SUSTAINABLE DESIGN OF OPEN-AIR EXHIBITIONS

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ABSTRACT:

This research is focused on the design of sustainable cultural services. Particularly, on the services associated with outdoor exhibitions, which represent an interesting alternative to traditional cultural services, being accessible to all populations, at any time and without ticketing. Open-air exhibitions are usually organized using different supports but the ones with counterweights are the most popular and versatile types. Sustainability aspects of three different design alternatives are studied. In the first alternative cultural content is exposed using printed and replaceable vinyl; in the second alternative, the exhibition is illuminated and content is printed on stretched canvas. The third alternative offers an additional service because when the display panels are replaced exhibitors are transformed into street furniture. The entire life cycle of the services has been reviewed. Moreover, environmental, economic, and social sustainability dimensions have been quantitatively evaluated using, respectively, the global warming potential, the execution costs, and the working time indicators. Thus, the study contributes to integrating sustainability in the design of service systems. The presented cases illustrate the sustainability assessment methods that could be used in the evaluation of different cultural services proposals and results obtained show that different alternatives can be selected according to the criteria applied to reflect the importance of each sustainability dimension.

Keywords: Sustainability, design; Service life cycle; Cultural exhibitions; LCSA.

RESUMEN:

La investigación presentada en esta publicación se centra en el diseño de servicios culturales sostenibles, en particular, en las exposiciones al aire libre, que suponen una interesante alternativa a los servicios culturales tradicionales, siendo accesibles a todas las poblaciones, en cualquier momento y de manera gratuita. Las exposiciones al aire libre suelen organizarse utilizando diferentes soportes pero los que contienen contrapesos en su estructura son las más populares y versátiles. En este estudio se comparan los aspectos de sostenibilidad de tres alternativas de diseño diferentes. En la primera alternativa los contenidos culturales se exponen mediante vinilos impresos y recambiables; en la segunda alternativa, la exposición se retroilumina y se imprime el contenido sobre un textil tensado. La tercera alternativa ofrece un servicio adicional ya que durante el cambio de los contenidos los expositores se transforman en mobiliario urbano. El ciclo de vida completo de los tres servicios ha sido analizado. Además, las dimensiones de sostenibilidad ambiental, económica y social han sido evaluadas cuantitativamente utilizando, respectivamente, los indicadores de potencial de calentamiento global, costes de ejecución y tiempo de trabajo. Así, el estudio contribuye a integrar la sostenibilidad en el diseño de los sistemas de servicios. Los casos presentados ilustran los métodos de evaluación de la sostenibilidad que podrían utilizarse en la evaluación de diferentes propuestas de servicios culturales y los resultados obtenidos muestran que se pueden seleccionar diferentes alternativas según los criterios aplicados para reflejar la importancia de cada dimensión de la sostenibilidad.

Palabras clave: Sostenibilidad, diseño; ciclo de vida del servicio; Exposiciones culturales; LCSA

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1.- INTRODUCTION

Nowadays, designers face the challenge of integrating sustainability into their designs. In the past, the focus was on developing eco-friendly designs [1]. At present, a comprehensive analysis of socio-economic aspects as well as the study in detail of systems in which products and services are combined [2], is considered indispensable to actually achieve sustainable designs. Thus, a sustainability concept in which three dimensions look simultaneously at economic aspects (profit), environmental issues (planet) and social concerns (people) should be considered [3]. The application of this approach, denominated "Triple Bottom Line (TBL)" [4], has been mainly applied to product systems. However, studies regarding the sustainability of service systems are much fewer and these are not carried out with a whole life cycle perspective. In addition, services development is commonly based on the use of products and products require some support services, so both can be considered as parts of larger interconnected systems [5]. The analysis of sustainability aspects in these systems where products and services are combined, becomes a challenge to carry out design applying sustainable principles.

The design of cultural services is also immersed in the application of sustainability approaches. Different efforts encouraged by a number of cultural organizations such as the Tourism Industry Association of Canada or the International Council of Museums [6], or UNESCO [7] have been made to adopt sustainable practices. In 2006, the Critical Assessment Framework was created by the Working Group on Museums and Sustainable Communities [8]. It is based on a stratified approach that helps planners develop museums that achieve a culture of sustainability and fulfill the needs and opportunities related to individuals, communities, the museum, and global reality.

Sustainability is also considered as the polar star that should guide cultural policies [9] and educational programs [10]. It is noteworthy initiatives such as the one carried out by the Museum of Fine Art in Boston [11], in which a significant number of materials and processes are reviewed to obtain impacts from an ecological point of view. In 2011, another study developed a new eight-step carbon footprinting methodology to manage the impact of the museum loan programmes, tested using data from the Art Department of Amgueddfa Cymru-National MuseumWales [12]. In 2015, various self-assessment methods were mentioned, such as 'sustainability audits' or checklists for the achievement of some sustainability standards in the Zimbabwe Military Museum [13]. However, the methods and tools used in these cases have a high degree of subjectivity, the results obtained for various museums are not comparable and do not apply a three-dimensional approach. Thus, the study from a socio-economic perspective in which issues such as equity in hiring and working conditions, applying responsible procurement policies, strengthening local economies and building a strong community should be also addressed [14]. Some examples of those assessments have been developed as a part of the Learning Museum project [15]. Different institutions' economic or social impacts have been assessed but neither of them has been simultaneously assessed in the three dimensions of sustainability.

Cultural activities aim at providing a service to the society. In the case of cultural exhibitions, these are events organized from a wide number of institutions offering varied experiences for education, enjoyment, reflection, and knowledge sharing [16]. Two types of cultural exhibitions can be differentiated: indoor and outdoor. Indoor exhibitions are usually of a permanent or semi-permanent nature and are linked to higher investment. As in other sectors, the introduction of new media, such as augmented reality [17] or interactive elements, is becoming increasingly important [18]. Outdoor or open-air exhibitions are usually organized by municipalities, cultural institutions or artistic collectives with the objective to favor access to culture for all audiences as well as to promote knowledge and reflection on the current social issues.

Open-air exhibitions are typically developed using different supports such as multimedia facades, urban furniture, commercial publicity supports and custom made of the cultural exhibition. Three types of supports are usually used in the last case: supports fixed to the ground, supports which guarantee the stability by its geometry and supports with counterweight. Although the first one can represent space for temporary exhibition, its fixture to the ground converts those elements into permanent city furniture. The second one requires larger space and can be exposed only in locations that have no strong winds, which makes the third one the most popular and versatile type and is chosen in this case. Main parts and function of the counterweight supports are shown in Fig. 1. On the other hand, the use of replaceable materials including different graphic reproductions is the method selected to create the cultural contents. This allows keeping the same support design for all topics addressed along the exhibition.

Cultural services are mostly provided to the population by public institutions, which in turn use tendering procedures to commission the services. In the vast majority of cases, supplier selection criteria is based on economic criteria, specifically on product implementation costs. This study shows the importance of the service assessment throughout its entire life cycle, as well as to analyze the products involved and the accompanying services not only according to economic, but also environmental and social criteria.

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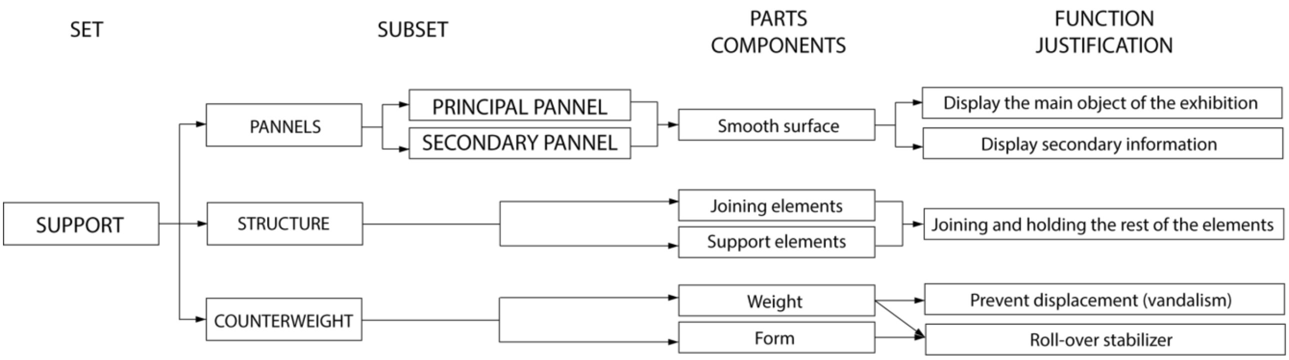

Fig. 1. Counterweight display supports used in outdoor exhibitions. Main parts and function.

2.- METHOD

Sustainability is understood in this work as the integration of aspects associated with the economic viability, environmental impact and social equity, along the entire life cycle of the cultural service system. Thus, the Life Cycle Sustainability Assessment (LCSA) methodology is applied to obtain specific indicators of each sustainability dimension. LCSA method is developed by several authors such as Kloepffer (2008) [19] and Finkbeiner et al. (2010) [20] taking into account a TBL approach. It is based on the same four-phases structure that is already applied in LCA [21], which consists of: i) definition of objectives and scope; ii) life cycle sustainability inventory; iii) life cycle sustainability assessment; iv) interpretation of the results; so can be considered a suitable and effective method to evaluate the sustainability of a product or service system.

LCSA is applied in this research to compare the sustainability behavior of different cultural service design alternatives. In order to quantitatively value the impact of those activities involved in the development of cultural exhibitions the following indicators are selected. The global warming potential (GWP) indicator, which represents total emissions of greenhouse gasses, is used in the environmental dimension. Economic feasibility is determined through the execution costs (Ce) of the cultural service. In addition, social impact is valued by the working time (Tw) or time required by the workers to carry out an activity. In this case, the execution costs indicator is selected in the economic dimension, since a net operating profit is not directly expected from the exhibition development. In addition, the greenhouse gas emissions and the accumulated working times by those workers involved in the different activities of the service development were, respectively, determined in the environmental and social dimensions. More details about the definition and application of these indicators can be found in Santolaya et al. (2019) [22].

Thus, the method of study can be separated into three main stages (Fig. 2). First, design alternatives of the cultural exhibition are proposed (stage 1), next sustainability indicators of each alternative are obtained (stage 2) and finally, design alternatives are compared in different cases (stage 3), in which different weights are assigned to indicators to reflect the importance of each sustainability dimension. These weights can be significantly different in each system analyzed, according to the particular interests and preferences of the decision makers. An aggregated index representing the global sustainability of each alternative could be obtained to facilitate the comparison process.

Sustainability indicators can be obtained if a detailed inventory is carried out for those activities involved in the development of the cultural exhibition. In addition, the use of databases and specific software is required to make the calculation for each design alternative. Database as GaBi ts 9.2 software [23], ProBas (v.1.5.5) database [24] and Cype software are used in this work to obtain environmental indicators of different materials and products; working times and workers' salaries were determined in accordance with the International Trade Union Confederation [25] and the emission factors of electric commercial companies [26] were used to evaluate greenhouse gas emissions from both electric and fuel consumptions.

On the other hand, it should be noted that the sustainable improvement of a product/service design would involve the application of different sustainability strategies in the preliminary design stage. Taking into account the development of a classic design process, in which strategic definition, conceptual design, preliminary design and detailed design stages are carried out [27], once sustainability approaches are put forward in the conceptual design stage, a number of design alternatives could be proposed applying different sustainability strategies. The sustainability performance of each alternative should be analyzed in the detailed design stage. Another aspect to consider in the design discipline is the user experience. Increasingly also the exhibition sector is analyzing it and putting forward solutions to improve the visitor experience [28]. However, in this study, in order to compare the different designs from the

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perspective of sustainability, the visitor experience was intended to be as similar as possible in all the projected alternatives, and its analysis is outside the limits of the study.

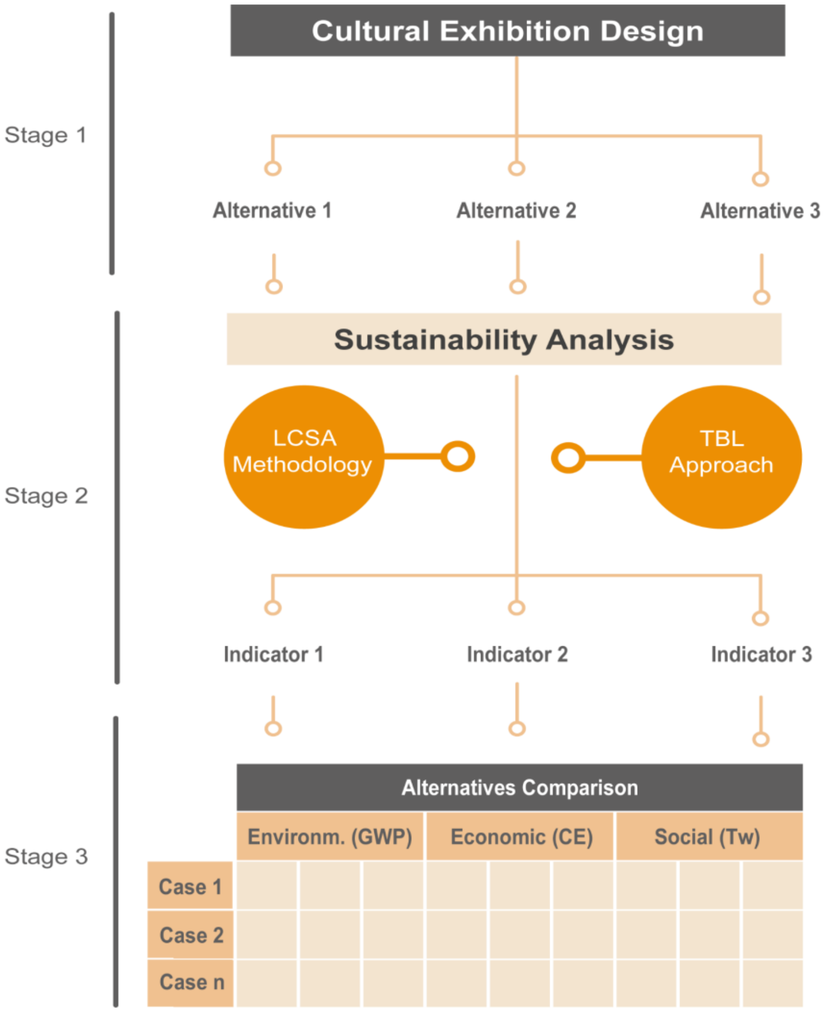

Fig. 2. Methodological scheme used to compare the sustainable behavior of different design alternatives.

3.- CASE STUDIES

In this work, the design of different alternatives of an open-air exhibition organized by the City Council of a middle size city in Spain is examined. A cultural exhibition entails the development of a number of activities, which begin with the ideation and selection of both exhibition space and contents to exhibit and finish archiving those contents and processing the waste generated. Other activities such as the transport of artifacts along the exhibition development, maintenance and cleaning activities or the exhibition disassembly and transport of materials to the waste treatment plant when it is finished must be also considered. It should be noted that three main stages named creation, provision and end-of-life, can be established (Fig. 3). On the other hand, activities such as those developed by the curatorial team and the marketing and promotion activities are not taken into account in this study.

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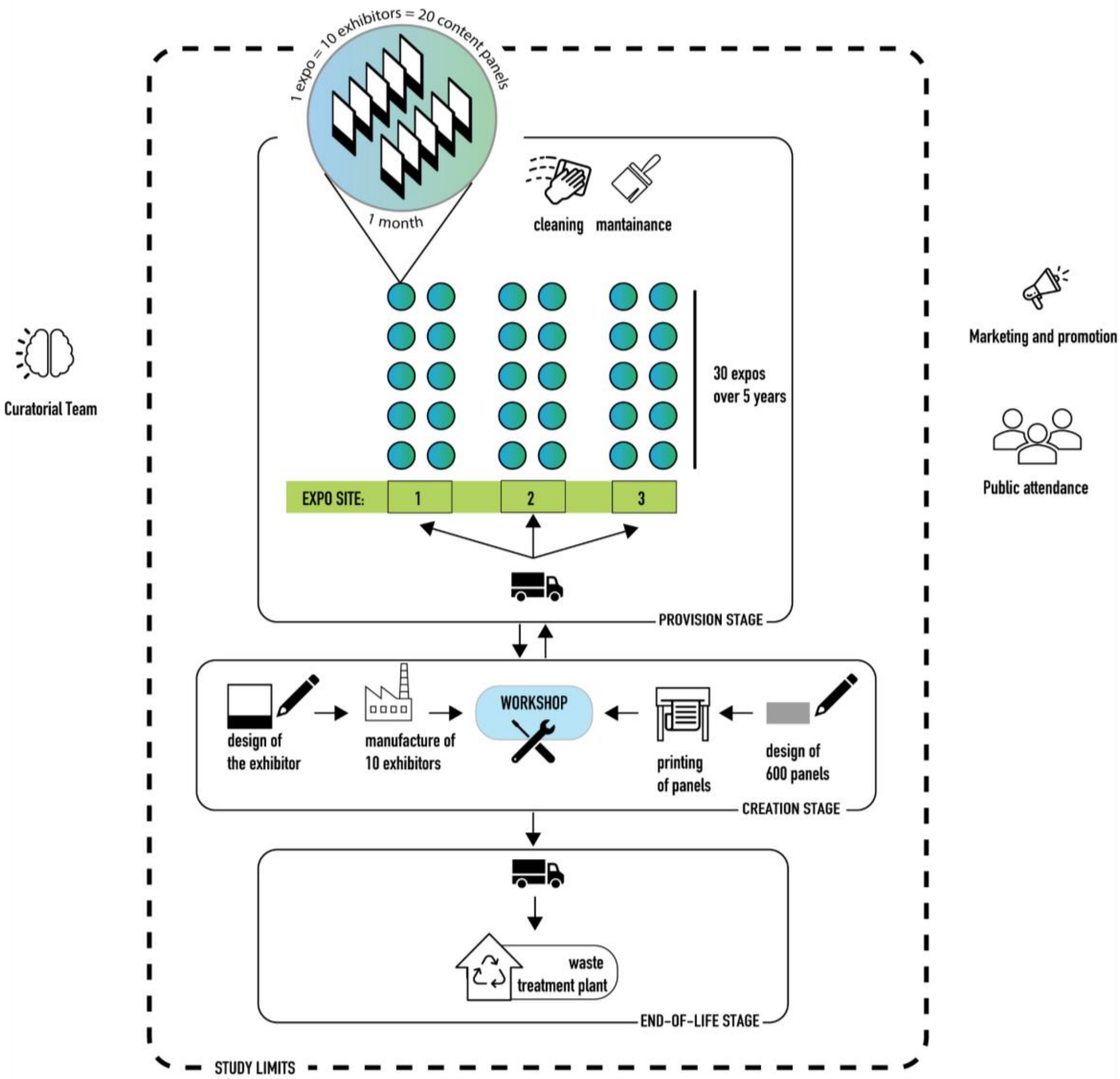

Fig. 3. Activities involved in the study of the open-air exhibition life cycle.

All alternatives presented have to respond to the same design specifications pointed out by the organizer: the cultural service should include 30 exhibitions presented during one month to the public, in three different locations over a period of five years. It should be designed using 10 exhibitors, which can be easily installed in different public places of the city without blocking people's transit, its weight is not less than 500 kg and divided into two main parts and. The lower part, which houses the ballast that protects the exhibitor from unwanted displacement, guarantees stability and prevents vandalism. The upper part, located at eye level, each with the same surface for the content presentation (1x2,1 m on both sides). In addition, one foreground system (FS) can be identified as the main or "core" system and different background systems (BS) or systems that support FS along its life cycle can be recognized as "satellite" systems. In this work (Figure 4), the study will be limited to the most significant BSs affecting the cultural exhibition development (FS), which are exhibitors (BS_1) and exhibited content (BS_2).

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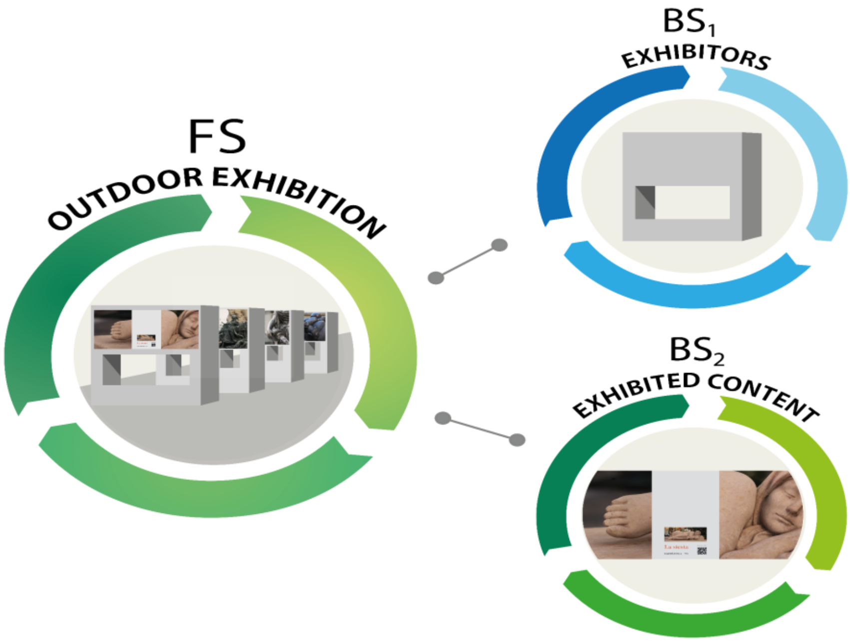

Fig. 4. Main systems involved in the development of the open-air exhibition.

Three design alternatives have been proposed (Fig. 5):

- *Alternative 1:* it is based on the existing service, in which cultural content is exposed using printed and replaceable vinyl. Regarding the creation stage, the supports consist mainly of two elliptical bodies 1m and 0.45 m-high whose casings are built in 2mm DC01 stainless steel sheets and S235 steel pieces (e=3 and 8 mm). The lower body is filled up with concrete, which acts as a ballast. Steel sheets are cutted with a N2 fibre laser and bending with rollers in a way that facilitates their transport. The exhibitor is mounted on a 8 mm base of 1.1 m diameter to give stability. The pieces are assembled with tongue and groove joints and welded. Two openings at the bottom allow a forklift to move it. Printing content is adhered to the upper part using PVC replaceable vinyl. Each exhibition requires the printing of 20 vinyl panels (42 m^2) and their placement on both sides of each exhibitor. The placement of the vinyls is done vertically. The transport of the exhibitors is done by crane truck with the help of a forklift. The provision stage includes maintenance labor such as cleaning (16 hours/month on average) and replacing two damaged vinyls due to vandalism (6.21 hours/month on average). At the final destination, all materials are sorted and classified into the categories: metals (293.34 kg), concrete (1.93 tons) and plastic (0.8 kg).

- *Alternative 2:* the exhibition is illuminated with LED lights and the exhibited content instead of being presented on vinyl is made on stretched canvas. Each exhibition requires settling 45 m^2 of replaceable printed textiles. Supports are made up of two prismatic parts made of DC01 stainless steel sheets (e=2 mm) and other S235 steel pieces (e=3 and 8 mm) and mounted on a round rubber base of 1 m diameter. The steel sheets are cutted with a N2 fibre laser, folded with rollers and assembled with tongue and grooves and welds joints and finally, painted. Because of the LED illumination, a set of components (solar panel, LED strip, arduino board, gel battery and proximity sensor) are included in the exhibitor design. The material used for ballast is water until it weighs 500kg. In each exhibition place, the exhibitor is filled and emptied. The transport is done by a load truck and distributed on the site by pallet trucks. The provision stage includes maintenance labor such as cleaning (8 h/month on average) and replacing two damaged fabrics due to vandalism (0.67 hours/month on average). The use of LED lighting and a proximity sensor allows making this exhibition service accessible at night, but it also supposes an additional energy consumption (30 Wh per night). At the end of life stage, all materials are sorted and classified into the categories: metals (161.86 kg), plastic (3.65 kg), fabric (4.76 kg) and mixed waste (0.31 kg) which is transported to a waste treatment plant. Water ballast is drained.

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DYNA Ingeniería e Industria
RESEARCH ARTICLE

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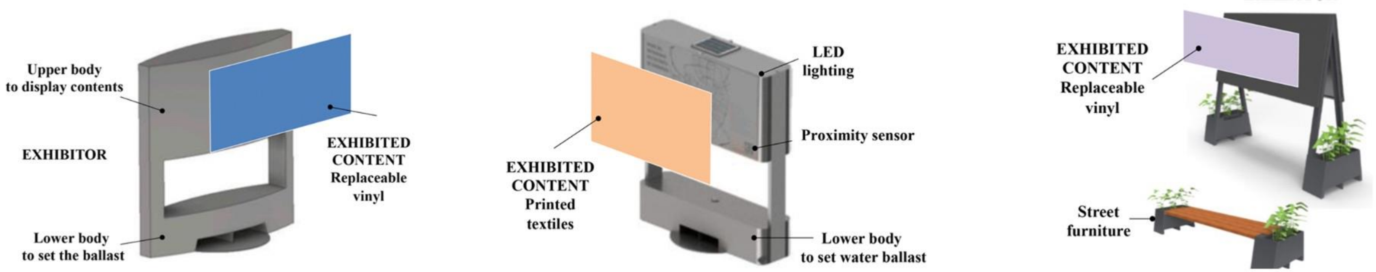

ALTERNATIVE 1

CREATION STAGE			
Support			
6.10 m²	stainless steel sheets DC01 2mm		95.58 kg
12 pc.	other steel pcs.	S235 3 & 8mm	196.85 kg
Counterweight			
0.80 m³	concrete		1932 kg
Printed contents			
20 units	replac. vynils	2100x1000 mm	0.40 kg
0.06 l	ink		0.06 kg
Manufacturing processes/support			
Fibre laser cut	41550 mm	1.29 hw	28.10 kWh
Bending with rollers	14 operations	0.08 hw	0.07 kWh
Threaded M20	4 operations	0.05 hw	0.01 kWh
Welded	805 mm	0.06 hw	$5x10^{-3}$ kWh
Premier + paint	11.81 m²	9.35 hw	0 kWh
Assembly	16 pieces	3.00 hw	0 kWh
Transport from workshop to location (3.5 km)/exhibition			
Truck IVECO	21 km	10 hw	28.05 $kgCO_2$
Forklift truck TOYOTA		2.70 hw	17.64 $kgCO_2$
PROVISION STAGE			
Maintenance/ exhibition			
Cleaning	16 hw	1 person	
Vynil replacement	6.21 hw	1 person	
END-OF-LIFE STAGE			
Transport from location to warehouse (3.5 km)/ exhibition			
Truck IVECO	21 km/ trip	5 hw	18.52 $kgCO_2$
Forklift truck TOYOTA		2.7 hw	17.64 $kgCO_2$
Material clasification and transport from location to local waste facilities (5 km average)/exhibition			
Metals	0.37 m³	− 98.90 €/dep.	15.10 $kgCO_2$
Concrete	7.89 m³	68.80 €/deposit.	0.02 $kgCO_2$
Plastic	0.01 m³	0.04 €/ deposit.	0.04 $kgCO_2$

ALTERNATIVE 2

CREATION STAGE			
Support			
2.41 m²	stainless steel sheets	DC01 2mm	24.38 kg
11 pc.	other metal pieces	S235 3 & 8mm	162.87 kg
1 pc.	solar panel	430x345x25 mm	0.76 kg
2 pc.	led strip	450x25 mm	0.14 kg
2 pc.	arduino boards	142x98x24 mm	0.06 kg
5 pc.	controller	58x37x10 mm	0.03 kg
1 pc.	gel battery	110x90x70 mm	1.63 kg
1 pc.	proximity sensor	72x110x8 mm	0.20 kg
Counterweight			
0.35 m³	water replaceable in each exhibition		253.78 kg
Printed contents			
10 units	stretched canvas	1764x494 mm	1.26 kg
0.06 l	ink		0.06 kg
Manufacturing processes/support			
Fibre laser cut	58850 mm	1.35 hw	35.90 kWh
Bending with rollers	12 operations	0.07 hw	0.06 kWh
Threaded M20	8 operations	0.10 hw	0.02 kWh
Welded	968 mm	0.06 hw	$6.2x10^{-3}$ kWh
Premier + paint	6.07 m²	4.81 hw	0 kWh
Assembly	25 pieces	3.00 hw	0 kWh
Water refill	0.25 m³	0.27 hw	
Transport from workshop to location (3.5 km)/exhibition			
Truck IVECO	21 km	8.20 hw	28.05 $kgCO_2$
Forklift truck TOYOTA		1.80 hw	17.64 $kgCO_2$
PROVISION STAGE			
Maintenance/ exhibition			
Cleaning	8 hw	1 person	
Vynil replacement	0.67 hw	1 person	
END-OF-LIFE STAGE			
Transport from location to warehouse (3.5 km)/ exhibition			
Truck IVECO	21 km/ trip	4.1 hw	18.52 $kgCO_2$
Forklift truck TOYOTA		1.8 hw	17.64 $kgCO_2$
Material clasification and transport from location to local waste facilities (5 km average)/exhibition			
Metals	0.21 m³	− 55.2 €/deposit.	8.45 $kgCO_2$
Cloth	0.04 m³	0.0 €/deposition	0.00 $kgCO_2$
Plastic	0.05 m³	0.02 €/deposit.	0.11 $kgCO_2$

ALTERNATIVE 3

CREATION STAGE			
Support			
8.5 m²	alucore display panel	15 mm	28.14 kg
2 pc.	steel pots	0.15 m³	240.24 kg
1 pc.	teak wood bench	2.90 m²	58.41 kg
4 pcs.	6061 alum. anchor		0.08 kg
45 pcs.	other metal pieces	3.26 kg	54.37 kg
0.07 m³	substrate		26 kg
8 pcs.	plants-dieffembachia		
Counterweight			
2 pc.	steel pots & substrate		266.24 kg
Printed contents			
20 units	replaceable vynils	2100x1000 mm	1.26 kg
0.06 kg	ink		0.06 kg
Manufacturing processes/support			
Fibre laser cut	13450 mm	0.70 hw	15.7 kWh
Circular sawn	8 operations	0.03 hw	0.02 kWh
Threaded M20	4 operations	0.05 hw	0.01 kWh
Welded	4044 mm	0.06 hw	1.10 kWh
Premier + paint	6.50 m²	5.15 hw	0 kWh
Assembly	81 pieces	1.50 hw	0 kWh
Transport from workshop to location (3.5 km)/exhibition			
Truck IVECO	7 km	3 hw	2.91 $kgCO_2$
Forklift truck TOYOTA		1.20 hw	0.80 $kgCO_2$
PROVISION STAGE			
Maintenance/ exhibition			
Cleaning	16 hw	1 person	
Vynil replacement	5.54 hw	1 person	
Gardening	8 hw	1 person	
END-OF-LIFE STAGE			
Transport from location to warehouse (3.5 km)/ exhibition average			
Truck IVECO	7 km/ trip	2.55 hw average	4.41 $kgCO_2$
Forklift truck TOYOTA		1.20 hw average	10.29 $kgCO_2$
Material clasification and transport from location to local waste facilities (5 km average)/exhibition			
Metals	0.41 m³	− 107.7 €/deposit.	16.50 $kgCO_2$
Plastic	0.01 m³	2.6 €/ deposition	1.30 $kgCO_2$
Wood	0.03 m³	0.2 €/ deposition	0.04 $kgCO_2$

Fig. 5. Design alternatives and inventory data along the entire life cycle.

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- *Alternative 3:* This alternative offers an additional service because when the display panels are replaced, exhibitors are transformed into street furniture. This multifunctional design consists of a metal display panel supported on two cast-iron pots. When the display panel is removed for the vinyl replacement a wooden bench is attached to the cast-iron pots and becomes available for use. Regarding the creation stage, the exhibitor consists of both, the exhibition display and the urban furniture. The display is made of ALUCORE sheets (2x2100 mm^2) and other joining components. Each exhibition requires printing and installation of 20 replaceable PVC vinyl panels of 2.1 m^2 each, on both sides of 10 exhibitors. The design of the display allows the vinyls to be placed horizontally, which makes the work easier. The urban furniture consists of a teak wood seat (560x1800 mm) with two plant pots made of cast iron, that work as supports. Both the substrate and the dieffenbachia plant were considered. For the preparation of the new exhibition, only the display part must be transported by platform truck and the rest of components are used as urban furniture in the meantime. Those are transported to different sites 3 times during the life cycle. The provision stage includes 16 hours of cleaning, 8 hours of gardening, and 5.54 hours for replacing two damaged vinyls (per month). At the final destination, all materials are classified into the following categories: metals (326,47 kg), wood (30.54 kg), and plastic (48.33 kg).

In order to assess the sustainability of each alternative, the LCSA method has been applied. Inventory data of each life cycle stage is presented in detail in Fig 5. The creation stage includes the fabrication of both supports and printed content needed for 30 exhibitions, its placement and logistics needed for the exhibition mounting in the public space. A distance of 3.5 km to the workshop (where the vinyls are placed, and exhibitors are stockpiled for one month in between the exhibition) is considered. Different means of transport are used depending on the type of exhibitor and its weight. The provision stage includes all activities needed for the proper development and maintenance of the exhibition as well as the materials for the replacement of the exhibited content in case of vandalism or deterioration. Each exhibition has the same duration of one month and no exposure requires spatial conditioning or contracting of staff for tickets, security or assistance, since it takes place in an outdoor environment. When the exhibition finishes after one month, those discarded contents are transported to a waste management plant. When the last exhibition is finished (after five years) the end of life activities include disassembly, classification of materials in categories and transport to the waste treatment plant, which is placed 7 km away from the city.

4 RESULTS

Applying a life cycle approach involves that a number of activities are examined along each stage of the cultural exhibition development. Service creation activities include concept generation of all exhibitors and exhibited contents, their manufacture and transport to the exhibition area and their adequate distribution in the site. In the provision stage, activities such as cleaning and maintenance of the exhibition as well as the materials replacement due to deterioration or vandalism are considered. The end-of-life stage includes those activities needed for the dismantling, treatment and final treatment of materials once the cultural service is over.

The selection of the most sustainable design alternative is based on the evaluation of indicators for each sustainability dimension. Thus, the estimation and study of a wide number of data associated with the exhibition development is carried out. In particular, data of working times, energy consumptions and costs of resources required in the service development are estimated for the full development of the 30 topics considered in the project. These are summarized in Table 1. Life cycle activities associated with the BS_1 and BS_2 systems are considered in each design alternative.

We can observe that the estimated data of working time and costs in the manufacturing process of the supports are generally lower in alternative 3 than in the other alternatives, due mainly to less amount of materials and painting required. However, the manufacturing of contents using fabrics (alternative 2) entails an energy consumption considerably higher than using vinyl (alternatives 1 and 3). In assembly activities, the working times and labor costs estimated for alternative 1 and 2 are significantly higher than in alternative 3. This makes sense since the placement of the vinyls in the latter option is done horizontally instead of vertically. In addition, the energy cost is much lower due to the use of fewer and smaller trucks. Along the service provision stage, the replacement of materials in alternative 2 is more expensive due to the use of textiles. The additional energy consumption due to lighting is also considered. In the end-of-life stage, data estimated in alternative 1 are higher than alternative 2 or 3, since more materials have to be processed.

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Table 1. Data estimated for each design alternative.

		Working time (h·10³)			Labor costs (€·10³)			Energy consumption (Kw·h ·10³)			Material + Energy Costs (€·10³)		
		Alt 1	**Alt 2**	**Alt 3**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 1**	**Alt 2**	**Alt 3**
Creation stage													
BS_1	Ideation	0.28	0.42	0.34	12.10	18.15	14.69	0.30	0.40	0.36	0.04	0.05	0.04
BS_2		2.40	2.40	2.40	103.00	103.00	103.00	8.00	8.00	8.00	0.90	0.90	0.90
BS_1	Raw material &	0.13	0.11	0.08	1.90	0.45	1.65	42.70	27.40	47.10	10.40	8.10	7.50
BS_2	Manufacturing	1.66	1.20	1.66	28.60	30.50	28.60	0.55	3.84	0.55	12.79	34.60	12.79
BS_{1+2}	Transp + Assem	0.35	0.33	0.24	8.62	8.04	5.45	5.20	6.10	0.34	2.96	3.12	1.71
	TOTAL	**4.82**	**4.46**	**4.72**	**154.22**	**160.14**	**153.39**	**56.75**	**45.74**	**56.35**	**27.09**	**46.77**	**22.94**
Provision stage													
FS	Maintenance	0.48	0.24	0.72	8.70	4.30	5.90	0.05	(*)0.40	0.06	1.20	(*)3.50	1.86
	Material Replac.	0.18	0.13	0.17	2.80	2.00	2.90		(**)0.27			(**)0.03	
	TOTAL	**0.66**	**0.37**	**0.89**	**11.50**	**6.30**	**8.80**	**0.05**	**0.67**	**0.06**	**1.20**	**3.53**	**1.86**
End-of-life stage													
BS_1	Disass + Transp	0.16	0.09	0.08	2.60	1.40	1.25	6.70	5.40	2.90	12.80	9.00	7.70
BS_2	+ Treat/Depos	0.20	0.20	0.20	1.60	1.60	1.60						
	TOTAL	**0.36**	**0.29**	**0.28**	**4.20**	**3.00**	**2.85**	**6.70**	**5.40**	**2.90**	**12.80**	**9.00**	**7.70**

* due to replacement ** due to lighting

Using previous metrics and those databases and specific software indicated in the methods section, sustainability indicators of the whole exhibition development were calculated for each design alternative. In particular, the GWP indicator can be calculated from the amount of each material used in each alternative and the corresponding unit indicator (expressed per mass unit in the databases). The execution costs are obtained by adding material, energy, and labor costs. In this work, the Kw·h price taken as reference for the cost energy calculation was 0.119 €/Kw·h. In addition, an average labor cost of 23.1 €/h is considered for all workers involved along the development of the cultural service. Nevertheless, different salarial levels are considered depending on the workers category required in each phase. The results obtained are presented in Table 2. Data are expressed globally and separately for each system initially identified. When comparing sustainability indicators for each system, Alternative 2 shows lower emissions and working times, but higher execution costs than Alternatives 1 and 3. An aggregated index is calculated to obtain a comprehensive sustainability evaluation, with weights assigned to each dimension. Four cases are considered: case 1, in which equal importance is given to each sustainability dimension and an equal weight of 0.33 is given to each of the three indicators; cases 2–4, in which one dominant sustainability dimension (weight of 0.5) is established and equal importance is proposed to the rest (weight of 0.25). Table 2 summarizes the results, where negative values indicate less impact and positive values indicate more impact. An aggregated index is calculated in each case to represent the relative sustainability improvement between design alternatives.

Table 2. Sustainability indicators for each design alternative.

	Environmental dimension GWP (Kg CO_2-eq ·10³)			**Economic dimension** Ce (€ ·10³)			**Social dimension** T_W (h ·10³)					
	Alt 1	**Alt 2**	**Alt 3**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 1**	**Alt 2**	**Alt 3**			
(BS_1) Exhibitors	21.41	15.33	19.77	43.08	72.69	33.79	0.7	0.75	0.57			
(BS_2) Exhibited content	3.33	4.61	3.33	152.17	177.47	153.06	4.46	4.00	4.42			
(FS) Provision stage	0.01	0.26	0.02	12.7	9.83	10.66	0.66	0.37	0.89			
Global system	**24.75**	**20.2**	**23.12**	**207.95**	**259.99**	**197.51**	**5.82**	**5.12**	**5.88**			
										Aggreg. index 2/1	Aggreg. index 3/1	Aggreg. index 3/2
Indicators variation (%)		-18.38	-6.58		+25.02	-5.02		-12.02	+1.03			
Case 1	0.33			0.33			0.33			**-1.78**	**-3,48**	**1,70**
Case 2	0.5			0.25			0.25			**-5.94**	**-4.29**	**4.93**
Case 3	0.25			0.5			0.25			**4.91**	**-3.9**	**-4.69**
Case 4	0.25			0.25			0.5			**-4.35**	**-2.38**	**5.02**

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We observe that when more weight is given to the environmental or social aspect, Alt 2 is the most sustainable alternative. However, by giving more weight to the economy aspect, Alt 3 is preferable. When balancing the weights, alternative 2 is the most suitable option. The findings presented herein shed light on the advantages of employing a life cycle analysis approach to inform decision-making processes. Typically, institutions make choices between different options based on the economic costs associated mainly with the production phase. In this regard, both Alternative 1 and Alternative 3 show a lower cost compared to Alternative 2 and could be preferably selected. However, the results obtained demonstrate that Alternative 2 outperforms the others when three sustainability dimensions are taken into account and a life cycle approach is applied, even when different cases are considered. Only if the economic dimension is dominant (case 3) alternative 2 is inferiorly valued. This cannot be discerned using the traditional method of evaluating alternatives only based on production costs.

5 CONCLUSIONS

This work analyzes the sustainability of an open-air cultural exhibition considering three different design alternatives, applying a life cycle approach and taking into account three dimensions of sustainability. Very few works have been published in relation with the sustainability of cultural services and, until now, none addressing the sustainable design of outdoor exhibitions using these complementary approaches.Although the research work has been focused on the design of cultural services, it is thought that these actions contribute to creating a methodological framework to approach and solve different design problems.

The case studies include three different alternatives for outdoor cultural exhibitions, in which both exhibitors and exhibited contents are critical systems. In the first alternative, cultural content is exposed using printed and replaceable vinyl; in the second alternative, the exhibition is illuminated and content is made on stretched canvas. The third alternative offers an additional service because when the display panels are replaced, exhibitors are transformed into street furniture.

In order to obtain a global sustainability evaluation a procedure based on quantitative indicators and an aggregate sustainability index has been used. It is observed that the alternative most sustainable depends on the different weights assigned to each sustainability dimension. In most of the cases analyzed, alternative two seems to be the best option with a special improvement over the others in terms of social and environmental impact. However, alternative 3 is the most indicated when greater weight is given to the economic aspect. These weights are selected according to the preferences of the decision-makers.This procedure allows comparing in a practical way different design alternatives. Thus, designers and decision makers, organizers and managers of cultural exhibitions concerned about the sustainability of the systems that they project and manage, can propose more sustainable designs. We consider that the application of study methods where products and services are interconnected and the simultaneous analysis of environmental and socio-economic issues significantly contributes to improving the design practice of sustainable systems. Limitations of the study are mainly related with the scope of the life cycle analyzed, since activities such as marketing and promotion of the cultural exhibition and the work of the organizers and curators have been outside the study limits, and the number of indicators obtained in each dimension.

Future research should expand the application of this framework to sustainably design other types of cultural services as well as more complex systems. Further studies including sustainability as a strategic principle in the design of services should be carried out, exploring and comparing the sustainable quality of these results from different design approaches and with greater emphasis on social concerns and different stakeholders.The group of visitors seems particularly interesting. Knowing their visit experience, possible once the projected alternatives have been prototyped, would allow the application of a mixed method of evaluation in which quantitative data referring to the three dimensions of sustainability and qualitative data of the visitor experience are taken into account. The assessment with a greater number of indicators as well as the inclusion of the cultural dimension of sustainability could also be an objective of future studies. Ultimately, we hope that more studies with greater scope can lead to changes in the criteria applied when selecting tendered services. The inclusion of the evaluation of the sustainability of the service throughout its life cycle should be part of the submission of proposals so that decision-makers can make more informed choices. Thus, designers would benefit from tools, techniques and methods to aid them with the sustainability challenge.

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