, disjunctive fusion is suitable for cases where reliable and unreliable sources coexist and prioritized fusion is suitable for cases where sources have different reliability level. In addition, average fusion can be used when sources can be viewed as one source providing random reading.

There is a difference when all source measure the same parameter and when each source measure a unique parameter for the observed object. Hence, aggregation operator must match the situation.

Example:

- Case1: a red apple measured by 4 sources all measuring its size.
- Case 2: a red apple measured by 4 sources where source1mesures size, source2: color quality, source3: taste quality and source4: smell quality.

Obviously, in case 1 applying sources concordance does matter while in case 2 applying concordance is not well-justified. Lima & Sauvé handled child-KPI and parent-KPI similarly except in parent-KPI they measure non-concordance in case of zero concordance.

On the other hand, Reference Quality which reflect desired or agreed quality doesn't have to be estimated using the same method used for quality rather using performance measures (KPIs) defined in the SLA and turn them to fuzzy using KPI-linguistic terms mapping suggested in [4].

To overcome these two limitations; quality evaluation method (equation 2 to 6) will be adopted for value estimation. Thus, total value for a service e will be in TFN form or its equivalent linguistic term.

As for parent-KPI aggregation, prioritized fusion[14] seems more reasonable. Where child-KPIs are classified into several classes Ã1,Ã2,..$\tilde{A}_n$ based on their reliability (or importance). After higher class Ã1 is fused, lower class Ã2 is used to refine the aggregation as below:

- If c(Ã1 , Ã2) = 1 , total overlap , Ã1 = Ã2
- If c(Ã1 , Ã2)= 0 , no overlap , Ã1 as Ã2 will be ignored
- If c(Ã1 , Ã2) = x where $0 < x < 1$, (Ã2 * x) + (Ã1*(1-x))

Similarly, lower priority set $\tilde{A}_n$ will be used to refine the fused set $\tilde{A}_{1,2}$. Notice that fusion is done in binary mannertill overall fusion is completed. The fusion definition was slightly modified from the one in [14] in order to handle triangle fuzzy umbers.

c(Ã1,Ã2) is the degree of consensus between the two fuzzy numbers.

$$c(\tilde{\mathbf{A}}\mathbf{1},\tilde{\mathbf{A}}\mathbf{2}) = \frac{\tilde{\mathbf{A}}\mathbf{1} \cap \tilde{\mathbf{A}}\mathbf{2}}{(\tilde{\mathbf{A}}\mathbf{1} \cup \tilde{\mathbf{A}}\mathbf{2}) - (\tilde{\mathbf{A}}\mathbf{1} \cap \tilde{\mathbf{A}}\mathbf{2})} \quad \textbf{(10)}$$

$$\tilde{\mathbf{A}}^{\mathbf{1>2}}_{\boldsymbol{Pri}} = \tilde{\mathbf{A}}\mathbf{1} \cap (\tilde{\mathbf{A}}\mathbf{2} \cup (\mathbf{1} - \boldsymbol{c}(\tilde{A}1, \tilde{A}2)) \quad \textbf{(11)}$$

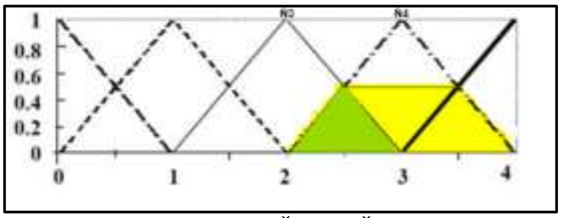

Figure 3: priority fusion forŇ3 and Ň4

Figure 3 is showing$\check{N}^{4>3}_{Pri}$ hence, c(Ň3, Ň4) = $\frac{0.25}{1.75}$ = 0.14 for Ň4 and 1 - c(Ň3, Ň4) = 0.86 for Ň3 assumingŇ4 has more priority than Ň3. Thus, $\check{N}^{4>3}_{Pri}$ = (Ň3 * 0.14) + (Ň4*0.86)

A Numerical example of Parent KPI aggregation using prioritized fusion: assume a metric with three children metrics K1,K2,K3 Ň(K1) = (2, 3, 4), Ň(K2) = (2, 3, 4) and Ň(K3) =(3,4,4). Assume that reliably for the metrics as follow K3 > K2 > K1.

First aggregation, $K^{3>2}_{Pri}$ = (K2 * 0.2) + (K3*(1-0.2)) = (2.8, 3.8, 4), then second aggregation $K^{3,2>1}_{Pri}$($K_{3,2}$, K1) = (2.6 , 3.6, 4).

III. PROPOSED MODEL:

In our proposed model we suggested two amendments to enhance the model;following fuzzy evaluation for value estimation and using prioritized fusionfor parent-KPI aggregation.It is assumed that parent-KPIsdon't have same priority.

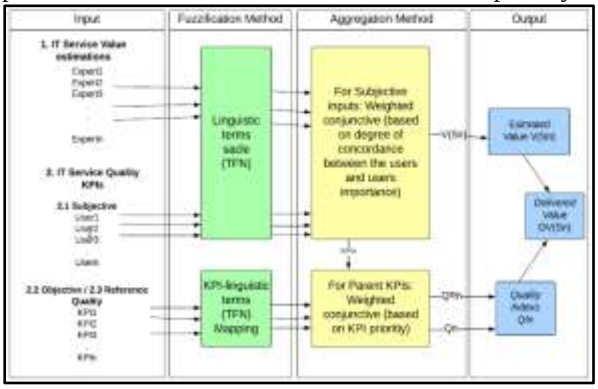

Figure 4: Proposed IT Services Evaluation Model

As illustrated in Figure 4, there are two inputs; IT service value estimations provided by experts (linguistic term) and IT service Mercies or KPIs (which include subjective and objective metrics). Both inputs follow weighted conjunctiveaggregation. Delivered business value (TFN) is the result of multiplication of business value (TFN) and quality index (ratio).Output isfuzzy values.

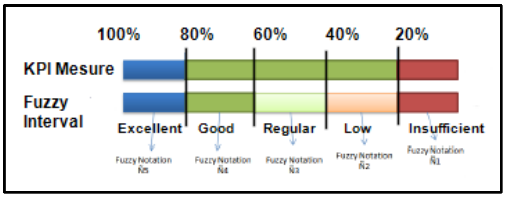

Figure 5: KPI-linguistic terms mapping

In Figure 5, KPI measured (from 0 to 100%) is mapped to linguistic term and their equivalenttriangle fuzzy number (from insufficient or Ň1 to Excellent orŇ5).

IV. CASE STUDY:

A case study was conducted to validate proposed amendments in section III in one of airlines based in Saudia Arabia. The airline's IT adopted ITIL processes since 2007 and offersmore than 52 IT services.

1) *Estimating IT Service Value:*

Four experts (two senior staff and two IT managers) participated in estimating services' value ofIT commercial applications unit; Expert was requested to estimate the business value using 5 linguistic terms as follow(Table 2): insufficient (I), low (L), regular (R), good (G) and excellent (E). Table 3 show experts' inputs and aggregated value for each service is presented in Table 4.

Table 3: Experts estimate using linguistic terms

Services	E1	E2	E3	E4
Web Booking Engine	E	E	G	E
Airline Reservation /Ticketing System	E	E	G	E
Airline Departure Control System - DCS	E	E	G	E
Frequent Flyer Program – FFP	R	R	G	G
Airlines Inventory	E	E	G	G
KIOSK machines	L	L	L	R

Using Table-2 WBE value evaluations translated to fuzzy numbers: ê1= (3, 4, 4), ê2= (3, 4, 4), ê3= (2, 3, 4) and ê4= (3, 4, 4)

ECM was calculated but we didn't present it due to space restriction. Then, we calculate mean concordance using equation (3) hence; ecd1= ecd2= ecd4= 0.82 and ecd3= 0.2

Then, we calculate relative degree of concordance as per equation (4) hence; ercd1= ercd2= ercd4= 0.31and ercd3= 0.075

Then, we calculate evaluator consensus coefficient (equation 5) ; e3 and e4 are managers and have 0.3 importance while e1 and e2 have 0.2 importance hence; ecc1= 0.25 = ecc2, ecc3= 0.1and ecc4= 0.39

Finally, total value for WBE is total of each expert evaluation weighted by his ecc (as per equation 6):

V(WBE) = (3, 4, 4)

Similarly, the value of rest services were calculated and aggregated, as Table 4showed:

Table 4: Aggregated IT services value

Services S	TFN V(s)	V(s)
Web Booking Engine	(3, 4, 4)	E
Airline Reservation /Ticketing System	(3, 4, 4)	E
Airline Departure Control System - DCS	(3, 4, 4)	E
Frequent Flyer Program – FFP	(1.6, 2.6, 3.6)	~G
Airlines Inventory	(2.4, 3.4, 4)	~G
KIOSK machines	(0.1, 1.14, 2.2)	~L

Two IT services was chosen for the study;

1. Web Booking Engine :

   It offers customers the facility to book, pay and issue tickets online.

2. Frequent Flyer Program (FFP):

   Loyalty management platform offers customers a range of benefits and privileges based on traveled miles earned. Mails can be redeemed for free flights, upgrades and etc.

2) Estimating IT Service Quality and KPI Aggregation:

WBE and FFP services are measured by three common KPIs(Table 5). Notably, Customer Satisfaction is collected subjectively by Helpdesk system through feedback survives but it is calculated in crisp manner.

Table 5: KPIs for WBE and FFP services

Perspective (KQI)	KPI	Target (min-max)	Relative Importance %	Frequency
Support	Resolution time as per SLA	MIN: 90% MAX : 100 %	70%	Monthly
	Customer Satisfaction	MIN: 80% MAX : 100 %	30%	Monthly
Service	Service Availability	MIN: 95% MAX : 100 %	100%	Monthly

To achieve the model goal, business KPIs was reviewed and IT related oneswere included. Also, a new KPI was introducedin service perspective; priority for KPIs and KQIs has been defined.Table 6show final KPI list:

Table 6: Final KPI list

Perspective (KQI)	KQI Priority	KPI	Target (min-max)	KPI Relative Importance %
Support	*3*	*Resolution time as per SLA (RT)*	*MIN: 90% MAX: 100 %*	*70%*
		Customer Satisfaction (CS)	*MIN: 80% MAX: 100 %*	*30%*
Service	*1*	*Service Availability (SA)*	*MIN: 95% MAX: 100 %*	40%
		External - Customer Satisfaction (ECS)	MIN: 80% MAX: 100 %	60%
Business (WBE)	2	Booking Counts (BC)	MIN: 80% Sales target MAX: 100 %	100%
Business (FFP)	2	Active members (AM)	MIN: 80% of target MAX: 100 %	40%
		Miles redeemed ratio (MRR)	MIN: 60% MAX: 100 %	60%

External -Customer Satisfaction was captured in term of customer experience using direct interviews with 9 customers. The question was; how do you rate your experience with below services?

Table 7: Customer experience input

Srvs /Rate	Insufficient	Low	Regular	Good	Excellent
WBE				**##	*****
FFP		*	***##	**	*

FFP Membership was used to categorize customer'simportance; FFP has three levelsfrom high to low level importance was givenrespectively 0.5, 0.3 and 0.2.

Using Table-2FFP customers evaluations translated to fuzzy numbers;ê1= (0, 1, 2), ê2= (2, 3, 4), ê3= (2, 3, 4), ê4= (1, 2, 3), ê5= (1, 2, 3), ê6= (1, 2, 3), ê7= (1, 2, 3), ê8= (1, 2, 3) and ê9= (3, 4, 4). Only ê4 and ê5 hold high membership and the rest have low membership. Then customers'inputs were calculated using equations (2, 3, 4, 5 and 6). Finally, total quality for ECS is:

$$\check{N}(ECS_{FFP}) = (1.1, 2, 3)$$

Similarly, External -Customer Satisfaction (ECS) for WBE was calculated and result is

$$\check{N}(ECS_{WBE}) = (2.5, 3.5, 4)$$

Other KPIs are transferred to fuzzy using KPI-linguistic terms mapping (Figure 5). Table 8 and 9 show total aggregated quality for FFP and WBE respectively. In both tables, the quarter performance ofResolution time (RT), Customer Satisfaction (CS) and Service Availability (SA) where assumed as they werenot provided by theairline IT.

Table 8: FFP aggregated quality

KQI	KPI	2017 4th Quarter Performance	Fuzzy Mapping	Quality Aggregation
3.Support	1.RT	72%	(2, 3, 4)	(1.9, 2.9, 3.7)
	2.CS	58%	(1, 2, 3)	
1.Service	2.SA	90%	(3, 4, 4)	(1.1, 2, 3)
	1.ECS	Table 7	(1.1, 2, 3)	
2.Business (FFP)	2.AM	92%	(3, 4, 4)	(2.2, 3.2,4)
	1.MRR	68%	(2, 3, 4)	
KQI 1st fusion: $KQI_{Pri}^{1>2}$				(1.2, 2.1, 3)
FFP overall quality: $KQI_{Pri}^{1,2>3}$				(1.4, 2.3, 3.3)

Prioritized fusion was used to calculate KQI and overall quality (as per equation 10 and 11). KQI and KPI priorities were defined in Table 6.

Illustration: on calculating FFP overall quality:

1st fusion: $c(KQI_1, KQI_2) = \frac{0.16}{1.7} = 0.1$

$$KQI_{Pri}^{1>2} = (KQI_1 * 0.9) + (KQI_2 * 0.1) = (1.2, 2.1, 3)$$

2end fusion: $c\left(KQI_{1,2}, KQI_3\right) = \frac{0.36}{1.6} \cong 0.23$

$$KQI_{Pri}^{1,2>3} = \left(KQI_{1,2} * 0.77\right) + (KQI_3 * 0.23) = (1.4, 2.3, 3.3)$$

Table 9: WBE aggregated quality

KQI	KPI	2017 4th Q Performance	Fuzzy Mapping	Quality Aggregation
3.Support	1.RT	78%	(2, 3, 4)	(2.2, 3.2, 4)
	2.CS	91%	(3, 4, 4)	
1.Service	2.SA	96%	(3, 4, 4)	(2.7, 3.7, 4)
	1.ECS	Table 7	(2.5, 3.5, 4)	
2.Business (WBE)	BC	86%	(3, 4, 4)	(3,4,4)
KQI 1st fusion: $KQI_{Pri}^{1>2}$				(2.9, 3.9, 4)
WBEoverall quality: $KQI_{Pri}^{1,2>3}$				(2.7, 3.7, 4)

3) Calculating Quality Reference and Reference Index:

As per KPI target in Table 6 quality reference (QR) transferred to fuzzy using KPI-linguistic terms mapping(Figure 5):

Table 10: FFP aggregated quality reference

Perspective (KQI)	KPI	Fuzzy Mapping	QR Aggregation
3.Support	1.RT	(3, 4, 4)	(3,4,4)
	2.CS	(3, 4, 4)	
1.Service	2.SA	(3, 4, 4)	(3,4,4)
	1.ECS	(3, 4, 4)	
2.Business (FFP)	2.AM	(3, 4, 4)	(2.2,3.2,4)
	1.MRR	(2, 3, 4)	
KQI 1st fusion: $KQI_{Pri}^{1>2}$			(2.9, 3.9, 4)
FFP Aggregated Quality Reference			(3,4,4)

Similarly,aggregatingWBE Quality Reference resulted in (3,4,4). Thus, $QI(FFP) = \frac{0.3*0.5*0.18}{0.95} = 0.03$ and

$QI(WBE) = \frac{0.8*0.5*1}{0.65} = 0.61$ as per equation (7).

Notice that QI(FFP) is below 1% although the current quality score is (1.4, 2.3, 3.3) which is regular quality, this is due to the fact that ECS in Table 8 is not high score and FFP quality target (Table 6) is set with high expectation.

4) Calculating Delivered Business Value:

Since we follow fuzzy evaluation with IT service value (table 4), the delivered valuealso follow the same. It was calculated as per equation 8.

Table 11: WBE & FFP delivered value using fuzzy value

IT service	Est. Value	V Ling. Term	QI	DV	DV Ling. Term
WBE	(3, 4, 4)	Excellent	0.61	(1.8, 2.4, 2.4)	~Regular

FFP	(1.6, 2.6, 3.6)	~Good	0.03	(0.04, 0.07, 0.1)	Insufficient

Result show that IT is delivering regular business value for Web Booking Engine (WBE) and insufficient business value for Frequent Flyer Program. Result can be improved by reviewing the Quality Referencecalculating method.

V. CONCLUTION

The overall goal of this work was to develop an evaluation model that address the end to end service thus beside the technical metrics accommodates subjective measures and vague uncertainty to quantify true service delivery in a time period. We have altered an existing model and proposed a fully fuzzy based model which use prioritized fusion for parent-KPI aggregation, and follow fuzzy based business value estimation.

Case study was conducted in an airline based in Saudi Arabia and two IT services (Web Booking Engine and Frequent Flyer Program) were evaluated.Result presented to two IT managers and they found it expressive. During time and periodic evaluation Quality Index and Delivered value can assist IT executive in decision making as they could producequantifiable evidence on quality and value over time hence improving service. Also, the hierarchy quality design and priority fusion can be link to strategy design of ITIL service life cycle.

In future, several research areas can be explored, since the model include subjective measure; risk behavior of evaluators could be included. Also, other fuzzification methods can be explored to enhance uncertainty such fuzzy logic type-2.

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