

Research paper

Designing the Conceptual Model of Digital Library Evaluation using the Fuzzy Delphi Method

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Date Received: 2021/12/14

Date Accepted: 2022/01/04

Abstract

Purpose: The present paper aims at identifying and extracting the dimensions, components, and criteria of digital library evaluation based on experts' opinions and the 5S conceptual framework of Goncalves. *Methodology:* This was an applied, documentary, and survey research making the best use of the fuzzy Delphi method (to extract criteria and develop the conceptual model), forming a trinity in methodology. To refine the components, and criteria, 20 Iranian and foreign experts were polled about digital libraries in 3 stages. The results of each stage were refined based on Minkowski formula. This was an applied research since it presented the evaluation criteria of Iranian digital libraries, and its results can be practically used, enabling digital libraries to evaluate and examine their status quo, and accordingly plan and enhance their activities. It was a descriptive study based on the research design and data collection method. To gather the data, three methods were used: documentary study, fuzzy Delphi (to extract criteria and develop the conceptual model), and survey, creating a trinity in methodology. *Findings:* During the three stages of the experts' poll, in Stream component 4 criteria, Structure component 4, Space component 4, Scenario component 5 and in societies component 3 ones were refined and also the results of each stage were refined using the formulas of Cheng and Lin model and ultimately the experts agreed with each other on 20 criteria.

Conclusion: A digital library evaluation model was designed with 5 dimensions (components), 20 criteria, and 50 sub-criteria. It was offered to all organizations and universities as an evaluation model for digital library performance examination, so that they properly perceive the efficiency and effectiveness of digital libraries and their services.

Keywords: digital libraries, evaluation, 5S framework, evaluation model, fuzzy Delphi method.

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Introduction

Digital libraries undergo a lot of changes in the course of time and these changes transpire when a comparison or analysis is carried out. It is possible that the existing content expand in terms of amount and variety, the existing services be rendered differently, their organization undergo a change, etc. so evaluations in a digital library mostly happen when there is a problem necessitating immediate attention and handling. The evaluations are usually special and depend on the system's characteristics. Thus, to enhance the development of digital libraries which is generally quite costly and time-consuming, and to improve the maintenance of such dynamic systems, the evaluation of the quality of digital library components must be carried out periodically and frequently. (Goncalves & Fax 2019, Siyaddaty 2016) so to evaluate the digital libraries in a comprehensive way, the 5S framework was adopted. It tries to consider both quantitative and qualitative aspects of research and to present a comprehensive approach given the level of the library. The 5S framework is based on Borgman information life-cycle model which is one of the first theories applied in the domain of digital library. 5S model stems from Dr Goncalves's PhD dissertation and stands for five components specifically Streams, Structures, Spaces, Scenarios and Societies (Samiee, 2016). Streams represent the characteristics of existing contents in digital library such as encoding and language in text resources or special forms in multimedia data. A structure specifies the way in which parts of a whole are arranged or organized. A space is a set of objects together with operations on those objects that obey certain constraints. A scenario is a sequence of events that also can have a number of parameters. A society is "a set of entities and the relationships between them" and can include both human users of a system as well as automatic software entities which have a certain role in system operation.

Prior to this research, some researches have been done into the domain of 5S, but none has presented a check-list according to the framework and apparently their methods have been different from this research's. The previous researches done by Mokhtary Asky & Alidousty (2013) Siyaddaty (2016), Samiee (2016), Goncalves (2004), Fax & Goncalves, (2009), Fax and et.al, (2012), Goncalves and "et al" (2007), Murty and et al (2007) and Randhawa & Ahuja (2017) emphasize the importance of the 5S framework and have utilized it for

such purposes as evaluation, integration and design. With a view to investigating the status of digital library and based on the five components of the 5S our check-list was designed. Since the researches done in Iran (into the evaluation of digital libraries) have only dealt with certain aspects of digital library and in principle have been done quantitatively, I have made an effort to present an evaluation model for digital libraries with a general survey of the designed check-list and based on the views and opinions of experts in the field.

The importance of evaluating digital libraries helps us understand the efficiency of libraries and their digital services better and using the results of the evaluation is for the enhancement and development of digital libraries. If we fail to evaluate digital libraries, we won't be able to know if the digital library in question is useful and efficient or not. And if it is not, how can we create the ideal conditions? Accordingly, attempts have been made to answer the crucial question that follows as:

As regards the components (Stream, Structure, Space, Scenario, and Society)" of 5S framework, what are the effective criteria for the evaluation of Iran's digital libraries from the viewpoints of the experts in the domain of digital library?

Methodology

The present research is an applied one based on the three methods: documentary, fuzzy Delphi (to extract criteria and develop the conceptual model) and survey forming a kind of trinity. The algorithm of the implementation of fuzzy Delphi method is represented by figure one:

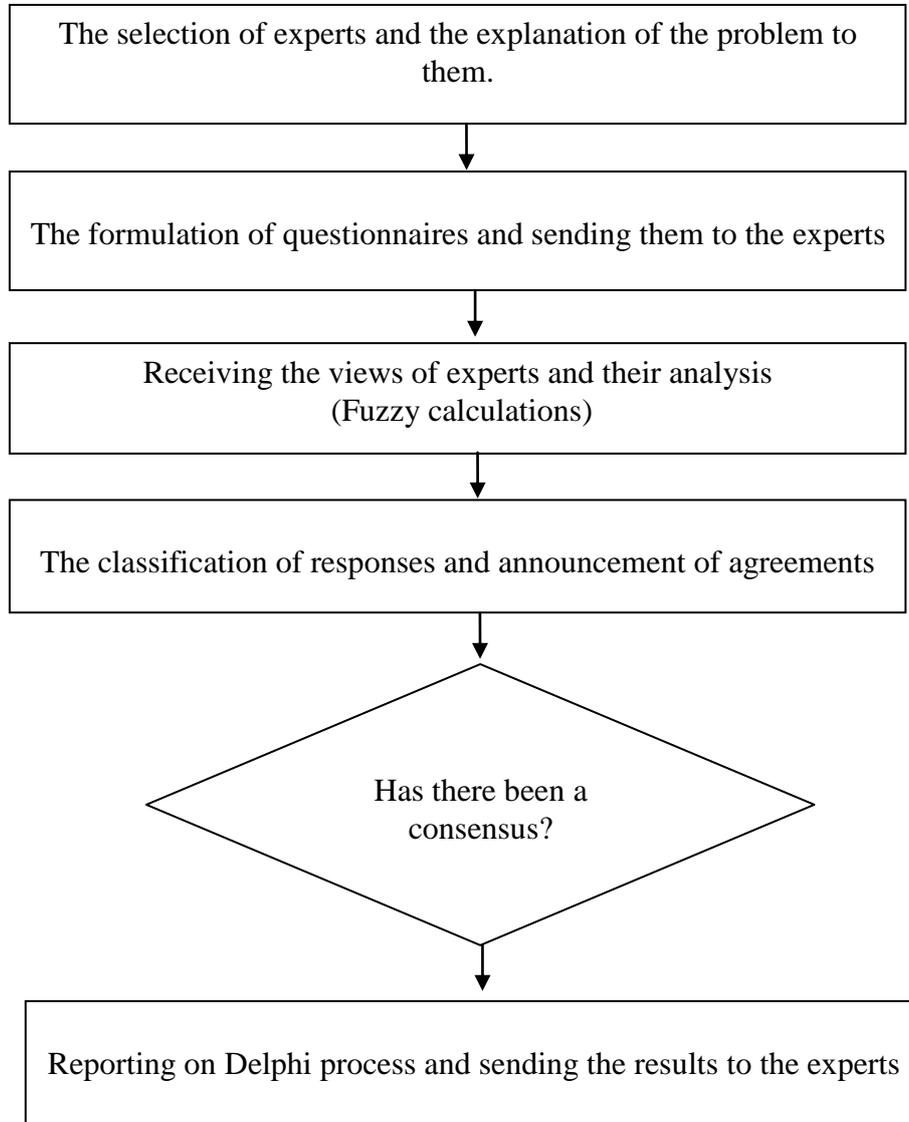


Fig.1. Algorithm of implementation of Fuzzy Delphi method

For the identification and prioritization of the criteria of digital libraries evaluation based on the 5S framework, twenty experts of digital library domain in three groups (15 fellow members of digital library, 3 managers of libraries who took an active part in the development of digital libraries and 2 foreign specialists in the domain of 5S framework and evaluation of digital library) were picked out as

the community of statistical research. The components of 5S framework based on studying the relevant texts and the crucial questions of the research were classified and presented and the items were arranged based on Likert spectrum and the initial questionnaire was drawn up. To confirm the face validity of the questionnaire the views of 6 specialists in digital library were applied and their viewpoints were reflected in the final questionnaire. The reliability of the questionnaire was calculated 96% based on the rate of Cronbach's coefficient Alpha. The questionnaire of the present research was formulated with a view to acquiring the opinions of digital library experts as to what extent they agree to the components and criteria of 5S framework. Therefore, the experts declared the extent of their agreement by means of verbal variables such as very little, not much, average, much and very much. On the applied scale the items represented the sequence of 1,2,3,4 and 5. As different characteristics or attributes of people influence their interpretation from qualitative variables, thus with the definition of qualitative variables range, the experts have answered the questions unanimously, These variables with regard to Table1 have been defined as triangular fuzzy numbers.

Verbal variables	Triangular fuzzy Number	Definite fuzzy Number
Very much	(1,0/25,0)	(0/9375)
much	(0/75,0/15,0/15)	(0/75)
average	(0/5,0/25,0/25)	(0/5)
Not much	(0/25,0/15,0/15)	(0/25)
Very little	(0,0,0/25)	(0/0625)

In the above table the definite fuzzy numbers are calculated using Minkovsky formula as:

$$x = m \frac{\beta - \alpha}{4}$$

Findings

The findings of the research are resulted from views of experts in the format of verbal variables by which are shown by fuzzy numbers technique in the tables below in three stages concerning criteria of digital library evaluation based on the 5S (stream, structure, space, scenario, and societies) framework.

The poll of the first stage:

At this stage, the presented conceptual model was sent along with a description of the components and criteria to experts` panel and the rate of their agreement with any of the criteria was registered and their suggested and corrective viewpoints were summed up as it is shown below. Given the proposed options and the defined verbal variables in the questionnaire, the presented answers were analyzed and the results were given at Table 2.

Table 2.Results of counting the answers of the poll's first stage

		Criteria	Very little	Not much	average	much	Very much
Stream	1	Motivation and efficient involvement of users	0	1	7	10	2
	2	Digital collection development	0	0	1	8	11
	3	Back up of Mark up languages SGML,HTML,XML	0	0	6	5	9
	4	The protocols of data encoding while transferring data such as WEP,SSL and TSL	0	0	0	4	16
structure	5	Digital Organization	0	0	0	16	4
	6	Using all kinds of metadata for the description of digital resources	0	1	2	6	11
	7	Social Tagging	1	2	0	7	10
	8	Web Indexing	2	8	5	5	0
Space	9	Models of information exchange	0	0	5	6	9
	10	Accessing information through web portal & using consistent search systems	0	0	2	4	14
	11	Security systems	0	0	3	5	12
	12	network Services	0	1	0	2	12
Scenario	13	policies of digital resources	0	1	0	11	8

	Criteria		Very little	Not much	average	much	Very much
	14	Reference digital & Distance membership services	1	8	5	5	0
	15	Programming laws and regulations	0	0	0	14	6
	16	Thesaurus	0	0	1	9	10
	17	Periodical evaluation	0	0	2	4	14
societies	18	Digital reference and Antivirus softwares and robots	0	1	13	4	2
	19	Public accountability	0	1	5	2	12
	20	Special Services to users	0	1	4	2	13

The fuzzy average of each criterion with regard to the results of this table was calculated based on the formulas below:

Formula (2):

$$A_i = (a_1^{(i)}, a_2^{(i)}, a_3^{(i)}), i = 1, 2, 3, \dots, n$$

Formula (3):

$$A_{ave} = (m_1, m_2, m_3) = \left(\frac{1}{n} \sum_{i=1}^n a_1^{(i)}, \frac{1}{n} \sum_{i=1}^n a_2^{(i)}, \frac{1}{n} \sum_{i=1}^n a_3^{(i)} \right)$$

In the above formulas A_i represents expert's view and IM & A_{ave} represent the average of experts' views. The results of these calculations are presented by Table 3 below.

Table 3. Average of expert's points of view resulted from the first poll

Criteria		Fuzzy Triangular average (m, α, β)						Fuzzy average was defuzzified		
Stream	1	Motivation and efficient involvement of users	(	0/10	0	0/21	0	0/51	)	0/48
	2	Digital Development collection	(	0/07	0	0/64	0	0/88	)	0/73

Criteria			Fuzzy Triangular average (m, α, β)					Fuzzy average was defuzzified		
	3	Back up of Mark up languages SGML,HTML,XML	(	0/06	0	0/53	0	0/69	)	0/57
	4	The protocols of data encoding while transferring data such as WEP,SSL and TSL	(	0/08	0	0/60	0	0/85	)	0/72
structure	5	Digital Organization	(	0/12	0	0/33	0	0/80	)	0/75
	6	Using all kinds of metadata for the description of digital resources	(	0/07	0	0/63	0	0/83	)	0/68
	7	Social tagging	(	0/08	0	0/58	0	0/79	)	0/66
	8	Web Indexing	(	0/17	0	0/17	0	0/41	)	0/41
Space	9	Models of information exchange	(	0/11	0	0/57	0	0/80	)	0/68
	10	Accessing information through web portal & using consistent search systems	(	0/05	0	0/61	0	0/76	)	0/62
	11	Security systems	(	0/08	0	0/69	0	0/86	)	0/71
	12	network Services	(	0/02	0	0/64	0	0/69	)	0/53
Scenario	13	policies of digital resources	(	0/09	0	0/50	0	0/83	)	0/72
	14	Reference digital & Distance membership services	(	0/17	0	0/17	0	0/41	)	0/41
	15	Programming laws and regulations	(	0/11	0	0/42	0	0/83	)	0/75
	16	Thesaurus	(	0/08	0	0/59	0	0/86	)	0/73
	17	Periodical evaluation	(	0/06	0	0/77	0	0/90	)	0/72
societies	18	Digital reference and Antivirus softwares and robots	(	0/20	0	0/31	0	0/59	)	0/56
	19	Public accountability	(	0/08	0	0/58	0	0/79	)	0/66
	20	Special Services to users	(	0/02	0	0/68	0	0/74	)	0/57

In the above table the triangular fuzzy average was calculated using the second formula and then was defuzzified using the Minkowsky's

formula. The resulted definite average stands for the extent to which the experts have agreed with any of the components of the conceptual model in the research.

As It can be observed in Table 3, the highest extent of experts` agreement belongs to the following criteria: motivation and the efficient employment of users, digital organization, web-indexing and programming and rules & regulations and the lowest extent belongs to the criteria: digital reference services, distance membership, softwares & robots, digital references and antivirus. Considering that in the presented questionnaire plus closed questions, the experts` views have been taken in the format of open questions too, thus after the refinement of the present viewpoints and holding meetings with them, the following corrective initiatives concerning the conceptual model were carried out:

- 1- Given the ever-increasing expansion of modern information technologies, the cloudy services were added to the criterion of network services.
- 2- The digital reference services and distance membership are not the only services rendered by digital libraries and there are some other services such as current awareness, private library etc, which are also given, therefore the inclusion of a general criterion entitled “digital services” in the conceptual model was recommended.
- 3- As the encoding protocols constantly develop along with IT changes and new kinds keep emerging, thus the comprehensive presentation of the criterion “encoding protocols” was suggested.
- 4- Ontologies that have precise semantic relations are most necessary and important for improving and boosting retrieval systems in digital libraries, so the inclusion of ontologies in the criterion “thesauri” was suggested.
- 5- Digital libraries have different formats to present different types of metadata, so the inclusion of the general criterion “metadata standards” in the conceptual model was recommended; a criterion that would contain all types of metadata ranging from descriptive, management, preservation, and structural to technical etc.
- 6- The emergence of social softwares altered the method of information organization. And social tagging which was the public method of organizing web information resources, was renamed as “social organization”, therefore the experts suggested that the criterion “social organization” replace the criterion “social tagging”.

The poll of the second stage

At this stage after making the required changes in the criteria of 5S model components, the second questionnaire was drawn up and sent again to experts` panel along with previous viewpoints of each person and the extent to which they disagreed with the viewpoints of the other experts. At the second stage members of the experts` panel, given the viewpoints of the other members and also the changes made in the criteria, answered the presented questions once again with results presented by Table 4.

Table 4. Results of counting the answers of the poll's second stage

	Criteria	Very little	Not much	average	much	Very much
Stream	1 Motivation and efficient involvement of users	0	0	0	6	13
	2 Digital Development collection	0	0	2	9	9
	4 Standards of Mark-up languages	0	1	1	4	14
	6 Encoding protocols	0	0	1	10	9
structure	7 Digital Organizing	0	0	2	8	10
	9 Social organizing	0	0	0	9	11
	10 Web Indexing	0	0	1	15	4
	12 Metadata Standards	1	0	0	13	6
Space	13 Models of information exchange	1	0	2	10	7
	15 Security systems	0	1	2	13	4
	17 All types of access to digital resources	0	0	0	6	14
	18 Cloudy and network Services	0	1	2	10	7
Scenario	19 policies of digital resources	0	0	1	15	4
	21 Digital services	0	0	0	14	6
	23 Programming laws and regulations	0	0	1	15	4
	24 Thesaurus and ontologies	0	0	2	4	14
	26 Periodical evaluation	0	0	2	4	14
societies	27 Softwares & Robots	0	0	0	14	6
	29 Public accountability	0	1	2	10	7
	31 Special Services to users	1	0	2	10	7

The results of counting presented answers at the second stage just like the first stage were analyzed using the formulas 1,2,and 3 and are presented by Table 5.

Table 5. Average of expert's points of view resulted from the second poll

Criteria			Fuzzy Triangular average (m, α, β)						Fuzzy average was defuzzified	
Stream	1	Motivation and efficient involvement of users	(	0/06	0	0/72	0	0/90	)	0/73
	2	Digital Development collection	(	0/09	0	0/55	0	0/84	)	0/72
	3	Standards of Mark-up languages	(	0/05	0	0/76	0	0/89	)	0/71
	4	Encoding protocols	(	0/09	0	0/55	0	0/85	)	0/73
structure	5	Digital Organizing	(	0/08	0	0/60	0	0/85	)	0/72
	6	Social organizing	(	0/07	0	0/63	0	0/89	)	0/75
	7	Web Indexing	(	0/13	0	0/34	0	0/79	)	0/73
	8	Metadata Standards	(	0/11	0	0/41	0	0/79	)	0/71
Space	9	Models of information exchange	(	0/11	0	0/46	0	0/78	)	0/69
	10	Security systems	(	0/06	0	0/72	0	0/90	)	0/73
	11	All types of access to digital resources	(	0/11	0	0/42	0	0/83	)	0/75
	12	Cloudy and network Services	(	0/11	0	0/47	0	0/11	)	0/70
Scenario	13	policies of digital resources	(	0/13	0	0/34	0	0/79	)	0/73
	14	Digital services	(	0/11	0	0/42	0	0/83	)	0/75

Criteria		Fuzzy Triangular average (m, α, β)							Fuzzy average was defuzzified	
	15	Programming laws and regulations	(	0/13	0	0/34	0	0/79	)	0/73
	16	Thesaurus and ontologies	(	0/06	0	0/77	0	0/90	)	0/72
	17	Periodical evaluation	(	0/07	0	0/77	0	0/85	)	0/68
Societies	18	Softwares & Robots	(	0/11	0	0/42	0	0/83	)	0/75
	19	Public accountability	(	0/11	0	0/47	0	0/11	)	0/70
	20	Special Services to users	(	0/11	0	0/46	0	0/78	)	0/69

Considering the present viewpoints at the first stage and their comparison with the results of this stage, the poll doesn't continue in case the rate of the disagreement between the two stages is even less than very little (0/1) (Cheng and Lin, 2002).

Formula (4):

$$S(A_{m2}, A_{m1}) = \left| \frac{1}{3} [(a_{m21} + a_{m22} + a_{m23}) - (a_{m11} + a_{m12} + a_{m13})] \right|$$

Based on formula 4, the rate of disagreement between the first and the second stage is shown in the table below:

Table 6. The rate of disagreement between expert's view points at the first and second stage of the poll

	Criteria	First stage	Second stage	disagreement between first & second stage
Stream	Motivation and efficient involvement of users	0/48	0/73	0/25
	Digital Development collection	0/73	0/72	0/01
	Standards of Mark-up	0/57	0/71	0/14

	Criteria	First stage	Second stage	disagreement between first & second stage
	languages			
	Encoding protocols	0/72	0/73	0/02
structure	Digital Organizing	0/75	0/72	0/03
	Social organizing	-	0/75	-
	Web Indexing	0/68	0/73	0/05
	Metadata Standards	0/41	0/71	0/30
	Models of information exchange	0/68	0/69	0/01
space	Security systems	0/62	0/73	0/02
	All types of access to digital resources	0/71	0/75	0/04
	Cloudy and network Services	0/53	0/70	0/17
	policies of digital resources	0/72	0/73	0/01
Scenario	Digital services	0/41	0/75	0/34
	Programming laws and regulations	0/75	0/73	0/02
	Thesaurus and ontologies	0/73	0/72	0/02
	Periodical evaluation	0/72	0/68	0/04
	Softwares & Robots	0/56	0/75	0/19
societies	Public accountability	0/66	0/70	0/04
	Special Services to users	0/57	0/69	0/12

As the above table shows, the members of experts` panel have reached an agreement on the components number 2,4,5,7,9,10,11,13,15,16,17,19 and the rate of disagreement at the first and second stage was less than very little (0/1), so the poll on the above components was stopped.

The poll of the third stage

At this stage after making the required changes in the components of the model, the third questionnaire was drawn up and again sent to the experts along with the previous viewpoints of each person and the extent to which they differed from the average of viewpoints of other experts. However at this stage, 12 cases were stopped out of 20 criteria which had been analyzed at the previous stage and the poll was taken regarding the rest of 8 criteria.

Table 7. Results of counting the answers of the poll's third stage.

	Criteria	Very little	Not much	average	much	Very much
1	Motivation and efficient involvement of users	0	1	0	13	6
2	Standards of Mark-up languages	0	0	2	4	14
3	Social organizing	0	1	2	13	4
4	Metadata Standards	0	1	2	13	4
5	Cloudy and network Services	1	0	2	10	7
6	Digital services	0	0	2	9	9
7	Softwares & Robots	0	1	0	13	6
8	Special Services to users	0	1	2	6	11

Considering the formulas 2,1 and 3 the fuzzy average of the results of counting data in the above table is shown in the table below.

Table 8. Average of expert's points of view resulted from the third poll

Criteria	Fuzzy Triangular average (m, α, β)	Fuzzy average was defuzzified
1 Motivation and efficient involvement of users	(0/05 0 0/72 0 0/89)	0/72
3 Standards of Mark-up languages	(0/06 0 0/77 0 0/90)	0/72
6 Social organizing	(0/06 0 0/72 0 0/90)	0/73
8 Metadata Standards	(0/06 0 0/72 0 0/90)	0/73
10 Cloudy and network Services	(0/11 0 0/46 0 0/78)	0/69
15 Digital services	(0/09 0 0/55 0 0/84)	0/72
18 Softwares & Robots	(0/06 0 0/72 0 0/90)	0/73
19 Special Services to users	(0/08 0 0/64 0 0/84)	0/70

Based on Cheng-Lin`s formula 4, the rate of disagreement of experts`views at the stages 2 and 3 was calculated and is shown in the table below.

Table 9. The rate of disagreement between expert's view points at the second and third stage of the poll

Criteria	Second stage	Third stage	disagreement between second & third stage
Motivation and efficient involvement of users	0/73	0/72	0/01
Standards of Mark-up languages	0/71	0/72	0/01
Social organizing	0/75	0/73	0/02
Metadata Standards	0/71	0/73	0/02
Cloudy and network Services	0/70	0/69	0/01
Digital services	0/75	0/72	0/03
Softwares & Robots	0/75	0/73	0/02
Special Services to users	0/69	0/70	0/01

As it is shown by the above table, the rate of disagreement of experts` views at the second and third stage was less than very little (0/1), so the poll didn`t continue.

Accordingly during the 3 stages of experts` poll, 20 criteria of the evaluation model of digital libraries based on the 5S framework were refined and some criteria were omitted and some added and eventually the final model consisting of 5 dimensions and 20 criteria, formed as it has been shown by Figure 2.

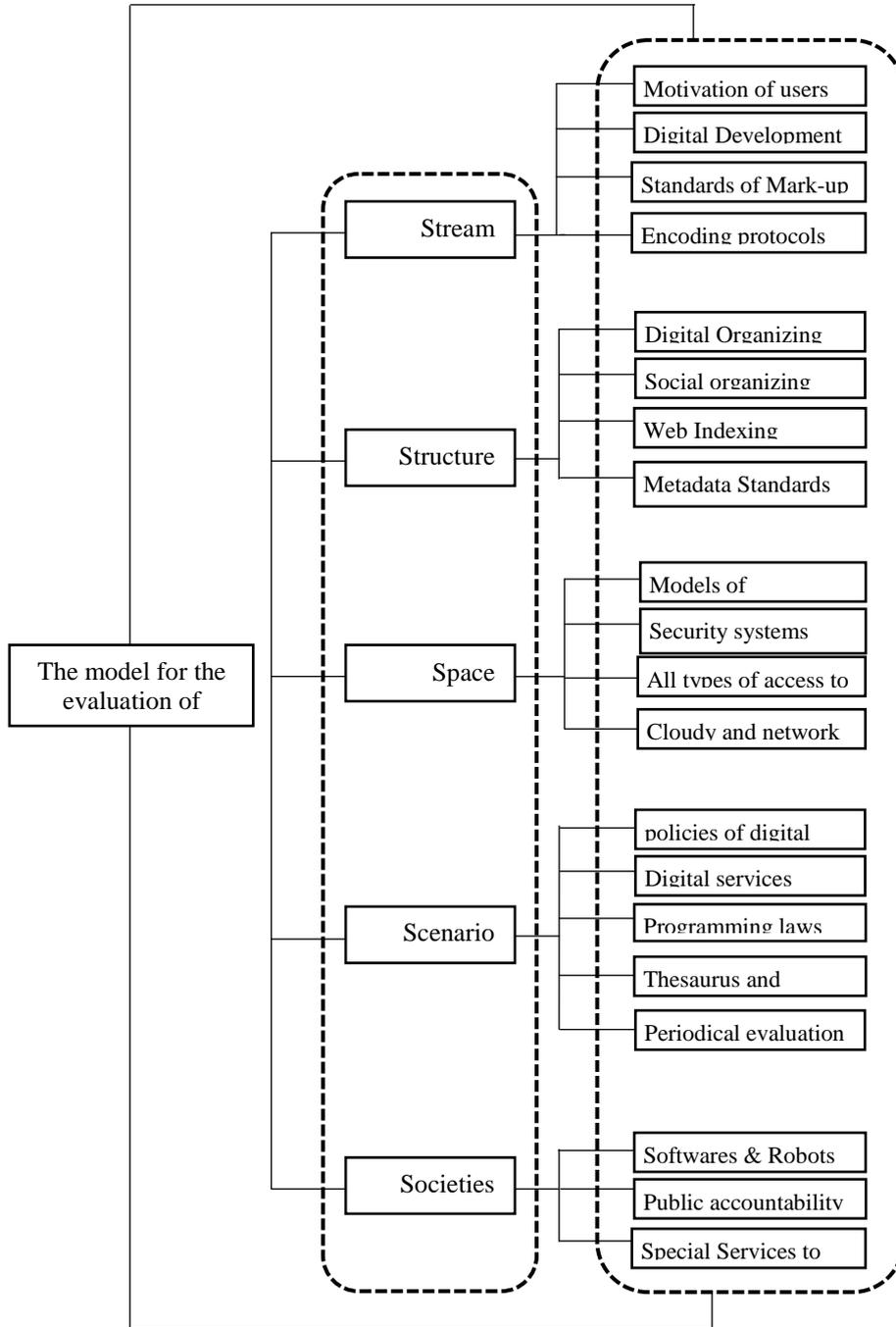


Figure 2. The model for the evaluation of digital library based on 5S framework

Conclusion

In view of the fact that the design and development of a digital library system is truly difficult and costly and also of the deep and extensive needs of these libraries, it is necessary to present a conceptual model for their evaluation and also to understand the intricate interchanges among their criteria better. Even though it is a long time since the necessity of designing such models in order to deal with the issues relating to the expansion of digital libraries has been perceived, as regards the development and presentation of official frameworks and models and for the structure of digital libraries, there has been slight progress. The conceptual model presented in this paper holds new orientations to present a comprehensive evaluation model for digital libraries while having a comprehensive systematic structure. This model has been refined by experts in 5 parts of the 5S conceptual framework while having sufficient theoretical back up. In the component *stream*, 4 criteria of "motivation and the effective involvement of users", "digital collection development", "standards of Mark-up languages" and "encoding protocols" were confirmed which is in agreement with the results of researches done by Mokhtary Asky & Alidousty (2013) and Samiee (2016) and Fax & Goncalves (2009). In *scenario* component, and the 5 criteria the following were confirmed: "policies of digital resources", "digital services", "Thesaurus and ontologies", "Programming laws and regulations" and "periodical evaluations". These results are in agreement with researches done by Goncalves & et.al (2007), Murty & et.al (2007) and Mokhtary Asky & Alidousty (2013). However, the result is in agreement with Samiee's research only in the criterion "service behavior of digital library" and with Fax & et.al (2012) in the criterion "periodical evaluation". In *space* component, 4 criteria of "models of information exchange" "network and cloudy services" "all types of access to digital resources" and "security systems" were approved of. The results of the research were not in agreement with the research done by Randhawa & Ahuja (2017) which dealt with the identification of existing gaps in the 5S framework from the viewpoints of researchers and specialists of the optimal use of work environment in order to maintain organizational improvement and not with Samiee's research (2016) which considered space as a measurable distance based on topology and vector, but they were in agreement with researches done by Mokhtary Asky & Alidousty (2013), Goncalves (2004), Fax & et.al

(2012) and Syaddaty (2016). However, they were in agreement with the research done by Shen & et.al (2015) which dealt with a tool named 5S Qual for the quantitative evaluation of digital library at levels of accessibility, connection or dependence, preservation, linking, importance, resemblance and updating of digital objects. In *societies* component 3 criteria were confirmed: "softwares & robots", "public accountability" and "special services rendered to users". The results were in agreement with researches done by Fax & Goncalves (2009), Mokhtary Asky & Alidousty (2013), Syaddaty (2016) and Samiee (2016). In *structures* component, "digital organization", "social organization", "web indexing" and "metadata standards" were approved of. The results were in agreement with the researches done by Goncalves & et.al (2007), Fax & Goncalves (2009), Syaddaty (2016), Randhawa & Ahuja (2017) but not with Samee`s research (2016) in which the structures included metadata, taxonomies, ontologies, user`s communications, etc. The presented criteria of this conceptual model offers a basis for definition, connection and integration of digital library concepts. This conceptual model can be used for the evaluation of digital libraries. In view of the results of the present research, the following initiatives are suggested:

- evaluation of all types of digital libraries using the catalogue of presented criteria in the conceptual model put forward in the present research.
- programming for the implementation of this conceptual model in Iran`s digital libraries and to fill the existing gaps in the model.
- reviewing the processes: collection development, organization, preservation and maintenance and dissemination of resources in Iran`s digital libraries.

Recommended Citation

Samiei, M., (2021). Designing the Conceptual Model of Digital Library Evaluation using the Fuzzy Delphi Method. *International Journal of Digital Content Mangement*, 2 (3), 25-43.

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