New ICT-based index for beach quality management

ABSTRACT

Beach management is based on administering technical, environmental, social and political issues to solve coastal problems. To assist coastal management, quality systems have evolved from Beach Certifications Schemes to indicator systems that take into account the three beach functions —natural, protection and recreation—. This study analyses: i) The usefulness of current indices for management decision making; ii) whether the beach user can both access information and participate in beach management; iii) whether the beach indices are dynamic, providing up-to-date information on the status quo of beach or is it merely a snapshot in time; iv) whether beach indices deliver the same result when used by different beach technicians. The results show that the current systems are subjective and based on static criteria, since most of them are obtained through expert opinion, visual inspection and/or interpretation of user surveys. Furthermore, most of the indices focus on the study of the recreational function leaving aside the other beach functions (especially protection). Therefore, the values obtained through these indices are more addressed to the beach user than to the beach manager, so (in general) they do not serve the beach manager in decision-making. Finally, to address the problems described above, a conceptual model based on ICT (Information and Communication Technologies) is proposed for the management and monitoring of beach quality. The computerization and automation of beach management, can be rendered more efficient and effective due to technological advances that can offer an integrated solution for the management of beaches.

Keywords: *index; indicators; beach management; ICTs*

1. INTRODUCTION

Beaches have been perceived by humans throughout history from different perspetives: fear of the unknown (17th Century); having medicinal properties (18th Century); a holiday place for the priviedged classes (1840-1960); and finally, from the 1960s as a place for mass tourism (Botero, 2013). Likewise, beach management has also evolved. The concept is best understood as the actions implemented by a competent organism to maintain the balance between the existing coastal ecosystem and the pressure exerted by human activity (García and Veneciano, 2011). This equilibrium requires an effective beach management systems.

Globally, beach management systems have always been closely linked to recognition and to valuing the quality of correct coastal management (Cagilaba and Rennie, 2005). These recognition systems are known as Beach Certification Schemes (BCSs), among which are, for example, the "blue flags" or the Q Mark according to compliance with ISO 13009:2016. Authors such as Nelson and Botterill (2002) indicate that the use of these quality awards allows a sustainable development of tourism, as well as a strategic comparison between different tourist destinations (Kozak and Nield, 2004).

However, different authors have openly criticised this type of management because they set the quality more from the perspective of beach users than from an environmental assessment point of view (Boevers, 2008; Micallef *et al.*, 1999; Micallef and Williams, 2009; Phillips and House, 2009). Moreover, they are not integrated management systems as they do not take into account all the processes and participants that may intervene in beach management (Barragán, 1997; Yepes, 2002). Furthermore, complying with the established parameters does not (by itself) guarantee user satisfaction, as it responds to a vision located at the precise time of the inspection, that by definition, is a static review of environmental requirements (Fraguell, 1997; Roig-Munar *et al.*, 2006). Nevertheless, they are the systems most used and accepted by users and managers in Europe, although their contribution to sustainable development is very limited (Boevers, 2008; Cagilaba and Rennie, 2005; Nelson and Botterill, 2002; Nelson *et al.*, 2000).

Given the shortcomings of these common approaches to beach management, a new component was added to the concept of beaches quality, namely sustainability (Cendrero, 1997) from which emerged the indicator-based evaluation systems. These systemsas are based on quantitative and qualitative parameters (indicators) that can be used to describe existing situations and measure changes or trends over time, and should therefore be clear, simple and universal (Gouzee *et al.*, 1995). If the values of the various indicators are added together and weighted, a total value is obtained, namely an index (Mondragón, 2002). The elaboration and monitoring of indices can be carried out under two approaches: i) objective (quantifiable information in an exact or generalizable way); and, ii) subjective (non-objective perceptions of reality). As long as these approaches are used properly, and the scope and limitations of each are understood, they can be used in a complementary manner (Sterimberg, 2005).

Therefore, the indices serve both to inform and to develop strategies aimed at improving the living conditions of the population (Tanguay *et al.*, 2009), as well as being accessible to the public (Velázquez and Celemín, 2011). However, there are limitations related to the accessibility, availability and reliability of the necessary data. Therefore, the shortcomings and limitations of these types of management systems make it necessary to consider other systems that consider ecosystems, and also permit more effective and simple management. In this sense, information and communication technologies (ICT) are the key tool to overcome the limitations raised. In particular, this is possible as a result of the progress made in ICT fields such as the internet of things, cloud computing, intelligent sensor networks or web technologies, among others.

Therefore, a study on the integral beach management involves the following three stages: 1) the existing related work needs to be evaluated for its suitability. This is why the recommendations made by previous authors need to be followed so that results can be checked when applied to another study area. Once the results are analysed, proposals are made to address the detected errors; 2) propose a new index aimed to assist the beach manager in devising a planning strategy for beach management. This index must be objective, comprehensive, citizen-centred and dynamic; 3) The model is validated, adjusting the indicators by means of ICT methodologies, techniques and tools.

Therefore, the objectives of this paper are focussed oon the first stage, which comprises the following steps: i) analyse the current Beach Certification Schemes, such as integrated coastal management; ii) analyse the strengths and weaknesses of the current indices and; iii) propose an evaluation system based on ICT for the management, monitoring and provision of information, resulting in a more efficient management of beaches.

2. METHODOLOGY

The methodology is divided into three sections: (1) Literature review; (2) Application of one of the indices studied; and (3) proposal of an ICT based model for the management of beaches.

2.1. Literature review

Scientific studies related to beach certifications, indices and indicators, and other types of management constitute the "universe" from which this research was developed. Studies from different countries were considered in order to have as broad a view as possible of the spectrum of alternatives used.

Table 1 shows the parameters studied for each of the indices.

Table 1. Summary of the data analysed for each of the indices studied in the scientific literature.

Index type (context)	Categoraization of how data were obtained	Data gathering method	Use of ormulas
1 Environmental	1 Objective	1 Formula	Yes
2 Economical	2 Subjective	2 Surveys/Opinions	No
3 Recreational	3 Both	3 Direct observation	
4 Physical		4 Measure	
5 Politician		5 Models	
6 Biological			
7 Miscellaneous			

2.2. Application of one of the studied indices

To demonstrate the conclusions obtained from the literature review, a study was carried that involved applying the Beach Quality Index, known as BQI (Ariza *et al.*, 2010), to the beaches Alicante province (Spain). This index was chosen because it includes the three functions that the beach performs: natural function, protection function and recreational function (MAGRAMA, 2008). Specifically 91 beaches were analysed for the 19 coastal municipalities of the province, covering 223 km of coastline and a beach area of 1,658 km^2, of which 67% is sand and 33% gravel (Palazón *et al.*, 2016): 65.5% of the sandy beaches in the province of Alicante are urban 24.5% are semi-urban; and, 10% are natural. For the gravel beaches, however, 56.6% are semi-urban, 23.4% are natural, and 20.0% are urban.

This paper presents the average BQI results for each municipality, as well as the sub-indexes of: Natural Function (NFI), Protective Function (PFI), and Recreational Function (RFI) (Ariza *et al.*, 2010). However, the remaining results for all the beaches studied are available in the supplementary material.

2.3. Proposal of ICT Models

An ICT model is proposed to make the integral management of beaches viable through: the monitoring of all related information; the calculation of the indicator in an exclusively automated way; and the provision of all this information to all the actors of the system, which will allow the manager to make decisions in a more precise and efficient way.

The fundamental objectives of the model to achieve: generality; flexibility; and, adaptability, that is, able to support any implementation scenario, and calculation of the different indices that are proposed. From the obtained model, a technical architecture was designed to allow: the monitoring and storage of information from various sources (external information systems, monitoring systems and users); the calculation of indicators based on the established configuration; and, the provision of all this information through a SOA approach. The objectives of the architecture are focused on obtaining scalability, interoperability, reusability, security, fault tolerance, and information availability.

3. LITERATURE REVIEW

Table 2 shows a summary of the most relevant characteristics for this article of the different indices discussed below. In general, most of the indices or indicators studied are dominated by user or expert field surveys (Cendrero, 1997; Cervantes *et al.*, 2008; Espejel *et al.*, 2007; Pereira *et al.*, 2003), combined in some cases with objective measures of physical or environmental aspects (Botero *et al.*, 2015; Velázquez and Celemín, 2011), or even the use of formulations (Cendrero *et al.*, 2003). For example, one of the first evaluation systems is that of Leatherman (1997), which is based on biophysical parameters establishing valuations from 1 to 5 in 50 sections ranging from the temperature of the environment and water in summer to security against theft or the presence of undesirable activities. But they omitted a fundamental factor, namely users experiences. Over the last 15 years, researchers have been incorporating user services into new evaluation and recognition systems. However, this participation does not imply a complete user integration, as it is not integral, active and continuous. Special care has also been taken to distinguish two completely different types of beach: the urban and the semi-urban beach. However, there is a tendency for beach users in rural areas to value very positively beaches that are as natural as possible (Cagilaba and Rennie, 2005).

Regarding the variable integration method, in most of the studied indices, these are integrated into the indicators by means of summands that are usually weighted by coefficients. The coefficients are generally obtained from the opinion of experts and beach managers (Cervantes *et al.*, 2008), which gives them a high degree of subjectivity. The index proposed by Pereira *et al.* (2003) the weighting given to the parameters is determined by the surveys of beach users. The combination of these elements also allowed several beaches across Europe to be evaluated and classified in a novel way, which in turn permitted the design of the most appropriate management or recovery plans for each one of them. However, the opinions obtained through surveys are subjective and static, since the data are taken at a given point in time, and therefore do not reflect changes over a period of time (Philipp, 1998; Ponce, 2004).

Another system is the one developed by the Surfrider Foundation (www.surfrider.org) called Beach Health Indicators, which uses a series of indicators to establish a quantitative rating of the state of beaches. For the evaluation of each beach, the following factors are considered: a) the accesses to the beach; b) the quality of the water in the surfing area; c) the presence of coastal erosion; d) ecology of the beach; e) coastal structure; f) actions against erosion; g) sites for surfing; and, h) the existence of Internet portals with data that promote and show the state of the beaches in each evaluated place. This system, although functional, lacks sociocultural aspects (Morgan, 1999).

In Spain, the first works were carried out by Ariza (2007) who proposed the use of a composite index (Beach Quality Index; BQI) based on the analysis of the functions of the beach and including thirteen sub-indices to evaluate practically all the urban and semi-urban beaches of the Mediterranean Sea. The components of the index were based on two questionnaires, one carried out by experts and the other by beach users (Ariza *et al.*, 2010). However, this index does not take natural beaches into account, and is also static (i.e., representative of the moment in which the survey was carried out).

Therefore, in general, although the indices detected in the scientific literature may reflect the situation of a beach, they have, as demostrated, a great disparity of criteria and results. Additionally, subjectivity is a very important factor both in the calculations and in the subsequent interpretation of the results. Furthermore, the indices are more oriented to user satisfaction than to manager needs since they use variables considered by the user/bather/tourist whose measurement is subjective and difficult, and as a consequence could be erroneous However, the indices represent an instrument that simplifies and quantifies the phenomena that occur on beaches, serving management decision-making and providing beach user information (Bermejo and Nebreda, 1998; ICOM, 2006).

Table 2. Summary of the indices analysed in the article.

Author	**Index type (context)**	**Categoraization of how data were obtained**	**Data gathering method**	**Use of Formulas**	**Number of variables**	**Weighting**
Leatherman (1997)	1-3-4-6	3	2-3-4	No	50	Yes
Nazarea *et al.* (1998)	1	2	3	No	-	-
McLaughlin *et al.* (2002)	2	1	3-4	No	6	No
Cendrero *et al.* (2003)	1	3	1-2-3-4	Yes	28	Yes
Pereira *et al.* (2003)	1-3-4-6	3	2-3	No	45	No
Ponce (2004)	7	2	2	No	34	No
Villares *et al.* (2004)	7	2	2	No	-	-
Pereira (2006)	7	2	2	No	10	No
Brenner *et al.* (2006)	7	1	5	Si	11	No
Espejel *et al.* (2007)	1-3-4	2	2	No	29 or 38	Yes
Quiroga (2007)	1	3	5	Yes	-	-
Cervantes *et al.* (2008)	7	2	2	No	25	Yes
Ariza *et al.* (2010)	1-3-4-6	2	1-2-3-4	Yes	13	Yes
Madanes *et al.* (2010)	1-2-3-4	3	2-3-4	No	30	No
Camino *et al.* (2011)	1	1	4	Yes	9	Yes
Velázquez and Celemín (2011)	1-3	3	3-4	No	23	Yes
Botero *et al.* (2015)	1-3-4-6	3	1-3-4	-	30	No

4. RESULTS AND DISCUSSION

4.1. Application of one of the studied indices

The application of one of the indices analysed is explained below. This is the BQI proposed by Ariza *et al.* (2010) and which was applied to the particular case of the province of Alicante in the Spanish Mediterranean (Table 3). According to Ariza *et al.* (2010), for the analysis of the index an initial differentiation of the beaches within 2 large groups was carried out: urban; and semi-urban. However, a third group was considered in this work, i.e., the natural beaches. Hence, the results obtained have also been divided into the three types (urban, semi-urban and natural).

The BQI contemplates the three functions assigned to the beach: natural function, protection function and recreational function (MAGRAMA, 2008). This is achieved through three subscripts: the Natural Function Index (NFI) (Table 4), the Protection Function Index (PFI) (Table 5) and the Recreational Function Index (RFI) (Table 6). The participation of each partial index of the BQI can vary depending on the set objectives, as defined by Yepes (2007). The weight of each factor will depend on its importance, and in order to arrive at a final weighting, the opinion of experts and beach managers is necessary (Ariza *et al.*, 2010). Herein rests the main criticism, based on the subjectivity of the people consulted despite their recognised experience. In addition, in this type of index such as the BQI, the index itself does not provide information on the problem or weakness of the beach. To identify this problem, it is necessary analyse the partial indices, and from them, the manager can take action to improve the situation on the beach. Also, as with other studied indices, this type of indice reflects the situation at a given time without taking into account the dynamic character of the beach (Roig-Munar, 2004).

From the analysis of the quality indices of the 96 analysed beaches, it can be deduced that the average quality index of the beaches of Alicante is around 0.625 (Table 3). The maximum value was 0.856 for the beach of Les Ortigues (Guardamar) and the minimum values was 0.278 for the beach of Les Rotes (Denia) —see supplementary materials—. By municipalities, the highest average BQI was recorded for the municipality of Alfás del Pi (0.804) whereas the minimum value was Denia — average of 0.416— (Table 3). The municipality of Calpe has beaches with some of the best quality indices as well as some of the worst quality indices. This is due to the poor beach access and very basic services of the beaches of Manzanera and Morelló.

Table 3. Mean BQI for each municipality by type of beach.

Municipality	Sand Beaches			Gravel Beaches		
	Urban	Semi-Urban	Natural	Urban	Semi-Urban	Natural
Alfás Del Pi				0.804		
Alicante	0.650	0.848				
Altea				0.612	0.607	0.526
Benidorm	0.741					
Benissa		0.656				0.660
Benitatxell						0.740
Calpe	0.710				0.584	
Denia	0.422	0.476		0.403	0.278	
El Campello	0.810	0.731			0.601	0.704
Elche		0.692	0.761			
Finestrat	0.757					
Guardamar	0.619	0.651	0.777			
Jávea	0.796			0.777	0.647	
Orihuela	0.705	0.600				
P. Horadada	0.565	0.690				
Santa Pola	0.677	0.692	0.525			
Teulada	0.576	0.722			0.554	
Torrevieja	0.632	0.746				
Villajoyosa	0.842				0.738	0.596

i) Green: excellent, ii) Yellow: good, iii) Orange: standard iv) Red: poor

Table 4. Mean NFI for each municipality by type of beach.

Municipality	Sand Beaches			Gravel Beaches		
	Urban	Semi-Urban	Natural	Urban	Semi-urban	Natural
Alfás del Pi				0.91		
Alicante	0.47	0.89				
Altea				0.68	0.76	0.89
Benidorm	0.43					
Benissa		0.79				0.97
Benitatxell						0.80
Calpe	0.75				0.87	
Denia	0.53	0.49		0.61	0.32	
El Campello	0.85	0.80			0.83	0.96
Elche		0.69	0.88			
Finestrat	0.85					
Guardamar	0.73	0.66	0.92			
Jávea	0.85			0.86	0.81	
Orihuela	0.76	0.73				

P. Horadada	0.76	0.81				
Santa Pola	0.78	0.98	0.88			
Teulada	0.56	0.72			0.87	
Torrevieja	0.81	0.84				
Villajoyosa	0.73				0.79	0.94

i) Green: excellent, ii) Yellow: good, iii) Orange: standard iv) Red: poor

Table 5. Mean PFI for each municipality by type of beach.

Municipality	**Sand Beaches**			**Gravel Beaches**		
	Urban	Semi-Urban	Natural	Urban	Semi-Urban	Natural
Alfaz del Pi				0.88		
Alicante	0.71	1.00				
Altea				0.40	0.40	0.00
Benidorm	0.97					
Benissa		0.46				0.35
Benitatxell						0.89
Calpe	0.62				0.18	
Denia	0.22	0.32		0.03	0.12	
El Campello	0.91	0.77			0.32	0.50
Elche		0.85	0.74			
Finestrat	0.68					
Guardamar	0.43	0.74	0.71			
Jávea	0.84			0.92	0.48	
Orihuela	0.56	0.30				
P. Horadada	0.28	0.55				
Santa Pola	0.48	0.43	0.07			
Teulada	0.47	0.70			0.00	
Torrevieja	0.43	0.64				
Villajoyosa	1.00				0.69	0.18

i) Green: excellent, ii) Yellow: good, iii) Orange: standard iv) Red: poor

Table 6. Mean RFI for each municipality by type of beach.

Municipality	**Sand Beaches**			**Gravel Beaches**		
	Urban	Semi-Urban	Natural	Urban	Semi-Urban	Natural
Alfaz del Pi				0.75		
Alicante	0.65	0.64				
Altea				0.71	0.61	0.56
Benidorm	0.69					
Benissa		0.66				0.55
Benitatxell						0.51
Calpe	0.75				0.61	
Denia	0.50	0.61		0.56	0.37	
El Campello	0.76	0.59			0.57	0.58
Elche		0.54	0.62			
Finestrat	0.78					
Guardamar	0.69	0.55	0.66			
Jávea	0.77			0.70	0.59	
Orihuela	0.77	0.72				
P. Horadada	0.67	0.67				
Santa Pola	0.76	0.57	0.51			
Teulada	0.64	0.75			0.68	

Torrevieja	0.71	0.72				
Villajoyosa	0.78				0.71	0.56

i) Green: excellent, ii) Yellow: good, iii) Orange: standard iv) Red: poor

The BQI environmental factors are subjective when assessing the aesthetic and hygienic quality of a beach through visual inspection. It is not the only index, others such as Enríquez (2003) also consider the quality of the beaches by means of visual appraisals of the surroundings. However, following the process established by the BQI, 44% of the beaches in the province of Alicante are included in what has been established as standard environmental quality (values of 0.75 to 0.51, supplementary). After the NFI study there is no clear trend, but there are 3 municipalities that stand out from the rest: Orihuela, Villajoyosa and Jávea (Table 4). However, this factor does not contemplate the quantitative and qualitative analysis of the sands which is very necessary, together with the quality of the water, due to the effect this can have on the swimmer (W.H.O., 2003). Finally, although the BQI is designed for urban and semi-urban beaches, municipalities that have their beaches integrated within the urban framework are those with a lower NFI (Table 4). For example, the beaches of Benidorm (Poniente and Levante) in the heart of the city have very low NFI values compared to the rest (0.55 and 0.33 respectively; Table Supplementary).

On the other hand, beach management has always found an antagonistic duality between the recreation function of the beach and the environmental value (Zielinski and Botero, 2012). This also occurs in the BQI, as can be seen when comparing the values of the RFI and NFI sub-indices, where as a general rule when one is high, the other is low (Tables 4 and 6). The best results are usually given for beaches that present a certain balance between their partial indices. These differences between the two sub-indexes are mainly caused by the need to pre-set values with which to compare the results. In the case of the BQI, one of the limiting factors is not to include gravel beaches, since for example in the study area gravel beaches represent 33% (Palazón *et al.*, 2016). However, although the NFI focuses on sandy beaches, the results obtained in the study yield values close to the maximum for gravel beaches (Table 4), while results worsen when the RFI is evaluated (Table 6). This is due to the fact that this sub-index gives a high weighting to services within the beach (showers, parks and outdoor leisure areas, etc.), which gravel beaches do not usually have. Hence the limitations of this type of index are evident, since the type of services and users in each beach are different.

Another limitation detected is the method used to obtain the quality of the bathing water. While this is an important factor that can influence human health, the source of the data does not correspond to instantaneous values (Nayade, 2015), but reflects a momentary situation that may not be the current one. However, this factor is given more weight than the rest within the RFI calculation. So a poor value (which could be momentary) will considerably penalize the indicator during its entire validity period. From the study of the microbiological quality indices of the water, it can be deduced that practically all the beaches analysed have very good indices with the exception of some beaches in the Denia area which have moderate to good indices (supplementary).

Within the RFI, safety is valued insofar as it is present or not without considering the number of beach users and specific characteristics of the beach (Navarro *et al.*, 2012). Similarly, the RFI does not consider the presence of seasonal services. These are evaluated as one more "service", without considering the exact occupation of the beach surface area, which is important because an overocupation could alter the load capacity of the beach (Jiménez *et al.*, 2007). Therefore, RFI does not correctly take into account overcrowding or saturation of the beach when considering the total width. A correct adaptation would be to use only the beach width that is used in practice (Yepes, 2002).

The PFI only studies the protection of the elements of the beach backdrop and does not detect the evolution of the beach in terms of erosion or accretion. However, the evolution of the coastline is indispensable information that can guarantee the protection function (MAGRAMA, 2008), and that must be known so that the manager can take appropriate measures. Thus, there are beaches such as Poniente in Benidorm undergoing a great erosive process — > 35% beach width in some areas (Aragonés *et al.*, 2015)— and yet its PFI is 1.00 (see suplementary material). Something similar occurs with the beaches of Guardamar (Rebollo or Babilonia) with acceptable indices of 0.74 and with significant erosion (Pagán *et al.*, 2017). These high PFI values are due to the fact that in spite of the high degree of erosion they suffer, these beaches still benefit from the protection of the beach backdrop.

Finally, as almost all the consulted authors state, an index will not be complete without the incorporation of visitor perception, since this can indicate peculiar aspects that a technical manager does not contemplate (Micallef *et al.*, 2004; Pereira *et al.*, 2003; Philipp, 1998; Ponce, 2004; Villares *et al.*, 2004). However, the BQI does not take into account the opinion of the user, nor does it establish any relationship between the user and the manager. Therefore, it follows from the analysis carried out that it is necessary to define an index applicable to coastal environments and beaches in particular, from an objective point of view . This would prevent the beach valuation to be influenced by subjective criteria of a manager. This index must be valid for all beaches, but it is evident that not all of them are equal, so the criteria for obtaining the index must take into account this premise. In addition, the index should strive to facilitate continuous updates, although having all the variables necessary for its generation in real time can mean a high cost in resources (for instance, number of managers deployed, and surveys carried out).

4.2. Proposal for the incorporation of ICT

The suitability of the index as a monitoring and control tool for beach management is clear. However, some of the shortcomings of these indices have also been identified. These include: heterogeneity and lack of generality; their subjectivity and lack of transparency; the limitations and restrictions in the calculation of their indicators due to the lack of real time information; and finally, the limited number of samples obtained for calculation.

Based on these previously mentioned premises, we have identified the need for an integrated model that manages and monitors beaches based on ICT. These technologies support the incorporation and calculation of any type of index, whose indicators will be provided in real time in accordance with the changes that occur on the beach. This approach makes information available to both managers and citizens, allowing them to make decisions more accurately and efficiently.

To design the model, and taking these objectives as a starting hypothesis, a research methodology based on Business Processes Management has been proposed (Andújar-Montoya *et al.*, 2015; Mora-Mora *et al.*, 2015). This proposal allows, in a systematic way, to divide the research process into small phases, identified as business processes. Following this process, the objectives of the proposal are: (i) those derived from the state of the art and the related works (goals); (ii) the related works and solutions where the problem is contextualized (inputs); (iii) the elements (paradigms, techniques, recommendations, technologies, etc.) that can transform the input to solve the problem (suppliers and controllers) and (iv) the results of the transformation process as partial solutions to each step and overall research solution (outputs). To define this process in a formal way, the modelling language created by Penker and Eriksson (1999) was chosen. It is an extension of the Unified Modelling Language (UML) for the intuitive and understandable representation of business processes for all involved participants.

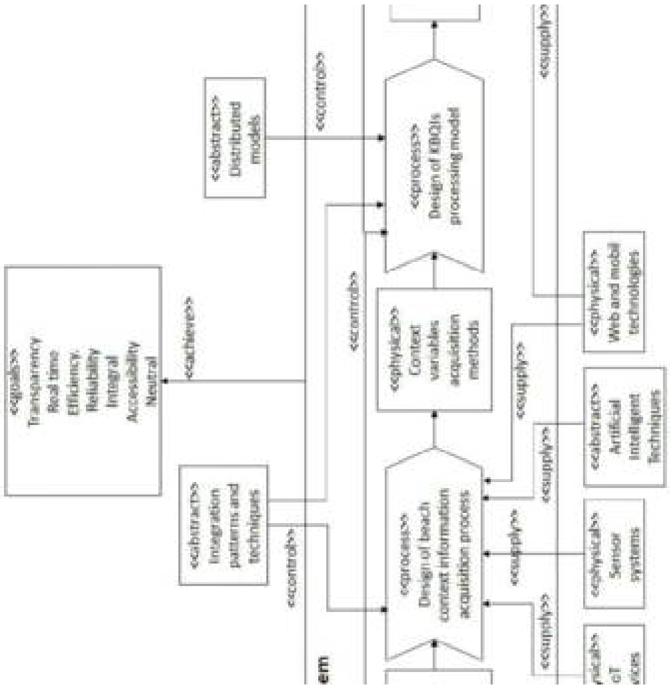

Figure 1. Modelling of the research methodology of the design process of the beach quality management system using the Eriksson-Penker notation.

As a result of the process, a conceptual model of beach quality management and monitoring has been obtained that reflects the information flow of the proposal and whose general scenario is shown in Figure 2.

Figure 2. Conceptual model of management and monitoring of beach quality. Information flow.

Firstly, in order to eliminate the heterogeneity of the different indices proposed, and to allow an integral, general, flexible and adaptable model, a conceptualization of the indicators has been established through the Key Beach Quality Indicator (KBQIs) concept. KBQIs are defined as quantifiable values that allow the quality of beaches to be measured transparently, following an analogy with key performance indicators (KPIs) of business processes.

Next, we classified the elements required to calculate the quality indicators of the beaches according to their nature and the method by which they were obtained, following the scheme used in Marcos-Jorquera *et al.* (2016).

- **Indicators.** These are values that make it possible to quantitatively measure the characteristics of the beach. They have been categorized into two types:
    - **Atomic indicators.** These are values that are directly obtained from the different monitoring methods and are stored as indicators without the need to perform a calculation after capture. This information provides added value for the systems and their users to manage and supervise the beaches.
    - **Calculated indicators.** These are values obtained from the calculation of operations, using a combination of atomic indicators and/or other calculated indicators. This process can be done automatically or, in some cases, will require human intervention through a user interface.
- **Variables.** These are values relating to the monitored information about the environment, which are necessary to calculate the indicators. These variables will be obtained by different methods based on ICT in the most automated way possible.
- **Parameters.** These are configuration data about beaches, necessary for the calculation of the indicators. These parameters will be configured by the managers

in the set up of the beaches in the system information. These are elements whose value is very unlikely to vary throughout their lifespan.

In this way, we can define the Beach Quality Management System (BQMS) as:

$$BQMS = (I, A, IA \cup L) \ where \ I = KBQI \cup V \cup P \quad (1)$$

Where:

- *I* represents the set of items associated to the beach, composed by a set of key beach quality indicators (*KBQI*), a set of variables (*V*), and a set of parameters (*P*).
- *A* represents the alerts that must be sent when a KBQI is outside the established ranges.
- *IA* and *L* represent the integration agents and listeners responsible for the acquisition of the context variables of the beach through different ICT techniques described below. These components can be configured to establish their performance as well as their sampling frequency, in order to obtain necessary variables

Following the process, a KBQI is defined as:

$$KBQI = (S, f, Q) \ where \ S \subseteq I \quad (2)$$

Where:

- ***S*** is the subset of items (indicators, variables, and parameters) required for the KBQI calculation.
- ***f*** is the calculation function, which takes the values of the indicated items to calculate and output a new value for the ***KBQI***.
- ***Q*** is the set of rules that define how the ***KBQI*** is classified according to the result obtained.

Next, an alert (***A***) is defined as:

$$A = (t, rl, d, i, v) \quad (3)$$

where:

- ***t*** is the type of alert that has occurred.
- ***rl*** is the rule that determines the set of conditions to launch the notification.
- ***d*** is the destination to which the notification should be sent.
- ***i*** is the indicator associated to the alert
- ***v*** is the value of the indicator that produced the alert

4.2.1. Monitoring of beach context information

The objective of beach context information monitoring is to determine the specific methods that allow the acquisition of the necessary variables in order to calculate the KBQIs. Unlike the existing proposals, these methods will be characterized by the following aspects:

1. Information must be continuously obtained and not at specific times.
2. Measurement must be representative of the entire beach and not of delimited zones that are generalised to the entire beach.
3. The monitoring process must be remote and as automated as possible.
4. Information must be obtained from heterogeneous sources.
5. The methods must guarantee the security and reliability in the capture and delivery of information.

To meet these requirements, different paradigms, techniques and technologies of ICT have been used. The methods used have focused on the Internet of Things, systems integration techniques, and specific mobile applications, creating a completely distributed information collection system that will be registered through a central system (Figure 2). More specifically, we can summarize that the proposal will focus on three possible methods obtaining information: i) acquiring context information through sensor networks and distributed sensors (cameras, environmental sensors, positioning ...); ii) obtaining data and information through connection to external Web applications and services (climatological, environmental, population data ...); and, finally, iii) acquiring the acquisition of user information through mobile Apps and Web management applications related to their use, experience, opinion or incidents.

4.2.2. Information provisioning

Finally, a key aspect of the proposed system is how the information about the quality of the beaches through the KBQIs is provided to the different users. The objective is to make this information accessible and available at any time to the users, offering a categorization of the state of indexed beaches in a transparent and objective manner. This proposal facilitates decision-making and has the potential to result in more efficient management. It is important that information provisioning is carried out in the most flexible way and through an approach that guarantees interoperability with different consumers and platforms. In this sense, the proposal is based on a Service Oriented Architecture (SOA) approach through the implementation of REST services (Erl *et al.*, 2012), whose principles guarantee these objectives. For this, the resulting information is offered through a standard API based on micro services whose messages encoded on the JavaScript Object Notation (JSON) standard.

Access to information is carried out through two approaches, namely B2C (Business to Customer) and B2B (Business to Business). In the first case, users can access the KBQIs through a Web-type user interface for thin clients through multiple devices. This interface will offer different functionalities according to the type of clients, such as citizens, managers or governmental organizations. The interface allows information based on certain search and selection filters to be obtained. For example, a citizen could indicate that they were shown all the beaches suitable for pets, with parking and with lifeguard services. A city council could select those beaches where there are complaints about the cleanliness of the beach. The second approach, B2B, allows external consumer applications to directly extract information through the services about the quality of beaches, and integrate this information into their own systems.

5. CONCLUSIONS

The indices that have been used in coastal research filed have been analysed, comparing the different approaches to a complex problem where multiple elements interact, and priotitising natural, social and economic component elements. From the study carried out in relation to the review of the current literature, it can be concluded that: i) the system of indicators is the one that best fits the problem detected; ii) there is a great disparity in terms of the criteria and results obtained from the current coastal management indices; iii) there is a high degree of subjectivity in their calculation and subsequent interpretation (most of the indices are qualitative); iv) the current indices are static, the data are not continuously obtained, and for this reason the indices are not up-to-date; and, v) the indices are generally user oriented (recreational function) and not manager oriented.

Likewise, it has been proven by the application of BQI, developed by Ariza *et al.* (2010), to the beaches in the province of Alicante that the index: i) is not entirely objective; ii) does not include the participation of the beach user; and iii) is not applicable to all types of beaches, such as gravel beaches or natural beaches.

For all these reasons, the conceptual model for management and monitoring of beach quality proposed in this work, together with the tools available on the market (the Internet of Things, the techniques of integration of systems and applications, mobile applications, etc.) provides the following benefits: i) conversion of variables into measurable, and thereby quantifiable criteria that facilitate objective decision-making that can be carried out on a continuous basis; ii) quicker, efficient and more secure data gathering; iii) interaction between manager and user, facilitating efficient management and providing the user with real time information about the beach state.

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