5. RESULTS

5.1. Introduction

There are several factors that influence the achievement of an event and regardless of its purpose, some characteristics are crucial to consider its success. It is essential to carry out an analysis of the results obtained after the realisation of an event to be able to know what were the strengths and weaknesses. In this way it is possible to qualify and quantify the effect of an event. In addition, considering the steps before and during the event, as well as comparing it with previous and similar events, are crucial steps for continuous improvement. There are several KPIs that can be used to measure an event's success and according to CASHMAN, (2005); FURRER (2002); IOC (2006); PREUSS (2007); CROMPTON & LEE (2000); STYNES (1997 and 1999); CROMPTON et al. (2001); WARNICK et al. (2017); PEREIRA et al. (2021), they are:

- Attendees: the most basic and important KPI. Whether physically or virtually, obtaining information on this data is very useful to measure the success of an event.
- Revenue from tickets or sponsorship: If the event has some kind of direct revenue, either sponsorship or ticket sales, the gross and net revenue should be calculated.
- Satisfaction surveys: It is important to listen to the opinion of the participants, as they are the centre of the event. It is also important to measure how many people recommend the event itself.
- Interest in the theme: Interest in the theme can be measured by the amount of people who can affect and seek interest in the subject.
- Repercussion on social networks: promoting the event on social networks serves both to attract the public and to evaluate its digital impact.
- Sales: The return can be financial or not. This KPI depends on the nature of the event. Not all events have a monetary purpose.

Many of these indicators mentioned above can be applied to Solar Decathlon events with the purpose of measuring their impact. As previously mentioned, the main objective of this work is to propose improvements to Solar Decathlon's performance in future editions and the best way to accomplish this process is by analyzing, comparing and interpreting existing data with the new information that was acquired through this thesis' methodology.

There were numerous results obtained through the methods of data collection executed for this thesis (worldwide survey, interviews, factsheets, methodology of international projects and indicators) and all of them will be analyzed in this thesis. Part of this data (the most significant) will be present in this chapter and the rest is present in the five Appendices of this document.

In order to organise the analysis developed through the multiple results obtained, this chapter was divided into six parts (categories), and for the creation of these categories, the KPIs used to measure the impact and success of an event, mentioned above, were taken into account, adapted to the reality of a Solar Decathlon competition. Figure 57 below illustrates the organisational scheme of this chapter. The titles of the next topics are represented by six colours, as shown in Figure 57, in order to facilitate the reader's understanding of this work.

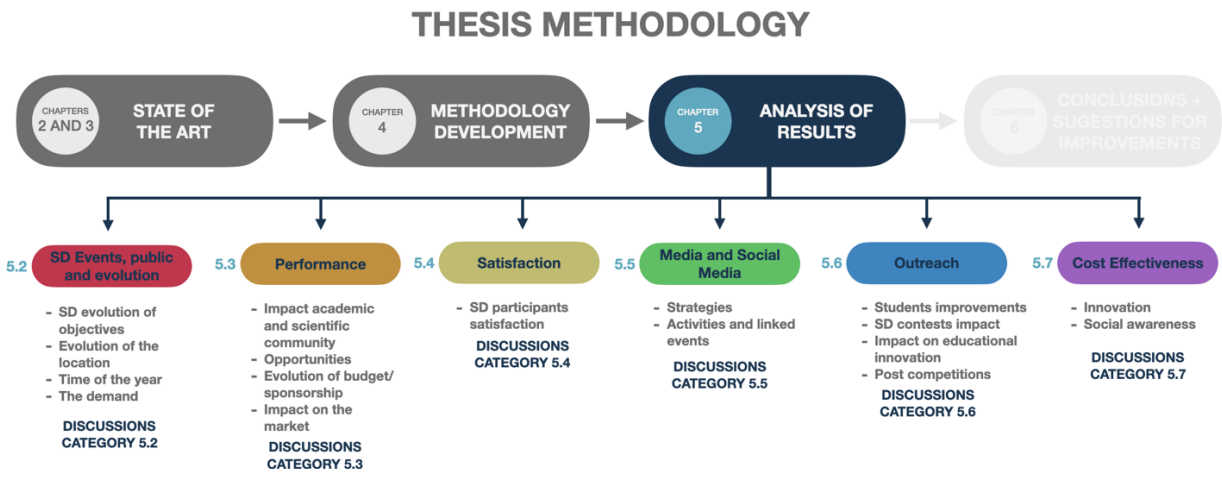

Figure 57 – Structure of the analysis of results applied in this thesis. Source: Richard Amaral.

The first category to be analysed is the event and the public involved (Topic 5.2). In this category a global analysis of the events will be made, their evolution over these more than twenty years of existence and their target audience.

The second category to be analysed (Topic 5.3) is related to the event's performance and in it will be present data related to the impact of the competition on the academic community and the opportunities generated. Furthermore, it provides information on investments (financial and in the form of services) injected into events and their impact on the market.

The third category (Topic 5.4) presents information on participant satisfaction in relation to event participation. Data on the positive and negative points of the competition according to the opinion of its participants shall also be analysed.

In the fourth category (Topic 5.5) an analysis is made about the media strategies adopted by the competitions and how they directly impact the success of a competition.

The information on the outreachs of the events form part of the fifth category analysed in this chapter (Topic 5.6). In it, the participants' opinions regarding the improvements and gains made by students after participating in an SD event will be presented. In addition, an analysis is made about the use of post competition prototypes.

The sixth and last category (Topic 5.7) to be analysed is the cost-effectiveness in relation to the interest in repeating the execution of a Solar Decathlon event. In this category, information on successful strategies adopted and that influenced the event's educational and innovative potential are analysed.

5.2. SD Events, public and evolution.

In this topic it will be carried out an analysis of the public involved in a Solar Decathlon competition as well as a global analysis of the events already carried out, together with the evolution of the competition along these more than twenty years of history. The information obtained to perform this analysis comes from existing literatures and official websites together with the results obtained through the methodology of this thesis. This analysis will be made from a comparison between the competitions on several aspects of the event.

5.2.1. The evolution of objectives and their impact on the visiting public

When it comes to planning the development of a project, one of the first assumptions to make is to establish its main objectives and strategies. In the case of Solar Decathlon, over the years these objectives have varied according to time, location, needs, among other factors that make each competition have some particularity.

About the North American competition, in 2002, ambitious goals and objectives for that time were set and they had the purpose of effectively integrating architecture and technology by creating an attractive habitat that was comfortable to occupy, provided the daily conveniences and energy to power the typical activities of homes and home offices, and produced enough additional energy to maintain the charge of an electric vehicle

(EASTMENT et al., 2002). In parallel to this, promoting the education of students, professionals and society on energy efficiency.

Currently the goals of the North American competition are to provide participating students with unique training that prepares them for the clean energy workforce. Furthermore, to educate and introduce not only the students but the entire participating public to the latest technologies and materials in energy efficient design, clean energy technologies, smart home solutions, electric vehicles and high-performance buildings. Successively to that, to demonstrate to the public that an energy efficient building also features comfort, innovative home systems and design (US DEPARTMENT OF ENERGY).

Making a comparison between the objectives presented previously, we can notice a subtle evolution since in 2002 the main focus was to present the effectiveness of the construction of a house 100% powered by solar energy and that it was demonstrable the effectiveness of its operation. At that time, it was an innovative proposal and as the years went by it became more and more usual as this concept was proven at each competition held. The objectives of the competition today, despite continuing to address the technological innovation of clean energy, are focused on promoting and attracting the population on this issue in addition to educating and training future professionals in the area. It is noticeable the addition of the social focus on the main concept that is sustainable innovation.

With the expansion of the Solar Decathlon to other continents, it can be observed a variety of objectives according to each place, although maintained the main essence of the event. In 2010 there was the first competition hosted in the European continent and its main objectives were: Raise awareness among students participating in the competition about the benefits and opportunities offered by the use of renewable energy and sustainable construction; Encourage building professionals to select materials and systems that reduce the environmental impact; Educate the public about responsible energy use, renewable energy, energy efficiency and the technologies available to help them reduce their energy consumption (VEGA & ARRANZ, 2011).

Making a brief comparison of the objectives of SDE 2010 with the analysis previously made on the evolution of the objectives of the North American competitions, we can observe that the first European competition already focused on the social aspect

by being concerned with contributing to the dissemination of knowledge about industrialized, solar and sustainable housing for the population, its professionals and the market.

Thirteen years after the first European competition, and like the North American competitions, the objectives were evolving. SDE has added to its objectives the demonstration that high performance solar houses can be comfortable, attractive and low cost (SDE WEBSITE). This shows that there is a concern to attract and convince the population that solar houses can be affordable, in all aspects in order to move the market and reach new people.

Besides new objectives, rules and contests, the expansion of the competition to the European continent also boosted the development of parallel projects with the purpose of adding value to the European competitions as well as contributing with the leverage of activities related to SD throughout the continent.

10Action was a project led by the Universidad Politécnica de Madrid (UPM) and financed by Intelligent Energy Europe (IEE) and its creation and development emerged when the competition migrated to the European continent. The basis of this project is to disseminate the knowledge acquired through the SDE. Furthermore, this project was responsible for developing various activities during SDE 2010 for both children and professionals in the area, with the aim of increasing awareness and learning about the themes addressed by the SD (VEGA & ARRANZ, 2011).

The Energy Endeavour Foundation (EEF) is a non-profit organisation endorsed by the U.S. Department of Energy (DOE) and staffed by experts and former SDE organisers. Its main objective is to position, promote and orchestrate activities in areas of responsibility for renewable resources and, since 2019, to contribute to and strategically guide the European competitions.

The competitions held in the Middle East, Africa, Latin America and China, which are more recent events, already contemplate all these objectives previously mentioned, and in parallel to this, specific objectives for each continent have been added, such as for example, in the African competition, promoting the integration of architecturally attractive solar systems replacing conventional building materials and having environmental, social and economic impacts in Africa. In the Chinese competitions, the promotion of transformation and regional development is also prioritised.

As seen, the evolution of the objectives of the SD went from being only a constructive and innovative focus and prospered to a social and educational aspect so that it was increasingly attractive to its participants reaching a large part of the population and the market involved. Furthermore, the expansion of the competition to other continents outlined new objectives, adapting them to the needs of each location.

The popularity (visitors) of SD events is one of the main factors to measure the success of the event (as SD's main premise is to spread its ideals to as many people as possible). It is extremely important to understand who the target audience of the competition is and what is the best way to attract these people to visit/participate in the event. Based on experience gained through the visit conducted at the SDE 2019 competition and the responses from the interviews done with the event organisers, the audience involved in the competition can be categorised by five groups which are:

- Students: These are generally students of Architecture and Engineering universities and who are pursuing an undergraduate, master's or doctoral degree.
- Institutions: In this group are considered the professors and members of universities and departments who, like the students, the vast majority are from universities of Architecture and Engineering.
- Professionals: Experts from the fields of Architecture, Engineering, Construction, Technologies, Sustainability, Urbanism and Design.
- Companies: Coming from the fields of Architecture, Engineering, Construction, Technologies, Sustainability, Urbanism and Design.
- Local visitors: Citizens and tourists (children, teenagers and adults) and influential people such as governors, ministers, etc.

In addition to these five aforementioned groups, one must also take into consideration that there is a portion of people who are at the event for the purpose of participating in the competition, whether as teams or as organizers and these people must also be taken into consideration when analysing the general public involved.

According to the chart below (Figure 58), which brings information from the factsheet of the 2012 European competition, the vast majority of the visiting public of this edition are local visitors (96.37%). This result demonstrates the importance of the event being well located in order to attract as many local people as possible.

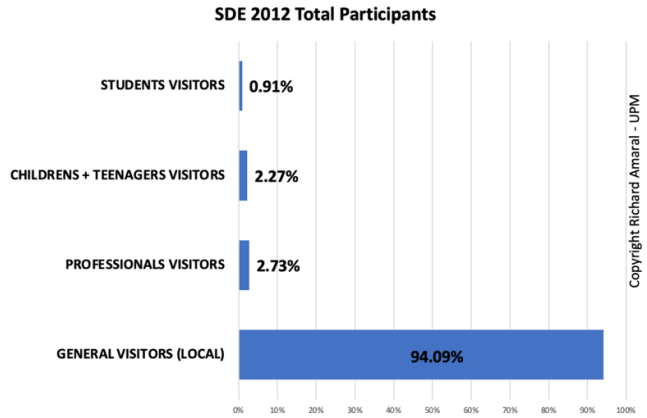

Figure 58 – Solar Decathlon Europe 2012 total public. Source: SD websites. Adapted by Richard Amaral.

5.2.2. Evolution of the location and visiting public of the events

Solar Decathlon competitions have become huge events, reaching several people, having an undeniable impact. Taking as starting point the result of the chart previously presented (Figure 58), where the vast majority of visitors come from local audiences, the following will present global information on the events already held (location, solar villa, general population and academic influence) relating them with other data, generating a qualitative analysis. For the better understanding of this topic, the table illustrated by Figure 59 below summarises the competition timeline, together with data on the venues hosted and some specific information and descriptions on each event.

COMPETITION	YEAR	SOLAR VILLA			HOUSES DIMENSIONS (m/m2)			EVENT		
		PLACE	SIZE (m2)	DISTANCE FROM CENTER (m)	LOTS	ARCHITECTURAL FOOTPRINT	CONDITIONED AREA	TEAMS	COUNTRIES	VISITORS TOTAL
U. S. SOLAR DECATHLON	2002	NATIONAL MALL, WASHINGTON D.C. - USA	48.000 m2	1.800 m	25 x 20.4 m	75 m2	41.8 m2	14	2	100.000
	2005							18	4	120.000
	2007							20	5	200.000
	2009							20	5	n/a
	2011				24 x 18.3 m	55.7 m2 - 92.9 m2	55.7 m2	19	5	25.000
	2013	ORANGE COUNTY GREAT PARK, IRVINE - USA	n/a	11.500 m (Irvine Centre)/74.200 m (Los Angeles Centre)				20	5	25.000
	2015							16	3	25.000
	2017	61st & PENA STATION, DENVER - USA	n/a	5.100 m				11	3	40.000
SD EUROPE	2010	MANZANARES RIVER, MADRID - SPAIN	166.400 m2	2.100 m	25 x 20 m	74 m2	42 m2	17	7	192.000
	2012	PUERTA DEL ÁNGEL, MADRID - SPAIN	52.900 m2	2.900 m	20 x 20 m	150 m2	45 m2 - 70 m2 (one story house) 110 m2 (multi-story house)	18	12	220.000
	2014	VERSAILLES - FRANCE	n/a	2.000 m (Versailles Centre)/20.700 m (Paris Centre)				20	16	82.000
	2019	SZETENDRE, HUNGARY	10.000 m2	5.000 m (Szetendre Centre)/17.600 m (Budapest Centre)				10	7	15.000
	2021	WUPPERTAL - GERMANY	n/a	1.400 m (Szetendre Centre)/30.100 m (Düsseldorf Centre)	28 x 18 m			18	11	n/a
SD MIDDLE EAST	2018	DUBAI - UEA	n/a	60.600 m	20 x 20 m	150 m2	45 m2 - 70 m2 (one story house) 110 m2 (multi-story house)	15	11	n/a
	2021	DUBAI - UEA	n/a					8	5	n/a
SD CHINA	2013	SHANXI DATONG - CHINA	205.000 m2	n/a	n/a	n/a	n/a	20	11	230.000
	2018	SHANDONG DEZHOU - CHINA	620.000 m2	n/a	n/a	n/a	n/a	21	9	500.000
	2021	ZHANGJIAKOU - CHINA	n/a	n/a	n/a	n/a	n/a	15	11	n/a
SD LATIN AMERICA	2015	UNIVERSIDAD DEL VALLE, CALI - COLOMBIA	n/a	9.300 m	n/a	n/a	n/a	15	10	n/a
	2019				n/a	n/a	n/a	13	7	n/a
SD AFRICA	2019	BENGUERIR - MOROCCO	52.900 m2	3.700 m	27 x 20 m	200 m2	55 m2 - 90 m2 (one story house) 110 m2 (multi-story house)	18	19	40.000

Figure 59 – Evolving table on relevant information from competitions. Source: SD websites and rules documents. Adapted by Richard Amaral.

Interpreting the table in Figure 59 it can be seen that North American, European and Chinese competitions have undergone changes in their location over the years. A good location contributes to an event having a high number of visitors. It is important that it be a busy place, so that it draws the attention of passers-by and also that it be accessible to visitors (near underground and bus stations, parking, restaurants, hotels, etc.).

In addition, the city has to be able to host an event of this size since the amount of population directly influences the amount of visitors. Another important factor that must be considered is the university influence that the city has since most of the visitors are students, normally coming from SD related courses (architecture and engineering), so that the city has this kind of public is very important. Another point that should be taken into account is a location that has a wide variety of public transport stations.

There are also those people from outside the city such as students coming from nearby cities, professionals and academics from the area and other relevant guests which are also a type of public that should be considered, so a space where there are airport/train services nearby is very important. Hotels and restaurants are fundamental to serve these people. In light of these points, the following will demonstrate and compare the locations of the European and North American competitions, as they have hosted several editions and have a vast amount of accessible information that favours comparisons between them.

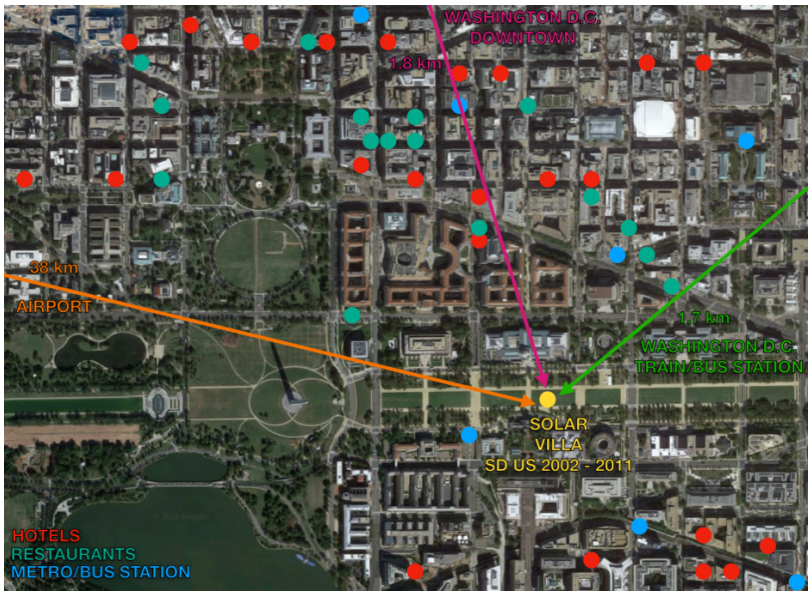

Figure 60 – Location and surroundings of SD US 2002 to 2011 in Washington D.C., USA. Source: Google Maps. Adapted by Richard Amaral.

In Figure 60, demonstrates the location of the first five North American Solar Decathlon events were. According to the image, it can be stated that it was a central

location, close to public transport stations and in an area full of hotels and restaurants. Moreover, being located in a tourist spot, the National Mall, the probability of attracting visitors is very high.

Figure 61 – Location and surroundings of SD US 2013 and 2015 in Irvine, USA. Source: Google Maps. Adapted by Richard Amaral.

Location of the 2013 and 2015 competitions, in Figure 61 we can observe that the location of these two events was far from the city centre and despite having some train stops, visitors definitely had to arrive by car to the event. Another factor to note is that the location was deficient of restaurants and hotels. A positive point was that it was situated in a park and people who were walking around the area could be motivated to visit the event.

Figure 62 – Location and surroundings of SD US 2017 in Denver, USA. Source: Google Maps. Adapted by Richard Amaral.

According to Figure 62, the Solar Villa location of US SD 2017 has the same characteristics described earlier about the previous two editions, but with even fewer facilities than the others.

Of the three locations presented, we can conclude that the first one is the most efficient since it is close to essential elements to make it attractive to visitors and as a response to that, according to the table in Figure 59 the editions held in Washington D.C. were the ones that had more visitors. Another point that influences the total amount of visitors is the local population and, even though Denver's Solar Villa was further away from downtown than Irvine's, the total audience was bigger and this may be related to the fact that, according to US SENSUS BUREAU < https://www.census.gov >, Denver is a more populated city than Irvine (712,000 and 310,000, respectively). Although the population factor has an influence on the number of visitors, if we compare Denver with Washington D.C., which according to the US SENSUS BUREAU has almost the same number of inhabitants, Washington D.C. had a higher number of visitors and this is certainly related to the location of the event.

Still analyzing the location versus public visiting the North American competitions, according to the list made in 2009 by Association of Collegiate Schools of Architecture there are 118 universities of architecture in the United States. Considering the US cities and states near Solar Villas, the competition held in Washington D.C. there are 7 universities of architecture in the region (Columbia, Maryland and Virginia). Near Irvine there are 5 universities of architecture (Los Angeles and San Diego). Near Denver there is only 1 university of architecture. As mentioned earlier, the amount of students is directly linked to the total visitor audience, so the closer Solar Villa is to universities of architecture, the larger the target audience.

The four locations of the European competitions are analysed below using the same criteria as above.

According to Figure 63, the first two European competitions held in Madrid were situated in a location close to the city centre, with several metro stops nearby. It can also be noted that there is a vast amount of restaurants and hotels due to the centric location. The Solar Villas of both editions were close to various tourist spots (Sol, Plaza Mayor, Palacio Real de Madrid, Plaza de España) which attracted even more visitors to the competition.

Figure 63 – Location and surroundings of SDE 2010 and 2012 in Madrid, Spain. Source: Google Maps. Adapted by Richard Amaral.

The third European competition (Figure 64) was located in a very touristic and centric area and this is a key attraction for visitors. Nevertheless, being more than 20km away from the centre of Paris, most of those interested in visiting the competition would have to be willing to take a train/bus/car to get to the Solar Villa, which can be considered a demotivating factor. With regards to visitors coming from other locations, as much as Versailles is a city that has a variety of restaurants and hotels their price can be considered high as it is a very touristy city.

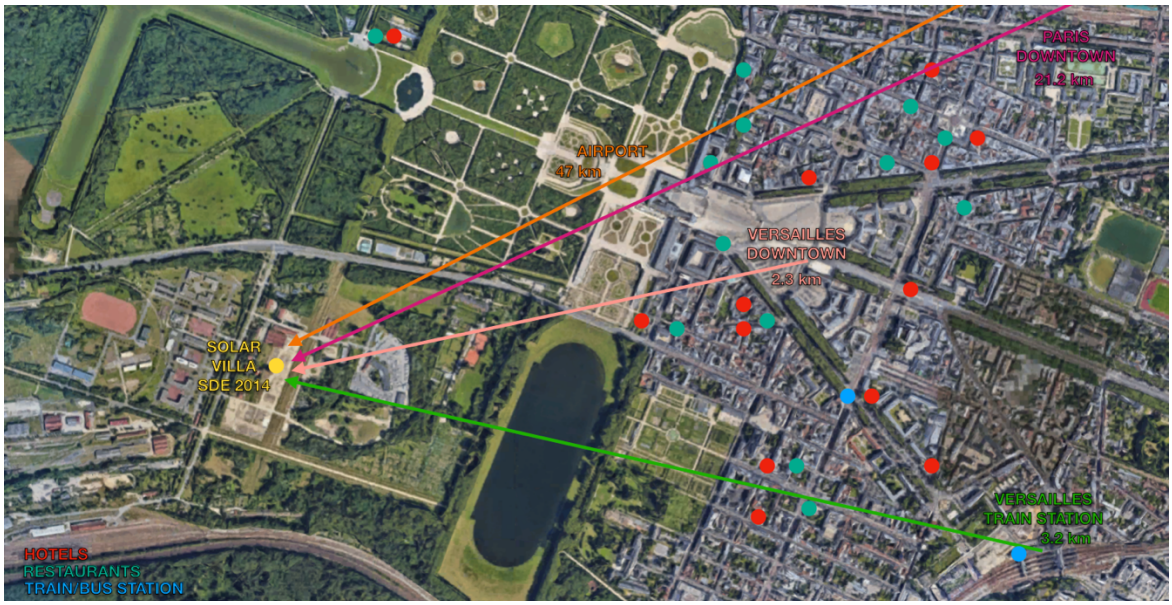

Figure 64 – Location and surroundings of SDE 2014 in Versailles, France. Source: Google Maps. Adapted by Richard Amaral.

Figure 65 – Location and surroundings of SDE 2019 in Szentendre, Hungary. Source: Google Maps. Adapted by Richard Amaral.

Looking at Figure 65, the 2019 competition was situated in a region that lacked basic infrastructure to make it attractive to visitors.

Figure 66 – Location and surroundings of SDE 2022 in Wuppertal, Germany. Source: Google Maps. Adapted by Richard Amaral.

Comparing the location of the fifth edition of SDE (Figure 66) with those of Versailles and Szentendre, which were in places away from major cities, this edition was better situated with respect to train stations and restaurants.

Of the five locations presented above, the two in Madrid are the best situated in relation to the items considered important. Besides, according to EIONET, Madrid is the

most populated city among the other european (Madrid: 3.225.000; Versailles: 85.800; Szentendre: 26.000 and Wuppertal 355.000) and because of that, the total number of visitors of this edition may influence before the others.

Considering the number of universities of architecture in each of the host countries, Spain has 38 universities (Ministerio de Universidades), France has 55 (PREPA), Hungary has 7 universities (Hungary ACE) and Germany has 63 (Association of German Architects). This is an important factor as students directly influence the total amount of visitors to the event. Among the four countries, Hungary is the country that has the least number of architecture universities and this may have influenced the visits of the 2019 event as according to the table in Figure 59, it had the least attendance. It is worth noting that in Madrid there are 12 universities of architecture in total (COAM) and for this reason, the amount of students and teachers who had the opportunity to visit the event without having to worry about travelling is very large.

What can be seen by analysing the locations of the European and North American events is that after 2012, the competition venue has become more distant from the centre of the big cities and that this may be a factor that triggered the drop in the total number of visitors. Considering that students are a large part of the visiting public, having multiple ways to access the event is essential and the fact that the more centric editions had a larger audience also justifies this reason. Another factor attracting more people is the academic influence of architecture on such a city, i.e. the more universities of architecture in the region, the greater the number of interested parties. Another data that influences the number of visitors is the population of that city, the more people, the greater the possibility of attracting visitors.

5.2.3. Time of the year

In addition to location, other factors can also influence the total visiting public, such as the time of year in which the event was held. According to the competition websites, North American events do not vary so much in the time of year they are held (usually between the end of September and the end of October). European competitions, on the other hand, had more variation. According to the table in Figure 67 below, it is possible to better visualize the seasons.

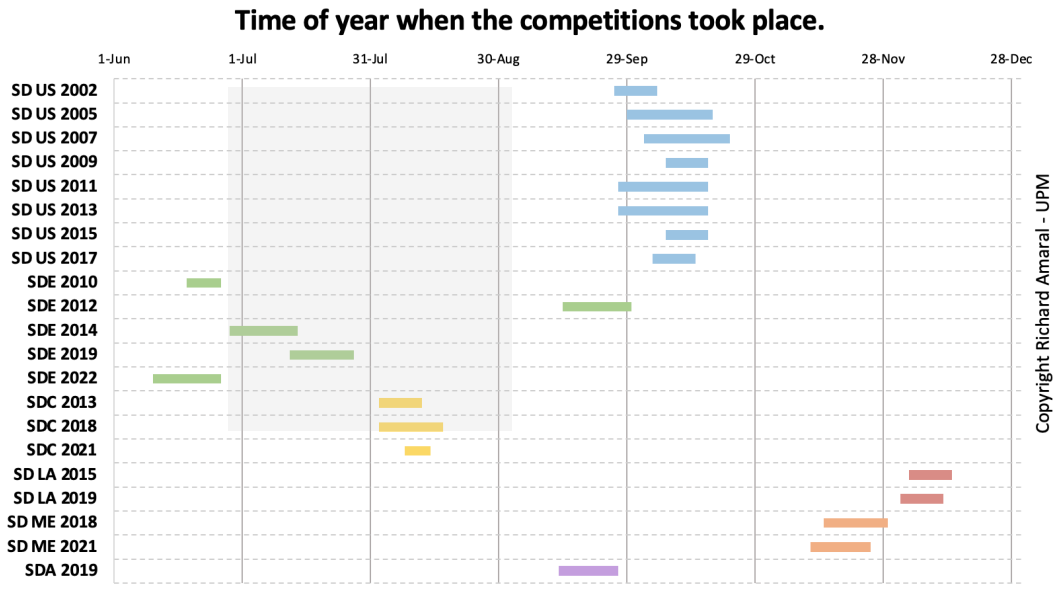

Figure 67 – Time of the year when the competitions took place. SD websites. Adapted by Richard Amaral.

Considering that in the northern hemisphere, holidays are usually in the months of July and August, the influence of this on the total visiting public can interfere. Holding an event at this time is risky as many people are away on holiday. In the case of Madrid and Versailles, despite being highly touristic cities, July and August are the months that receive the least number of tourists, compared to the rest of the year (AYUNTAMIENTO DE MADRID and INSEE – INSTITUT NATIONAL DE LA STATISTIQUE). From the students' point of view, according to Szentendre's interview ,the end of a school year is always very stressful as the final exams and project deliveries are always exhausting. It is much more attractive to visit an event in September, when a new school year is beginning and the weather is more pleasant than in June/July/August when the will to go on holiday is greater than visiting an event on a subject you work/study all year round. Given this thought and analysing the table in Figure 67 with the total number of visitors in the table in Figure 59, the increase in visitors from SDE 2010 to SDE 2012 may be related to the timing of the event. Still considering this same thought, decrease of visitors in SDE 2014 and especially SDE 2019, in relation to the previous ones can also be related to this factor.

5.2.4. The demand for the event as a function of the evolution of participating teams, universities and countries.

During these more than twenty years of competition, several universities and teams have had the opportunity to experience this event. We know that the novelty factor

is very important for the longevity of an event because it is a factor that adds motivation and attracts those involved. In the case of Solar Decathlon, the more teams/universities are willing to participate in the event, the greater will be its impact and one of the causes that interferes directly in this aspect is the novelty factor. In this topic we will analyze the teams, universities and countries participating in some of the most significant events and how this data can influence the demand for future editions. Other relevant information such as the willingness of former participants to compete in future editions and the need for the event as an additional complement in the training of future architects will be analyzed in this topic.

The chart in Figure 68 below shows the number of teams and universities participating in all competitions held. It is possible to observe that in the case of North American competitions, there was an increase in the number of teams and universities involved until 2013. In the case of the European competitions, the number of teams and universities started and remained high in the first three editions and with a sharp drop in the 2019 edition and an increase in the 2021 competition. It is worth noting that between the third and fourth European competitions, there was a five-year gap, which may have motivated this drop. Still about the European competitions, the fact that the first edition has a high number of participating universities and teams may be related to the novelty factor in the continent and also because the competition is already known by the North American editions held previously.

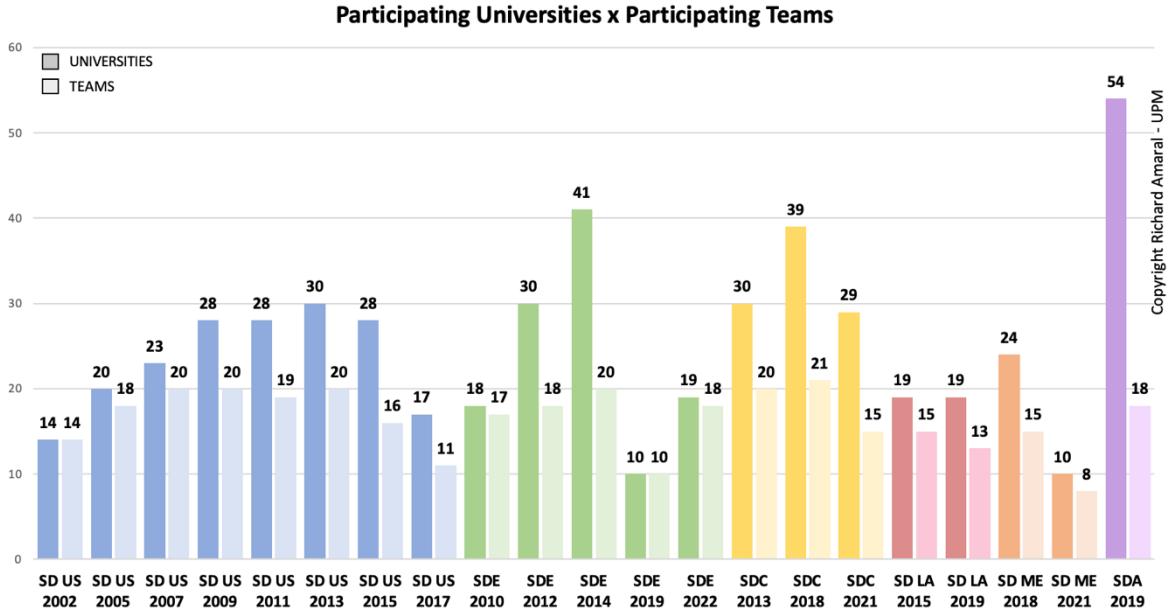

Figure 68 – Number of universities on participating teams. Source: SD websites. Adapted by Richard Amaral.

Still on Figure 68, Chinese competitions have a high rate of teams and universities despite the fact that their last competition had a significant drop. It is worth noting that the time gap between competitions is greater than in other continents. In the case of the two competitions held in the Middle East, there was a notable fall between the two editions. In the case of the Latin American editions, this figure remained practically stable between the two editions.

Considering that the US SD and SDE are the events that had more editions, in the next charts these competitions will be analysed with the purpose of knowing if the novelty factor on the universities is something that can still be explored for future editions. The main premise to perform this analysis is the existence of universities that still haven't had contact with the competition and that may possibly participate in the event seeking new participants, renewing the competition's audience.

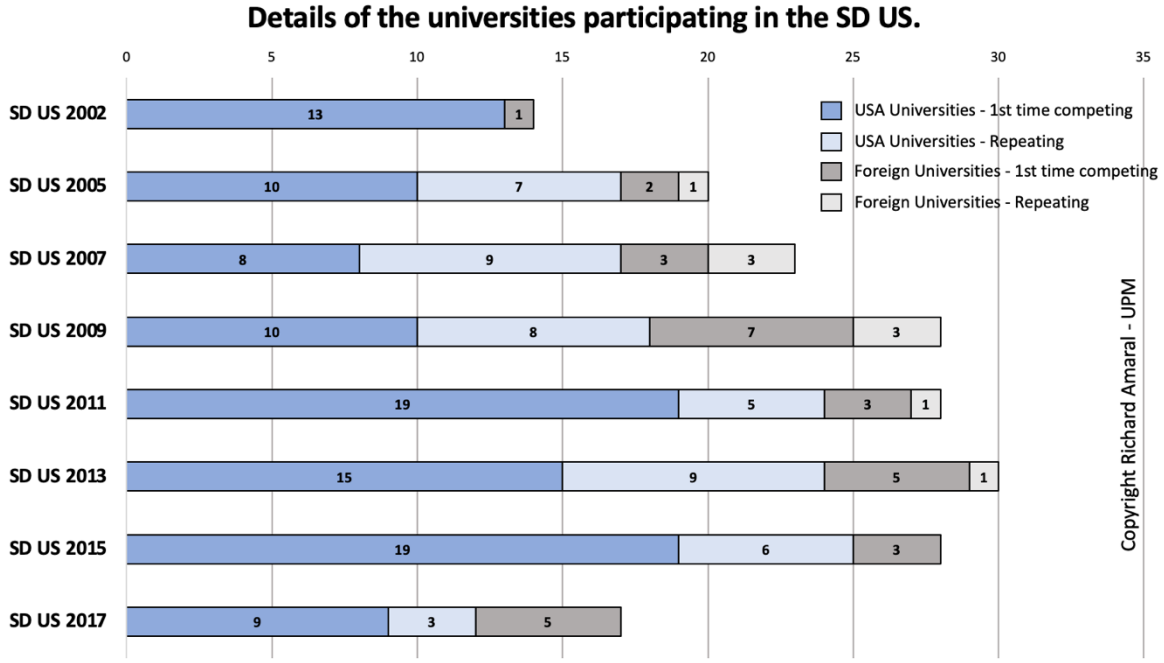

Figure 69 – Details of the universities participating in the SD US. Source: SD websites. Adapted by Richard Amaral.

According to the graph in Figure 69, we can observe that of the 133 universities involved in the eight North American competitions, 104 are universities from the USA and 29 are foreign. It can be affirmed that the vast majority of the participating teams/universities are North American and that although it is smaller, there is also an interest from foreign universities in participating in this competition. Still on these figures, and comparing with the information given by Association Of Collegiate Schools Of Architecture, that there are 118 universities of architecture in the United States and

that although the 104 universities that participated in the competition are as much of architecture as of engineering and arts, there is a large portion of US institutions that had contact with the competition. This comparison shows that the North American competition has reached many universities and perhaps this is why it is a factor that since 2017 there are no new face-to-face editions.

Using the same assumptions of the previous chart and applying them to the SDE competitions, according to the chart in Figure 70 below, 106 universities in total participated in the five editions, 86 of which were European and 20 foreign. What can be analysed is that in Europe there are many universities of architecture and only 86 of them had access to the competition. There is a large number of universities that can still be affected and it is evident that the competition still has room to reach new audiences.

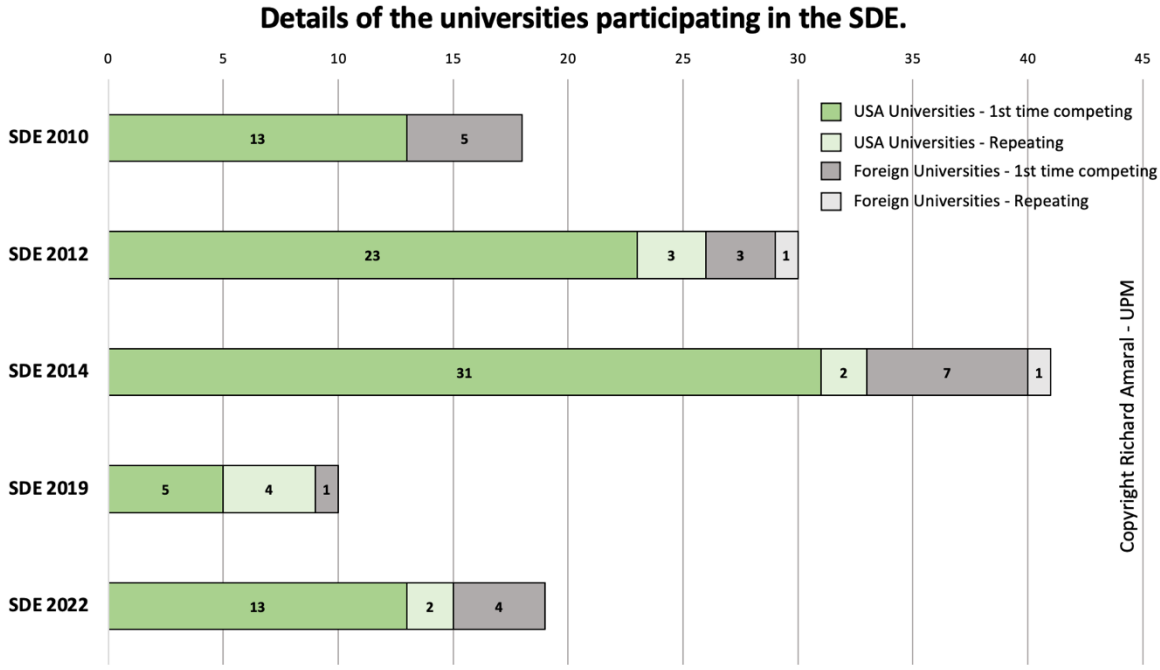

Figure 70 – Details of the universities participating in the SDE. Source: SD websites. Adapted by Richard Amaral.

There is definitely still an interest in participating in the competitions as in none of the cases there is an abrupt drop in the participating universities/teams (Figure 69 and Figure 70). What can be stated is that in the US SD there is a larger number of American universities affected by the competition and it may be that in the future there is not a great search and demand from these universities to participate in the competition. Besides, the novelty factor is reduced. The opposite happens in the European competitions as there is a high number of universities that have not had contact with the competition, in which the possibility that this event is prolonged for more years is greater.

Emphasising the statement made that there are a high number of European universities that have not yet participated in the competition and may be a target audience in future events, the graph in Figure 71 below illustrates an indicator created on the amount of European countries that have participated in SD competitions as a function of which events these countries have participated in. In this case two important points can be observed. The first is that there is a great diversity of the participations of European countries in competitions around the world. The second point is that only 18 European countries participated in the competition and many of them had the opportunity to participate in 1 or 2 events, which is a very low figure.

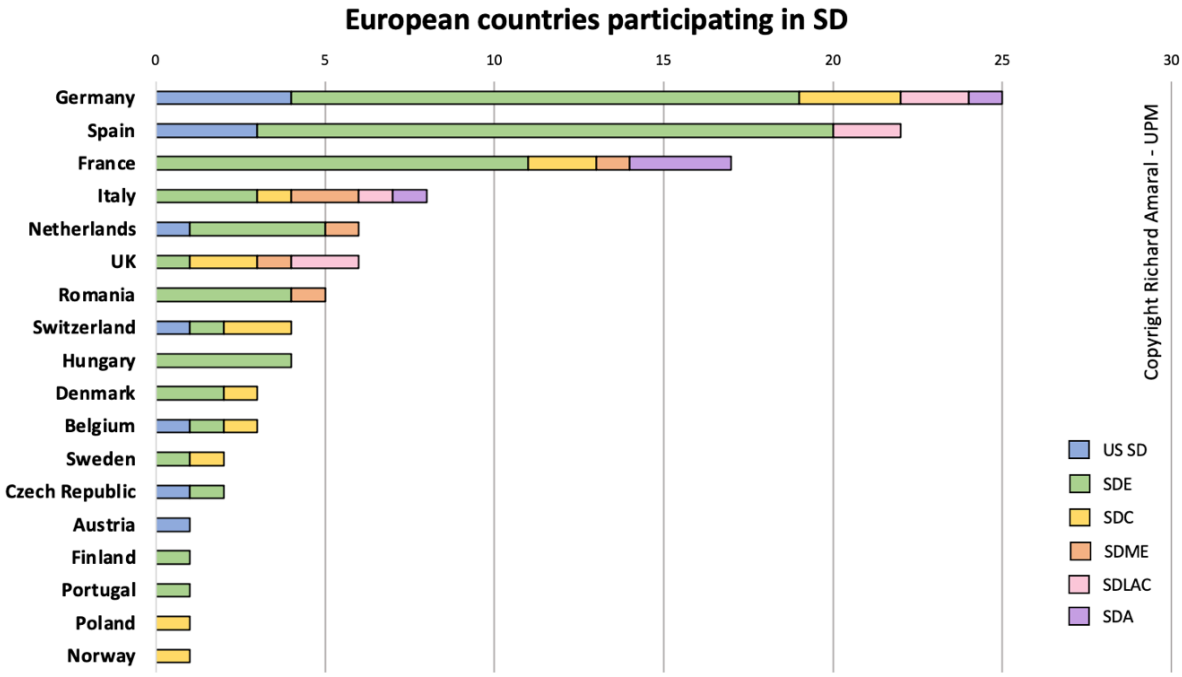

Figure 71 – European countries participating in SD. Source: SD websites. Adapted by Richard Amaral.

Still on Figure 71, it can be observed that there are great European countries, which have a high interest in participating in sustainable policies, are not present in this graph, which serves as an affirmation that there are possible countries/universities that may be interested in future editions of the competition. Furthermore, according to the graph of Figure 72 below from The European Environment Information and Observation Network (EIONET), it ranks the European countries that have the highest index of Sustainable Development Goals (SDG) and in the top 10 of this ranking, 6 countries did not participate in the competition or participated in very few editions of the SD.

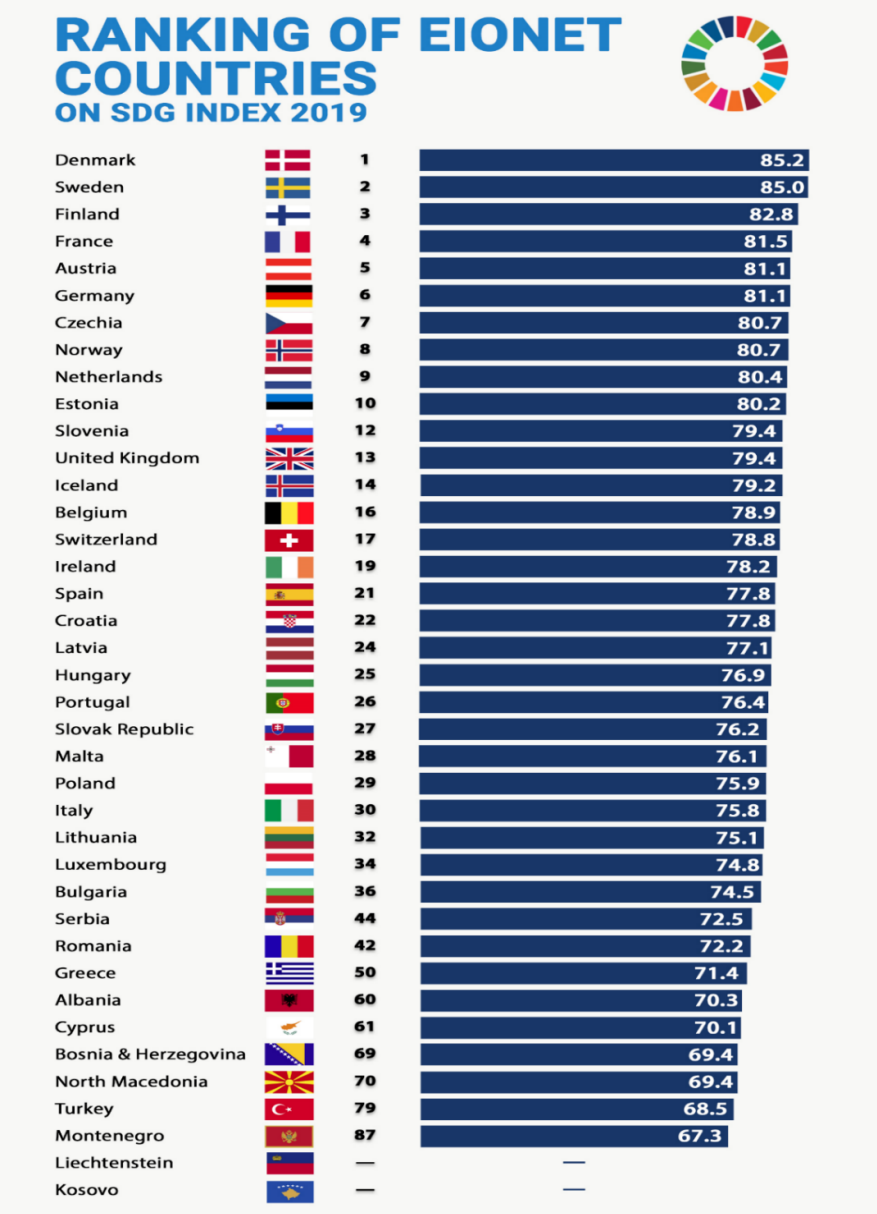

Figure 72 – Index of European countries of Sustainable Development Goals (SDG). Source: EIONET.

Therefore, it is possible to affirm that there is a great demand from European countries that have interest in participating in projects related to sustainability and energy efficiency and the Solar Decathlon can be one of these projects.

Besides the demand of possible countries in participating in the competition, the novelty factor is something that must be taken into account and to be able to demonstrate this within the Solar Decathlon competitions, we can analyze the numbers of teams initially registered and that show interest in participating in the event according to the participating teams. According to Figure 73 below, in the case of North American competitions, with the exception of the 2007 competition, it can be stated that there was a constancy between the interest of teams in participating in the competition and the final

scenario of participants, i.e., most of the registered teams participated in the event. Furthermore, this number did not vary over the years. Differently, in the case of European competitions, what can be observed is that the number of the search for participating in the event has grown exponentially and even though there has been a sharp drop in 2019, the number of teams registered is higher than the number of participants, demonstrating that there is a high number of people interested in participating in the competitions.

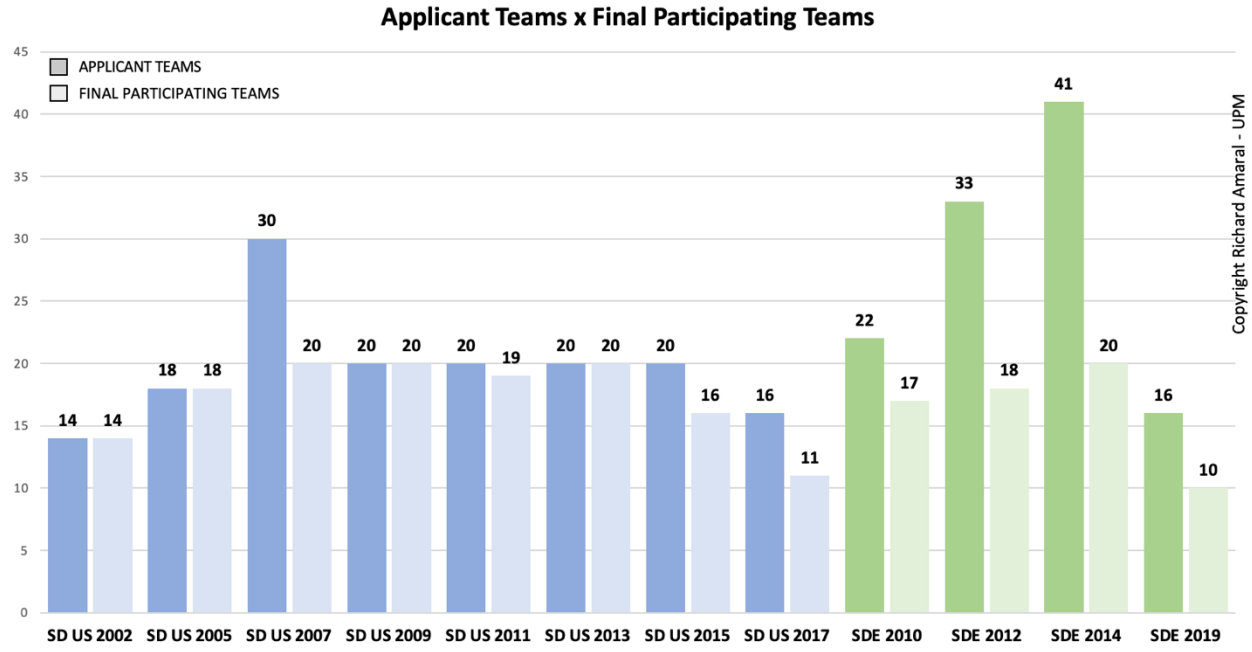

Figure 73 – Applicant Teams X Final Participating Teams. Source: SD websites. Adapted by Richard Amaral.

A high number of teams registered in the competition demonstrates that universities continue to be interested in experiencing the event. Furthermore, in comparison with the data presented above, in the case of Europe (Figure 73), there is a large portion of universities that were not "impacted" by the event. Thus, what can be concluded is that in the European competitions there are more possibilities and demands for the continuation of the SD competitions than in the United States.

In addition to analysing, via SD's competition history, the possibility of demand from teams/universities/countries to participate in future editions of the event, another important piece of data to further enhance this analysis is the perception of those who have already participated in an event as to the possibility of them reliving the experience by participating in future editions. According to data obtained through the worldwide survey, when participants (whether visitors or competitors) were asked if they had the

opportunity, would they compete again, according to Figure 74 below, 88% of them said yes.

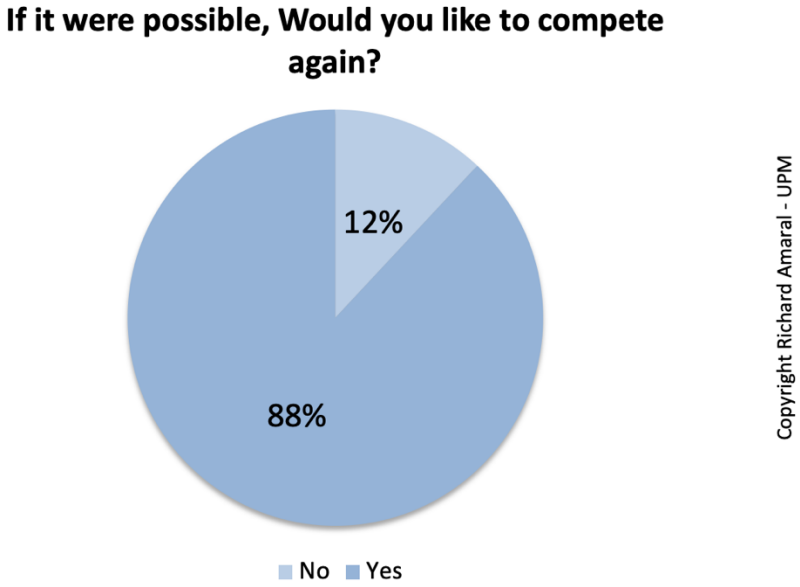

Figure 74 – Respondents' assessment of competing again at the Solar Decathlon. Source: Richard Amaral.

To finalize the analysis of the demand for future editions, another point to highlight is the need for the existence of the Solar Decathlon competition nowadays as an effective complement to the learning of future architects. More than twenty years ago, when the competition was created, issues related to sustainability and energy efficiency were not in evidence and were not treated with relevance, both in the academic field and globally. Therefore, at that time the competition had a relevant novelty factor, and successively to that it had a high educational and social impact on all the people who were participating.

More than twenty years later and issues related to sustainability and energy efficiency have become popular and are relevant in many areas today. In the academic field, in architecture universities, nowadays there are more subjects and projects about sustainability and new technologies, which is a great advance. However, when making a deep analysis about the curricular structure of an architecture course nowadays, subjects related to sustainability and new technologies are very few. The chart of Figure 75 below shows the percentage of subjects contained in an architecture course according to its area of learning and what can be observed is that the areas of Materials, Sustainability and Technologies are the areas with less related subjects.

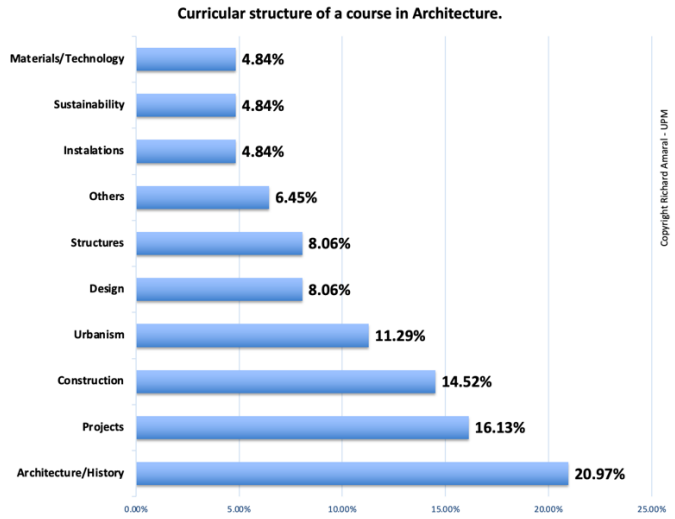

Figure 75 – Curricular structure of a course in Architecture. Source: UPM. Adapted by: Richard Amaral.

Although the architecture students nowadays have contents and subjects related to sustainability inside the university, what can be said is that they graduate with very basic knowledge about these subjects. Therefore, an event like the Solar Decathlon that promotes knowledge about new technologies, sustainability and energy efficiency is still necessary to add to the training of future architects and engineers.

5.2.5. Discussions Category "SD Events, public and evolution"

In this first category it was possible to carry out an analysis about the event and the public in a general scope, through a relation of existing data with new data generated by the methodology of this thesis. As a result, it was possible to develop the following observations:

The competition has grown and expanded over the years and successively to this its main objectives have changed and adapted to the needs of each continent. In 2010, when the event had its first edition in Europe, the main objectives of the competition focused on innovation and dissemination of knowledge to people and since then, this premise was adopted in the following editions held.

The audience involved in the competition is mostly formed by local visitors, so it is very important to establish facilitating strategies to make the event as attractive as possible for these local citizens. Analyzing articles (BOTTYAN, 2015; LÓPEZ-BONILLA et al., 2010; ÖZDEMIR, 2016; MCKERCHER et al., 2016) that speak about the main factors that drive the attraction of tourists/visitors to distinct events, regardless of their purpose, all of them have the same similarity which is the importance of a good location. According to these articles, the choice of the venue of an event carries a great

responsibility, being one of the most important decisions in its organization, and may itself determine the success or failure of the initiative.

According to MORGAN (2007), there are several conditioning factors that influence the choice of a place to host an event and applying these conditioning factors in the context of Solar Decathlon, the place to be chosen must have the following characteristics: a large location, conducive to the construction of the Solar Villa; a location where access by public transport is fairly easy; a location that has parking nearby or in its absence that has a space that can receive this use; a location that has proximity to accommodations (hotels) to receive tourists; a location that can receive cathering service or that is close to restaurants; a busy location and that brings security to its visitors.

The location of previous events was one of the issues analyzed in this topic taking into account the conditions mentioned in the previous paragraph. According to this analysis, the location of the competitions held in Washington D.C. (USA) and Madrid (Spain) had the most favorable characteristics to receive an event of Solar Decathlon and according to the graph of Figure 76 below, which illustrates and compares the total amount of visitors of each of the competitions, this statement can be confirmed since of the events held in the United States, the competitions in Washington D.C. were the ones that had a larger audience. And in the case of the European events, the Madrid editions were those that had the most visitors.

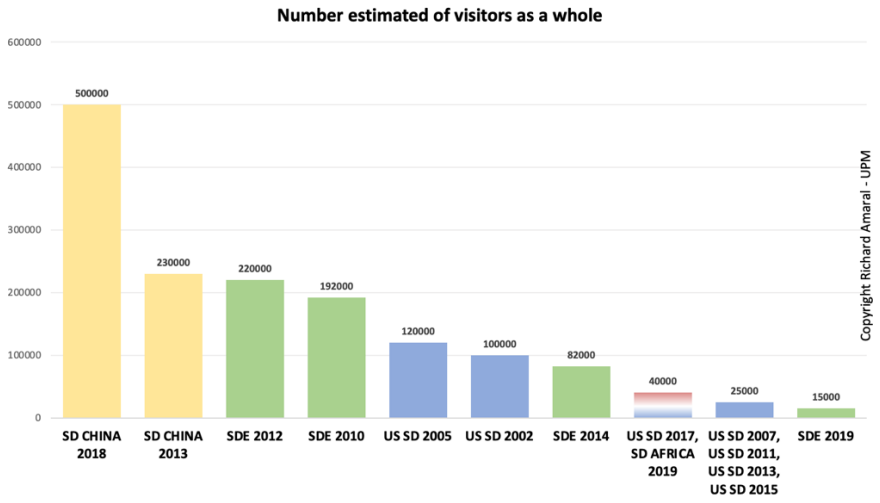

Figure 76 – Total number of visitors at SD competitions. Source: Competitions websites. Adapted by: Richard Amaral.

There are other factors that increase the chances of attracting people to an event and, as seen in this topic, the size of the population of a host city influences the total final

number. Another factor to be considered is the academic influence that the host city has in the areas of engineering and architecture. The closer the city is to the universities of architecture and engineering, the more people are likely to be interested in the event.

Furthermore, the time of the year the event is held is a factor that influences the total number of visitors. Holiday periods are times which should be avoided. Finally, the demand for future events according to the analysis of previous participations was another factor studied in this category. There is a high number of North American universities that participated in the competition, especially in events held in the United States. There is a possibility of promoting the participation of universities from the USA in events in other continents. This analysis can also be used for the competitions held in China, Latin America, Middle East and Africa as the vast majority of universities participating in these events are located in the same continent where the event is held. There are countries (universities) that are great powers, that are interested in sustainable policies and that have conditions and interest to take teams to compete in events in other continents.

In the case of the European countries, what was found is that there is a diversity of participation of these teams in various continents, which is a positive fact since it demonstrates the interest of these teams in taking their projects outside Europe. Moreover, not all European countries have had the opportunity to participate in an SD competition and many of them are dedicated to participate in sustainable policies, so there is a high margin for possible future participants in the event.

5.3. Performance

This topic will analyse the event's performance. To this, themes related to the impact of events on the scientific and academic community will be studied along with the opportunities generated. The investments and the impact on the market are themes that will also be illustrated in this topic. To develop this analysis the results of this thesis methodology were used (Survey, indicators, factsheets and interviews) in addition to the information studied by literature reviews on the themes.

5.3.1. Impact on the academic and scientific community

Regarding the impact that the competition generates in the scientific and academic community, it is related to scientific publications, articles, books, theses, etc. However, there are other aspects that should be considered, such as the use of prototypes post-

competitions, the impact of the event on students due to knowledge and exchange of experiences, etc. In the following, the performance of the DS for the scientific and academic community will be analysed.

In the questionnaire sent to the organisers in order to obtain concrete information about the event, there was a question about the number of articles, books, theses, publications, etc. that were produced from that event. Surprisingly, of the 15 factsheets obtained, only 4 of them had data related to this question (Table 9).

Table 9 - Total number of publications in SD. Source: Richard Amaral.

	BOOKS	PAPERS	THESIS
SDE 2010	1	50	3
SDE 2012	3	47	3
SDC 2018	50	35	50
SDA 2019	3	7	5

Interpreting the Table 9 above, two conclusions may be reached: one that the organizers who answered the factsheets of the competitions (15 in total) do not know what has been published about that specific competition or that in fact there is no publication, book, thesis related to that competition. To reach an answer about this doubt created, in the worldwide survey carried out in 2020, the student respondents were asked if they developed any publication or scientific work together with the university about the SD and according to Figure 77, 52% of the respondents stated that yes.

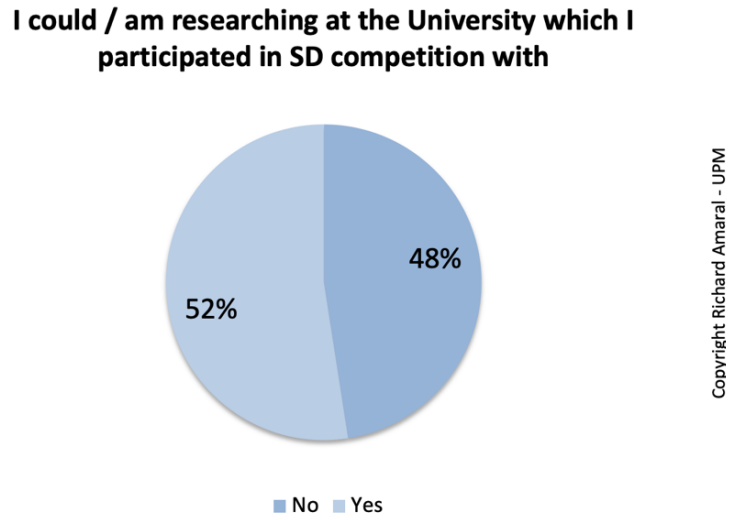

Figure 77 – Percentage of students who are developing research after participating in SD. Source: Richard Amaral.

When analysing the previous graphic (Figure 77), what can be observed is that in fact there is a large portion of students (52%) who participated in the competition that developed some publication/scientific work after the competition, so what can be concluded is that there is in fact an interest (and execution) of the students in scientific publications but what happens is that some organisers do not have control of what is being/was published about the competitions held. This analysis also served to bring veracity to the survey conducted at SDE2014 (Figure 78) where students and teachers are asked about having participated in research projects before/after the competition.

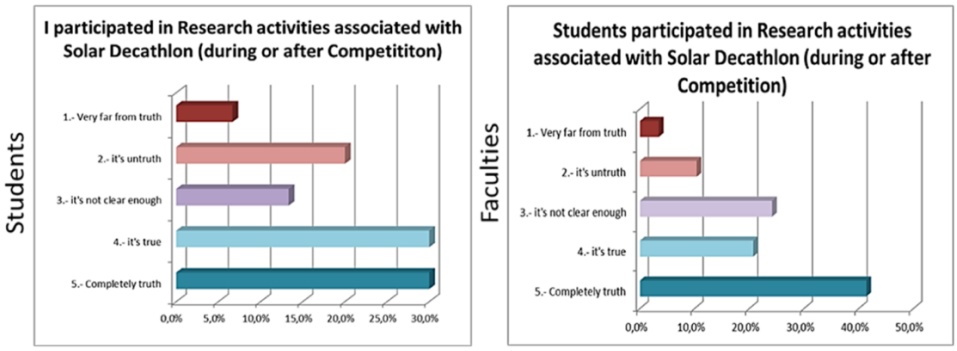

Figure 78 – Percentage of students who are developing research after participating in SDE 2014. Source: Annex 74.

Another factor to be analysed in this topic, about the performance of the event is the use of the prototypes intended for education after having participated in the competition. It is very important that the prototypes have a post competition use since it is a very high investment made by the teams and the existing educational potential is very high. In the worldwide survey conducted in 2020, respondents were asked to give grades from 1 to 6 (where 1 is the lowest and 6 the highest) on whether the prototype was intended for educational or research use after participating in the competition, and according to Figure 79 below, the averages of these grades were a 4.07, which can be said to be a positive average.

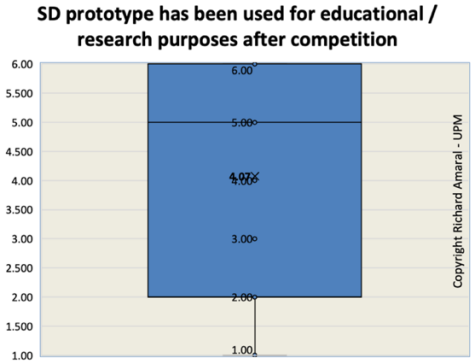

Figure 79 – Respondents' assessment of the use of the prototype after competition. Source: Richard Amaral.

As a way of complementing the information presented above, in this same survey the respondents were asked if educational initiatives linked to the prototypes were developed/planned and according to the graph in Figure 80 below, 67% of the respondents said yes, positively confirming the educational purpose of the prototype after the competition.

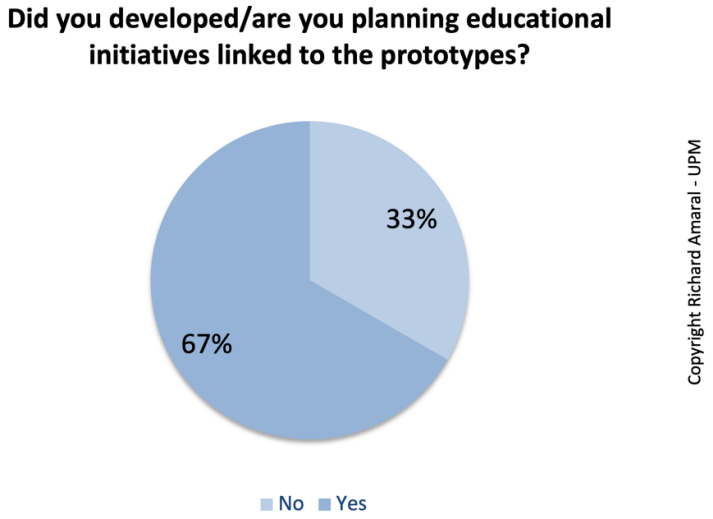

Figure 80 – Responses from teachers/institutions when asked if they have developed/planned educational initiatives to the prototypes. Source: Richard Amaral.

Another factor that influences the final performance of the event is the implication of the universities about the competition. This factor is very important because the more involved the university is with the competition, the greater will be the fostering of its objectives and principles to the students. According to the students' answers (Figure 81) when asked whether the SD is part of any official university programme, 35% of them said yes. This result portrays a low involvement of universities in implementing SD principles/activities internally.

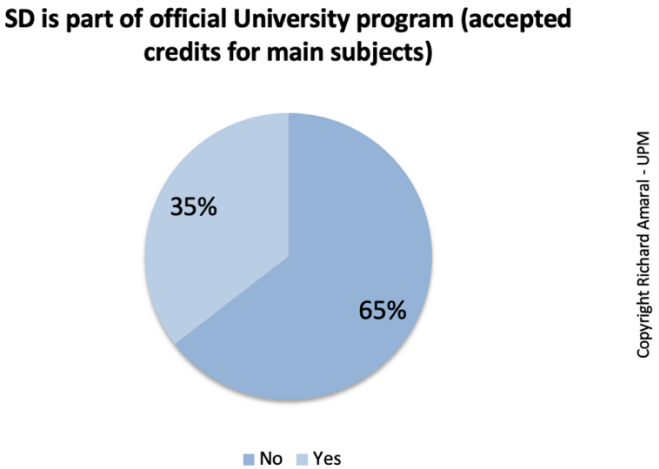

Figure 81 – Percentage of universities that have SD in the official program. Source: Richard Amaral.

To be able to better visualise why the percentage of Figure 81 was so low, it is necessary to analyse other factors that influence universities' commitment to fostering competition internally. To this end, the organising bodies of the competitions held to date were analysed and according to Table 10 below, which lists all these bodies, what can be observed is that of all of them, only in four editions (SDE2010, SDE2012, SDE2019 and SDA2019) there were universities participating in the organisation of the event and, coincidentally or not, it was precisely the editions that informed in the factsheets data on publications and work carried out at these events (Table 9).

Table 10 – Organization bodies in SD competitions. Source: Richard Amaral.

COMPETITION		ORGANIZATION
US SD		US Department of Energy, National Renewable Energy Laboratory (NREL), The American Institute of Architects
SDE	**2010/2012**	Universidad Politécnica de Madrid
	2014	Solar Decathlon Europe
	2019	Energy Endeavour Foundation
	2021	Energy Endeavour Foundation, Bergische Universitat Wuppertal
SDC		China Overseas Development Association
SDME		Supreme Council of Energy, Dubai Electricity & Water Authority
SDLAC		Departamento Nacional de Planeación de Colombia
SDA		Instituit de Recherche en Energie Solaire et em Energies Nouvelles, Mohammed VI Polytechnic University

Having universities as part of the competition organising teams can be a positive factor for the event, as it is possible to promote other activities related to SD within the universities themselves; it allows a greater proximity between the organisation and the participating teams, it is a means that helps to spread the competition to other institutions; it helps to promote the participation of students and academics in the event; it allows greater control over what is scientifically published about the event, as well as helping to promote it.

5.3.2. Opportunities

The legacy of Solar Decathlon on its participants is related to the gains made and the opportunities that the event provides for them. Regardless of how they participated,

there are many positive points. According to the interviews conducted with the organisers, many of them stated that the experience of an SD competition is unique and intense, leaving a mark and a commitment for life.

This topic will portray the opportunities that SD generated in its participants. The students had to evaluate from 1 to 6 what degree of employability Solar Decathlon helped after participating in a competition and the average of this evaluation generated around 4.26. According to Figure 82, the students' scores had a range of 3, 4 and 5.

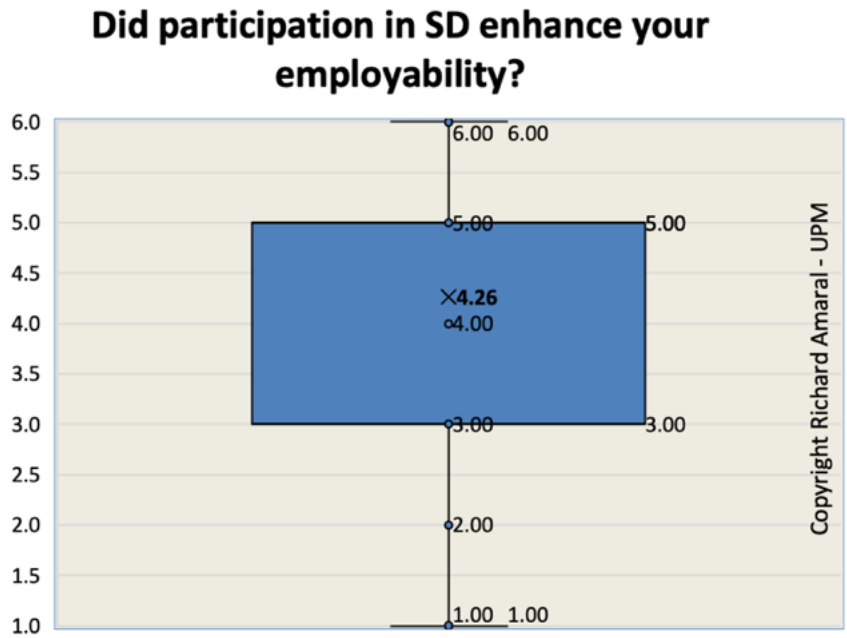

Figure 82 – Students' assessment of their participation in the SD improved their employability. Source: Richard Amaral.

Even if this average is considered positive, in the opinion of the author of this thesis, it is a low figure since there is a very high expectation that the competition may be a boosting factor in the professional career of its students. When interviewing students on site at the SDE 2019 competition in Szentendre, when asking them why they decided to participate in that competition, many of them said that they believed that the experience of participation could open doors to the labour market.

On the other hand, when the companies were asked if they would indicate to other professionals the participation of the SD, unanimously the answers were positive (Figure 83a). Furthermore, when asked if they would give priority when hiring a student who had participated in a competition, again the answer was unanimous (Figure 83b), confirming the interest of companies in having people who had experienced the competition in their staff.

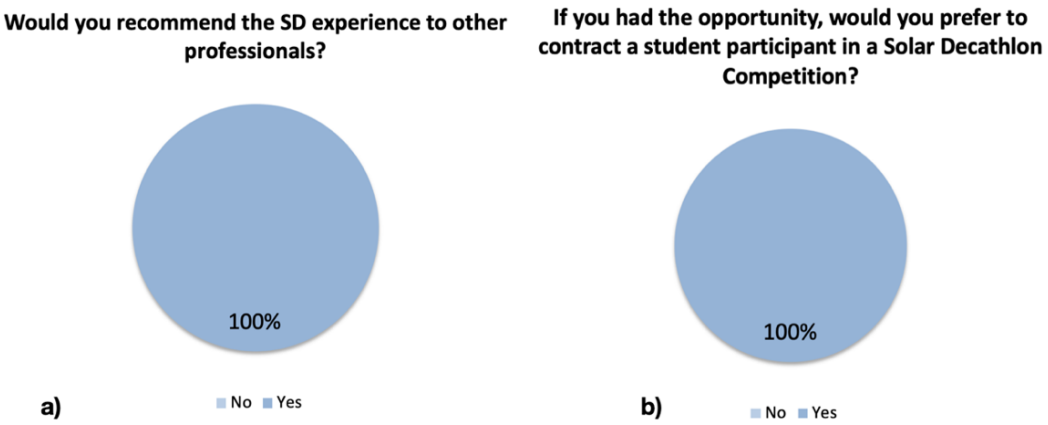

Figure 83 – Respondents' opinion of recommendations for a) other professionals and b) hiring students who participated in the SD. Source: Richard Amaral.

Although the previous graphs have been positive, when asked if innovation and environmental awareness were inserted at the company after participating in the competition, according to Figure 84, the average rating was 3.40. One notices that there was a variety in the grades given, what can be stated that there were positive and negative cases concerning this aspect.

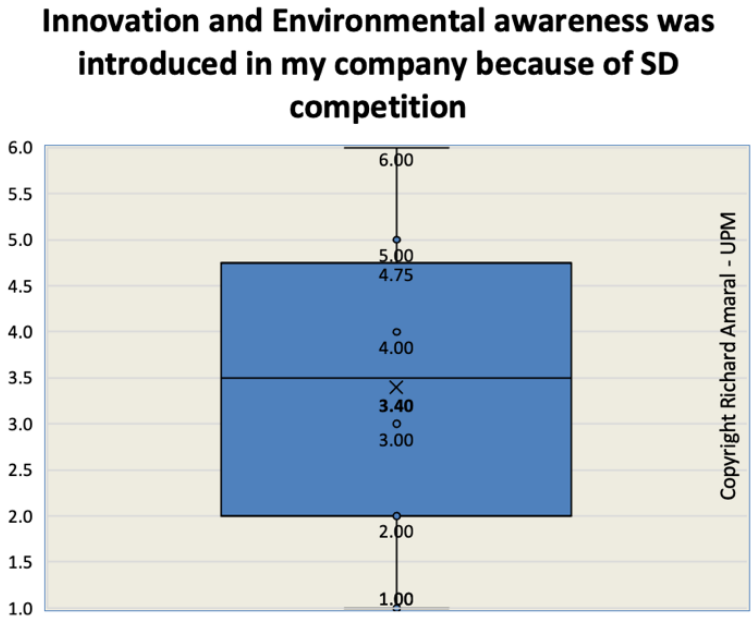

Figure 84 – Answers of innovation and environmental awareness were introduced in the company after participating in the event. Source: Richard Amaral.

When asked if the companies took advantage of their participation in the competition to train new sustainable technologies, according to the chart in Figure 85 below, the average score was 3.70. Again there was a variety in the scores given which makes us interpret that in fact some companies took advantage of the content that the SD had to offer and others did not.

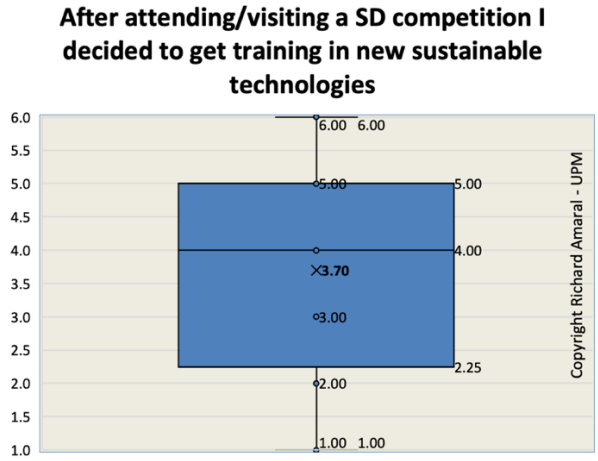

Figure 85 – Assessment of respondents on the formation of new technologies after participating in the event. Source: Richard Amaral.

What can be stated after observing the opinions of the professionals and the companies is that although the professionals are interested in hiring people who have the Solar Decathlon experience in their curriculum (Figure 83), when it comes to implementing the competition principles internally in the company, the opinions were low (Figure 84 and Figure 85), which hints that maybe these hires are not being made since having a decathlete within the staff of a company considers that the competition principles are being inserted internally in a natural way.

Regarding the opportunities generated by SD for the organisers of the competitions, a question was asked in the 2020 worldwide survey that aimed to know if the experience of having organised a competition helped them to progress in their professional career and according to Figure 86 below, 89% of the organisers believe so, which is very positive data.

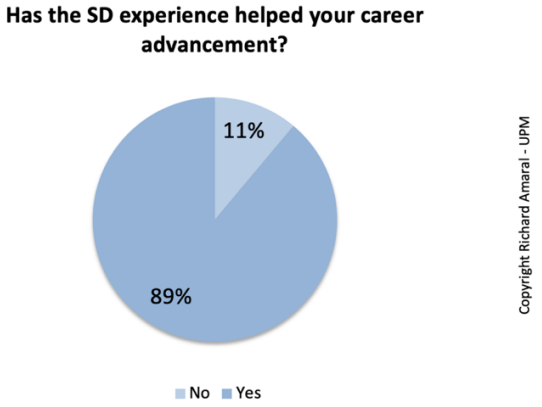

Figure 86 – Respondents' opinion on if the SD experience helped their career progression. Source: Richard Amaral.

Regarding professors and institutions, the graph represented by Figure 87 below had the intention of knowing if the universities recognized/valued the performance of the

work developed by them in the competition. The average presented was 3.70. This value can be considered relatively low. The scores obtained in this question varied from 2 to 5 and as previously mentioned, universities must motivate all participants (be they students or professors) so that the benefit of the competition participation happens.

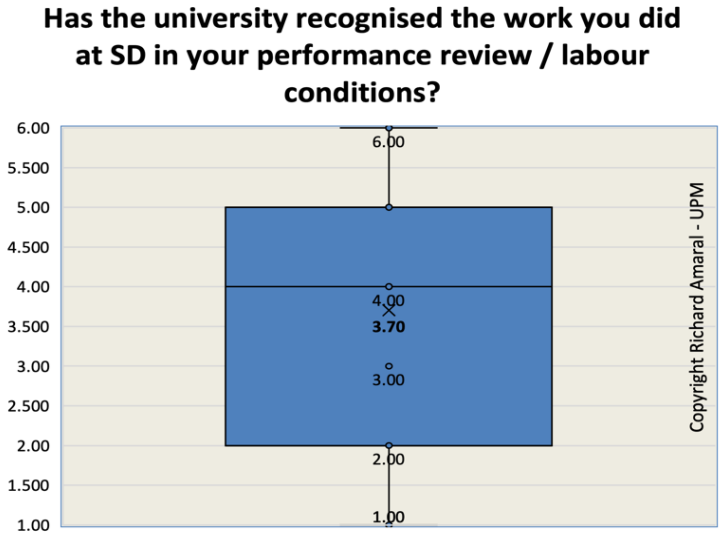

Figure 87 – Average of the respondents' evaluation when answering if there was recognition from the university when receiving performance/working conditions evaluations. Source: Richard Amaral.

Still on the graph of Figure 87, when the author of this thesis states that the value of the average is relatively low, it is because it was taken into consideration the on-site responses of the teachers participating in the SDE 2019, where most of them stated that although they are there as a way to represent the university where they work, they consider the participation a means of recognition of their work. Furthermore, what can be observed after analysing the previous graph is that this result confirms what was presented in Figure 81, this is universities' lack of commitment to developing internal activities related to the competition is demonstrated.

To finalise this topic, the opportunities generated by the competition in the lives of citizens who attended the event will be analysed. The next four results (Figure 88) are the result of questions that aimed at ascertaining what these people acquired by visiting the competition. 100% of them learned about sustainability and the responsibility of these resources. 75% of them state that the SD influenced decisions and changed their lifestyles.

Still on Figure 88 below, when asked about the influence of SD on the purchase of appliances, the answers were balanced. And when asked if SD had influenced them when it came time to do some renovation in their homes, 75% believe it has.

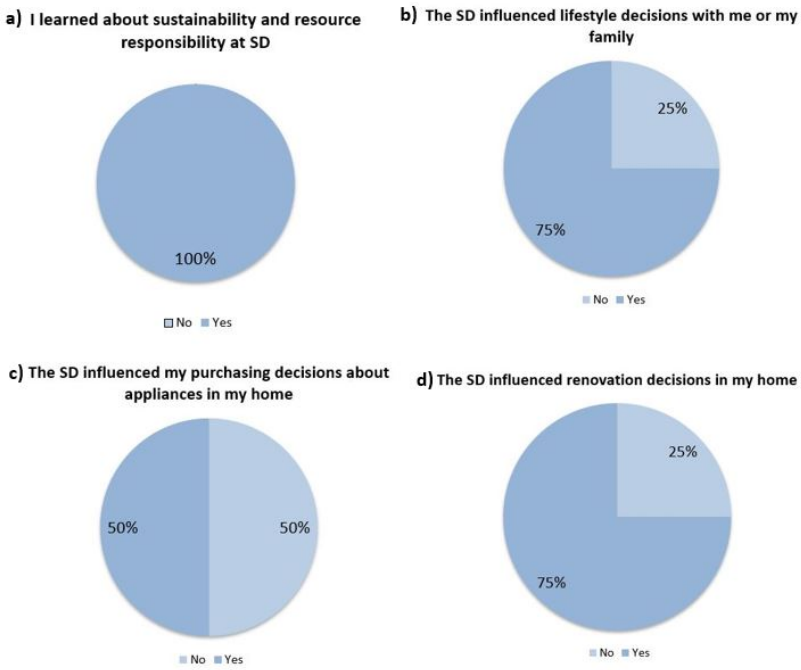

Figure 88 – Answers about SD's influence on a) learning about sustainability and resource responsibility: b) lifestyle change; c) in home appliance purchasing decisions and d) in home remodeling decisions. Source: Richard Amaral.

After analysing the data collected on the opportunities generated by the competition in the lives of its participants, what can be stated is that there is a need for greater fostering between the relationship between students (decathletes) and companies. Student employability, according to participants, has a low impact and is an important issue to consider. Moreover, it is also important to create plans for a greater promotion of the Solar Decathlon principles internally in the sponsoring companies. And lastly, that universities have a greater involvement with the competition, since this helps not only in the development and organization of the event but also there is a greater recognition of their participating teachers/students and also encourages internally the creation of activities/works related to the event within the institutions themselves.

5.3.3. Evolution of Budget/Sponsorship

The budget/return factor is an important factor when developing and measuring the impact of any event. Defining strategies and having a detailed planning equipped with several tools, along with a skilled team to carry out this work, is the key to achieving success. In the case of Solar Decathlon competitions certainly the budget directly influences the development of the event, but with a good organizing team and a planned and balanced distribution of money can further ensure the success of the project. The budget is also considered by the organizing teams as the biggest challenge faced.

The money used to run the Solar Decathlon competitions comes from three types of funding:

- Funding from public bodies: Money received by public bodies (central, regional or local governments) and ministries.
- Funding from companies in cash: companies that sponsor the event because they have some relationship with the sustainable and technological field.
- Funding from companies in kind: Companies that sponsor the event through infrastructure or services.

It is the duty of the event's organization to seek funding and sponsoring companies so that the realization of the event is possible and it is for this reason that we state that having a detailed planning along with a competent team directly influences the budget and consequently the success of the event. Regardless of this, there are other external factors that can influence this search or even the non-consolidation of the event, such as the delay in the supply of public money, the uncertainties of the companies, etc. To be able to circumvent these setbacks, the organisers should adjust the total initial budget through conservative expectations of revenues that can be expected, both from governments and from private sponsorships "in cash" and "in kind". Another measure is to have mechanisms to make project progress more flexible in order to adjust the pace of revenue. In addition, budget cuts should be planned in order to adapt to possible (and probable) problems.

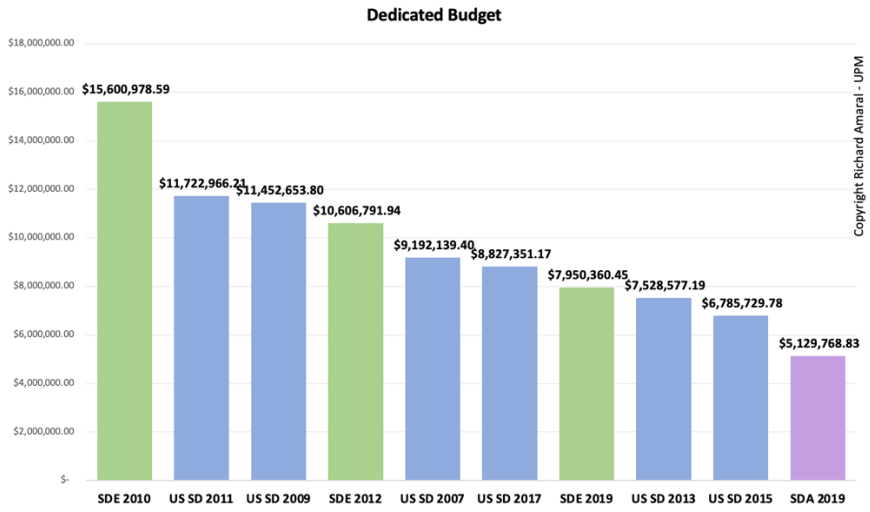

Figure 89 – Dedicated budget. Source: Richard Amaral.

The values presented in the chart of Figure 89 shows the budget used in the events according to their organizers. The intention of this chart is not to analyze the amount itself

but to make a comparative analysis with the event in general and its total visiting public. These values have been unified to a single currency (US dollar) according to the annual average exchange rate established by the European Central Bank (ECB). In addition, the figures presented are updated to the year 2022 according to the inflation rate of the United States (THE WORLD BANK).

According to the graph, excluding the SDE 2010 competition, the total event budget was between 11.7 and 5 million dollars. In addition, the graph represented by Figure 90 below shows the number of companies that sponsored the events in cash and kind. By comparing the two graphs it is possible to state that the competitions that had the highest number of in-cash sponsorships were the ones that had a higher total budget, so it can be said that these competitions may have had better organisation and effectiveness when it came to attracting sponsoring companies.

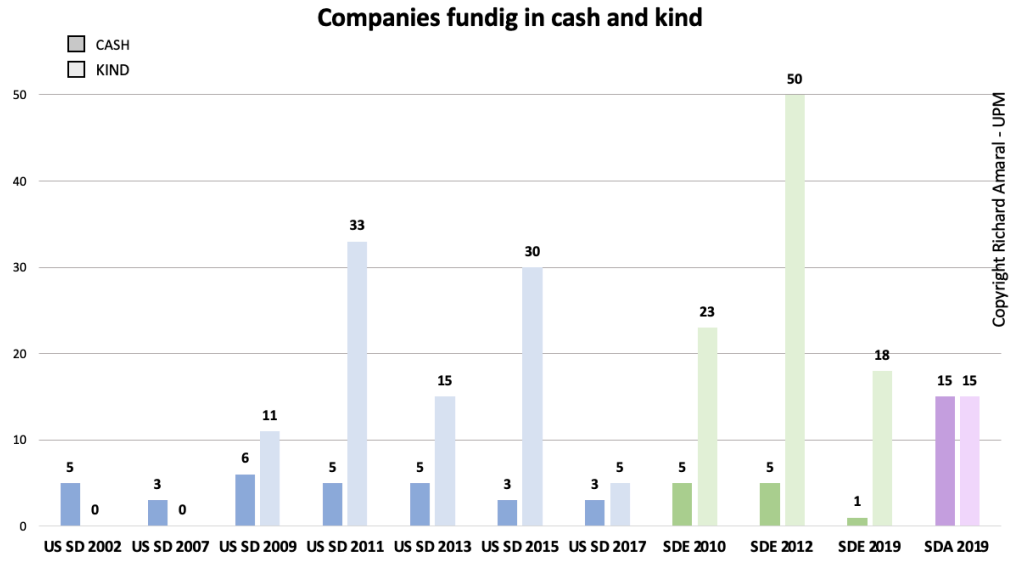

Figure 90 – Companies funding in cash and kind. Source: Richard Amaral.

Another factor that must be considered is that the amount spent to hold the competitions on each continent varies according to the currency and cost of execution. In the case of SDA 2019, the total budget is lower than the other competitions, but this does not mean that the organisation of the competition was less efficient, as according to Figure 90, this edition attracted the most in-cash sponsors.

Another important aspect to be mentioned is the number of companies that sponsored the events over the years. Performing a deeper analysis on this subject, still according to the graph of Figure 90, there are many companies that sponsor the competition, however what one might highlight is that there is a great variety of new

sponsoring companies throughout the years whilst there isn't much fidelity with the companies that already sponsored the event, not giving continuity to this "relationship" in the following years. It is very important that the competition seeks new companies to sponsor but it is also important that it maintains a relationship with the old ones so that there can be more sponsorships.

However, according to the 2020 worldwide survey, when companies were asked about the financial return of Solar Decathlon in their opinion, according to Figure 91 below, when asking if SD was a profitable activity for the companies sponsoring the teams, the average score was 4.40. There was a small variation between the scores (4 and 5) and this shows that there is indeed a financial return.

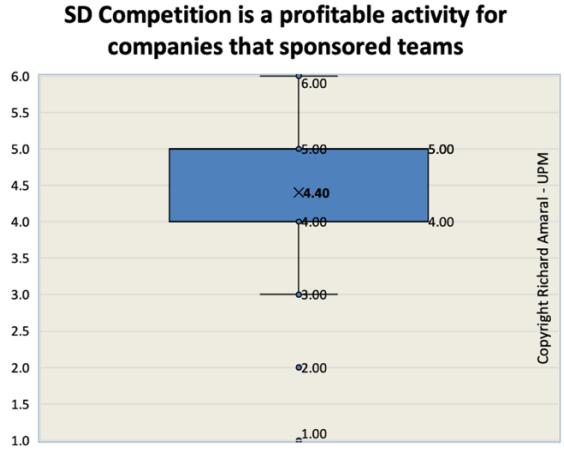

Figure 91 – Assessment of industries regarding the financial return when investing in SD. Source: Richard Amaral.

As with the previous question, when asked if SD was a profitable activity for the companies sponsoring the organisation, according to Figure 92 scores were considered high as the average was 4.32.

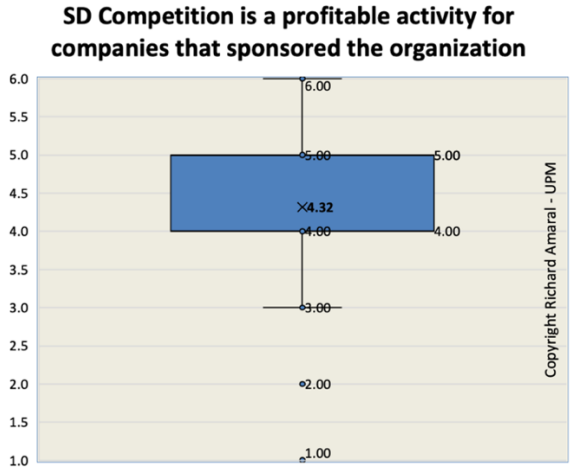

Figure 92 – Respondents' opinion when asked if SD is a profitable activity for companies that sponsored their organization. Source: Richard Amaral.

After analyzing this data, one can affirm that companies confirm that investing in the event was an activity that brought a return; however, one must ask why most of these companies do not continue with their sponsorship in the following years.

5.3.4. Impact on the market

The market impact is the last point to be analyzed in this second category and when we think of Solar Decathlon, we naturally think of the new technologies that emerged and what was presented as innovative to the market. To perform this analysis, it is necessary to understand in which moment this subject was inserted in the competition. When the competition moved to the European continent, new objectives were implemented with the purpose of meeting the needs of that moment. According VEGA & ARRANZ (2011), transferring the knowledge generated to the industry and professionals in order to create a core group of technicians who can integrate innovative and eco-energy solutions in their projects and routine activities was one of the objectives created for the European competitions.

As a result, the European competitions have been adapted in the market feasibility contest. According VEGA & ARRANZ (2011), in the SDE 2010 competition, this contest was renamed "Industrialization and Market Viability" and was incorporated into the competition to close the gap with the market, encouraging teams to be creative in this matter.

According to the SDE 2010 competition rules document, the viability of the prototype is assessed by analysing three main aspects, which are:

- Commercial and economic viability. A potential market is identified and explained: the prototype must attract future inhabitants and property developers.
- Industrialisation of the construction process. The design is evaluated as to its eventual mass production, focusing on three different production volumes.
- Flexibility and reorganisation. The ability to possibly generate different urban models is examined.

As from this reformulation, competition may foster development and innovation in the field of industrialization applied to sustainability and energy-efficient architecture and, as a result of this change, prototypes started to be concerned with industrialization and, successively to that, the possibility of commercialization. Next, some examples of

prototypes, which emerged from European competitions, will be presented and analysed to illustrate the subject of this topic. It is worth emphasising that the approach is very different from one team to another, as many teams proposed prototypes with innovative industrialisation systems.

According to VACAREZZA (2015), within industrialised construction, modular construction is perhaps the one that presents the greatest finish before its installation on site, and can reach 90% completion. The prototype developed by Spanish universities (Universidad de Sevilla, Universidad de Jaén, Universidad de Granada and Universidad de Málaga) for the SDE 2012 competition, called "Patio 2.12" (Figure 93) explored an innovative concept of prefabricated habitable modules with a high commercial potential. According to the description of the team itself (Andalucía Team) through VEGA & ARRANZ (2012), the prototype was based on the ideas of "Kit of Spaces" and "intermediate Scale of Prefabrication" and was built by aggregating fully prefabricated modules, transported by road for their assembly on site, using the "patio" as a connecting element.

Figure 93 – Andalucián Team house Patio 2.12 in Solar Decathlon Europe 2012. Source: Andalucían Team/SDE 2012.

What can be observed in the prototype plan below (Figure 94) and according to the team's description, several "pavilions" are assembled around an intermediate space, the "patio", which accommodates the extensions of the spaces that surround it.

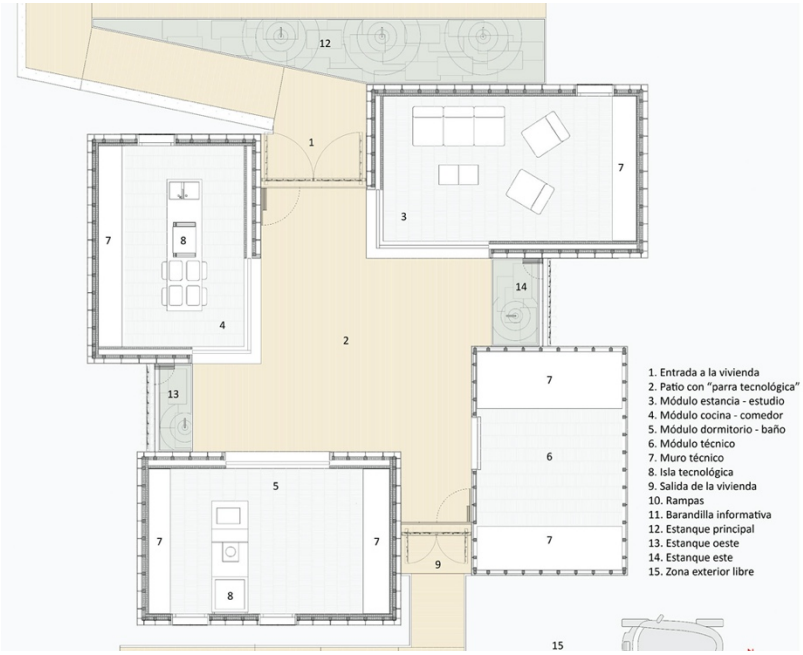

Figure 94 – Andalucián Team house plan Patio 2.12 in Solar Decathlon Europe 2012. Source: Andalucían Team/SDE 2012.

There are cases of teams who understood that their prototypes should be applied to their cities of origin taking into account their surroundings, so there were cases of proposed adaptations of the traditional models of houses on the modern demands and technologies of today (MED in Italy Architectural Brief Report), as in the case of the teams (Figure 95) of the SDE 2012 competition "MED in Italy" (Università degli Studi di Roma TER, Sapienza Università di Roma, Free University of Bozen and Fraunhofer Italy) and "PRISPA" (on Mincu University of Architecture and Urbanism, Technical University of Civil Engineering of Bucharest and University Politehnica of Bucharest).

Figure 95 – a) Med in Italy house. b) Prispa house. Source: Teams/SDE 2012.

Other industrialisation concepts considered innovative and marketable were presented at Solar Decathlon Europe 2014. In the case of the teams "OnTop",

"PLATEAU" and "PHILÉAS", prototypes were developed for the rehabilitation of existing buildings by creating roof extensions by additional floors on top of an already constructed building. According to the "OnTop" house team (Figure 96) from the University of Applied Sciences Frankfurt Am Main, (OnTop Architectural Brief Report) there is a "growing demand for housing in urban areas (lack of housing space) and the need for rehabilitation of existing buildings require new approaches in the future of housing."

Figure 96 – On Top house. Source: SDE 2014.

In the case of the "PLATEAU" team (Figure 97), coming from Spanish universities (Universidad de Alcalá and Universidad de Castilla) a total energy rehabilitation of antiquated housing estates in Spanish cities was proposed, becoming an affordable and socially sensitive alternative for the construction industry (Plateau Architectural Brief Report).

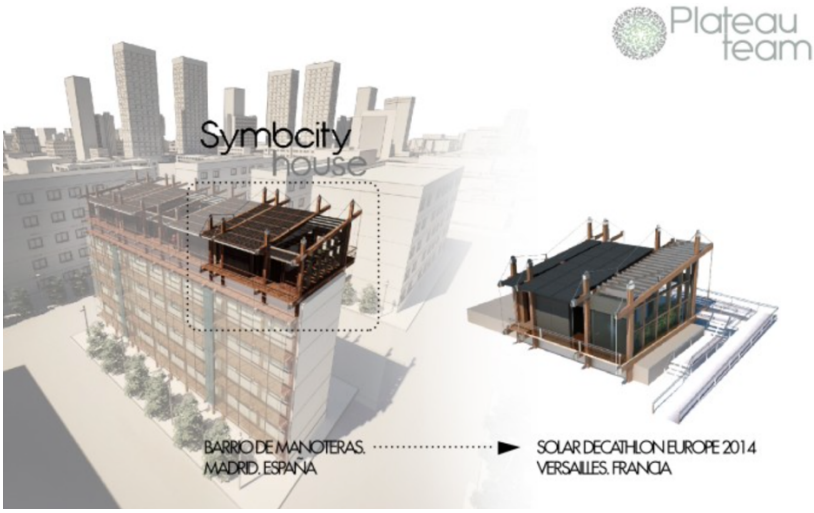

Figure 97 – Symbcity house. Source: Plateau Team. SDE 2014.

The house team "PHILEAS" (Figure 98), coming from the French universities École Nationale Supérieure D'architecture, École Centrale de Nantes and École Supérieure du Bois has created a proposal to rehabilitate a historical building by creating a flat and a greenhouse on its upper part.

Figure 98 – Phileas house. Source: SDE 2014.

Finally, another innovative concept that emerged from the SDE 2014 competition was the one proposed by the Delft University of Technology team through the "Home with a skin" house (Figure 99) where a solution was presented for Dutch semi-detached houses by inserting a "skin" in its surroundings, improving the spatial and climatic performance of the existing house without affecting its quality (Home With a Skin Architectural Brief Report).

Figure 99 – Home With a Skin house. Source: SDE 2014.

5.3.5. Discussions Category "Performance"

After presenting an analysis of four important points related to the performance of the Solar Decathlon, it can be concluded that the involvement of universities in the organization of the competition, as it was in the case of the SDE 2010, 2012, 2021 and SDA 2019 editions, can bring great long-term benefits to those involved.

There should be a plan for companies to have a deeper relationship with the competition, which makes it possible to generate mutual benefits. Finally, it was demonstrated that the alterations/adaptations undergone by the competition throughout the years with the purpose of improving its impact have brought successful results, as for instance, the promising ideas of some teams of the European competitions that brought commercial proposals with the purpose of attracting the market's attention.

5.4. Satisfaction

5.4.1. SD Participants Satisfaction

This topic will address the satisfaction, in several aspects, of the participants of the Solar Decathlon competitions. The analysis of this category is very important because according to KENETT & SALINI (2011), customer satisfaction is an important aspect that drives business results and process performance in organizations of services and products. Also according to KENETT & SALINI (2011), the measurement of a customer's satisfaction is usually based on questionnaires and interviews, where users or consumers are asked to express opinions on satisfaction statements or scales.

Several examples were read (CASTLE & ENGBERG, 2004; APPLEBAUM et al., 2000; COHEN-MANSFIELD et al., 2000) of methods and instruments to collect valid data, as well as advice on the use and analysis of satisfaction results. And from these bibliographies, the strategies of this thesis were adopted for the collection of information about the satisfaction of the participants of the competition.

The data collected and that will be analyzed in this chapter come from the worldwide survey conducted in 2020 along with the answers of the participants (students and teachers) of the SDE 2019 competition. According to the answers in Table 11 below, when asked if the SD was a positive experience, the answers were unanimous and positive.

Table 11 - Respondents' opinion regarding the SD being a globally positive experience. Source: Richard Amaral.

PUBLIC TYPE	YES	NO
Students	183	0
Professors and Institutions	66	0
Organizers	26	0
Professionals and Companies	20	0
Citizens	4	0

Considering that 100% of the respondents considered the SD a positive experience, it was already expected that the questions contained in Figure 100 below, the respondents would have an optimistic opinion about the competition since 97% of them would recommend it to other people to participate in the event and 88% of them would come back to compete again.

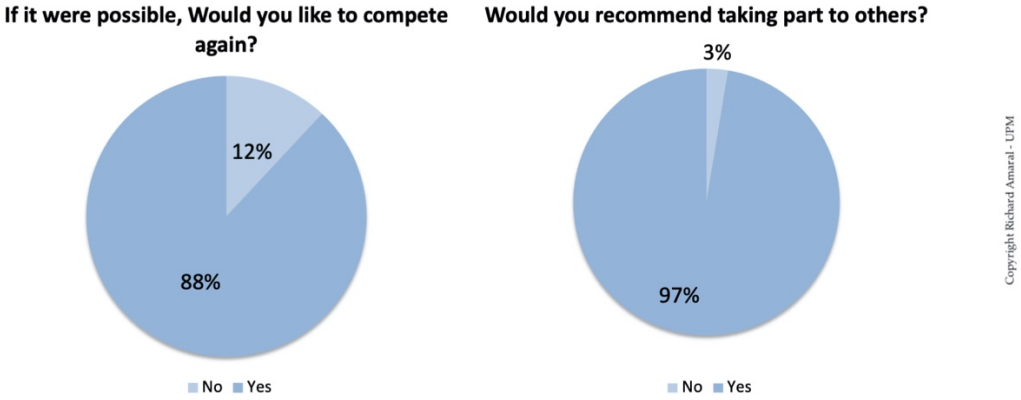

Figure 100 – a) Respondents' assessment of competing again at the Solar Decathlon; (b) Respondents' assessment of recommending the competition to others. Source: Richard Amaral.

Considering that most of the people who answered the 2020 worldwide survey were participants of more recent editions (Table 3), the results presented above are important because they show that even after more than twenty years of existence, the competition continues to impact the lives of participants, and the vast majority not only recommend it to others but also participate in future editions. This shows that there is great interest in the competition and demand to participate in future editions of the event.

After the analysis of the results presented above, what can be stated is that most participants, regardless of the manner in which they were involved in the event, are satisfied with the event. Emphasizing this statement, when interviewing the teachers and students at the SDE 2019 competition, all of them stated that they would try to visit the

next European editions of the competition and 70% of the respondents said that if they had not participated in that event, they would go as visitors, which confirms the satisfaction of its participants.

Another factor that should be considered when analysing the satisfaction of an event is to identify the reason (motive) (LEE et al., 2014) for satisfaction and the positive/negative points of the event under analysis. According to OLIVER (1980), a consumer's satisfaction or dissatisfaction is the balance between consumers' feelings about the perceived performance of a service provided versus their own expectations. Adapting this concept to the reality of Solar Decathlon, two questions were developed in the 2020 global survey for participants to answer about these aspects.

The next two questions below are of a selective evaluative nature (positive and negative points) about the satisfaction of attending the event and respondents had to select one of eight options provided, which were innovation and knowledge generation, environmental and sustainability awareness, promotion of education, professional awareness, employability of students, social awareness, media and social media impact and all of the above (the latter is only found in one of the questions). The reason for synthesising the responses into these eight categories and that the respondents had to choose only one of them was so that there would not be large discrepancies between the responses, and furthermore, to be able to analyse and compare them in a more orderly way.

The professionals and companies category and the citizens category were not included in the individual count of the following two charts because they provided few responses, and so, in order not to affect the comparison with the three categories, the were only counted together in the sum of all responses.

The objective of the question represented by Figure 101 was to identify the main objective fulfilled by the competition in the opinion of the interviewees. From analysis of the total result (the sum of the responses of the five groups), the category that stood out the most in this question was innovation and knowledge generation, chosen by 63.76% of the respondents. This same category was also considered the main reason for satisfaction with the SD in the individual opinion of each group, as shown in the graph. The results show that the event is indeed fulfilling its main objective, and that a non-formal education brings beneficial and complementary results to the academic journey of

the students. The category that had the worst evaluation both in the opinion of the three groups individually and in the overall total of responses was the media and social media impact option (34.90%).

From the analysis of the total result (the sum of responses from the five groups), the category that stood out the most in this question was innovation and knowledge generation, chosen by 63.76% of respondents. This same category was also considered the main reason for satisfaction with the SD in the individual opinion of each group, as shown in the graph. The results show that the event is indeed fulfilling its main objective and that non-formal education brings beneficial and complementary results to the students' academic journey. The category that had the worst evaluation, both in the opinion of the three groups individually and in the general total of responses, was the option of impact on the media and social networks (34.90%).

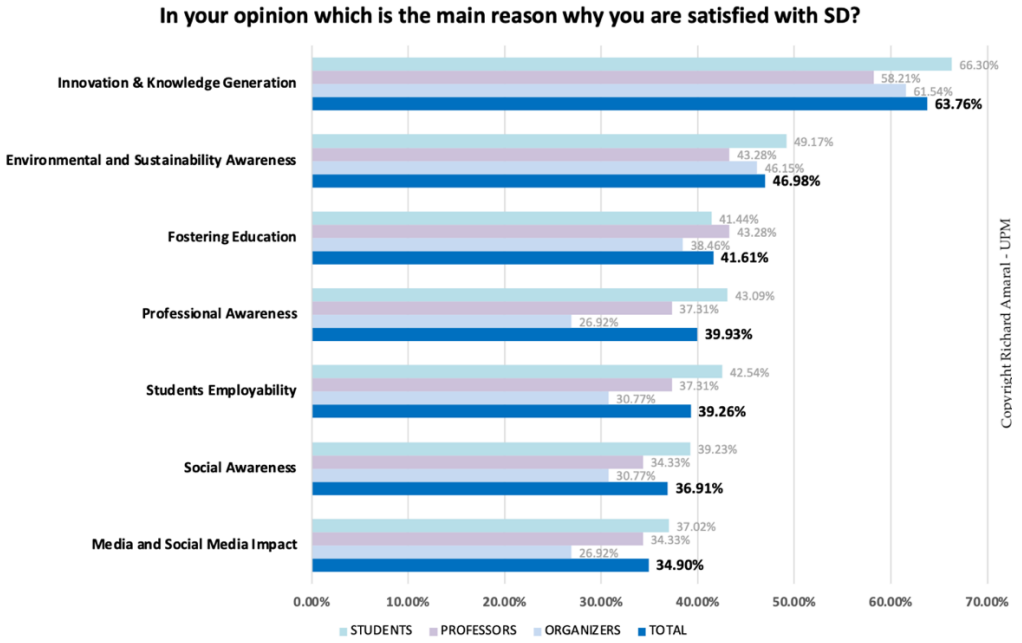

Figure 101 – Respondents' assessment of the main reason why they were satisfied with the SD. Source: Richard Amaral.

Still on Figure 101, respondents had the opportunity to mark the option "all of the above". This option is not reflected individually in the graph as we considered it better to add the percentage obtained in this option in each of the other seven categories. Therefore, when interpreting that 66.30% of students considered the Innovation and Knowledge Generation category to be the most important, it should be considered that this figure reflects the sum of those who voted for this category individually and those who voted for the "all of the above" category. In the case of the total values, which had a percentage of 63.76%, this value is the sum of the responses of the five categories of target audience

who voted both individually in this option and the voters of the option "all of the above". That is why the sum of the percentages of the other seven categories exceeds 100%.

In Figure 102, the question aimed to identify the main area of the SD in which it was necessary to work on improvement. Unlike the question presented previously, in this question there was not the option "all of the above" because we would like the respondent to be able to choose directly one of the seven options. Because of this, the sum of the percentages for each category has a total of 100%, reflecting the true value of the responses.

Analysing Figure 102, in the general opinion, the objective that was not reached by the SD was student employability (29.38%). According to the analysis of the answers of the individual groups, students and organizers shared the same opinion (student employability). Professors and institutions believed that the goal not achieved by the SD was social awareness. The option "media and social media impact" was among the three highest scoring answers. Perhaps the two most voted categories for this question were related to each other, because the less publicized the event is, the less impact it has on people and the market. Thus, companies' lack of knowledge about the event could be a factor that influences their decision not to hire a person who has taken part in this experience.

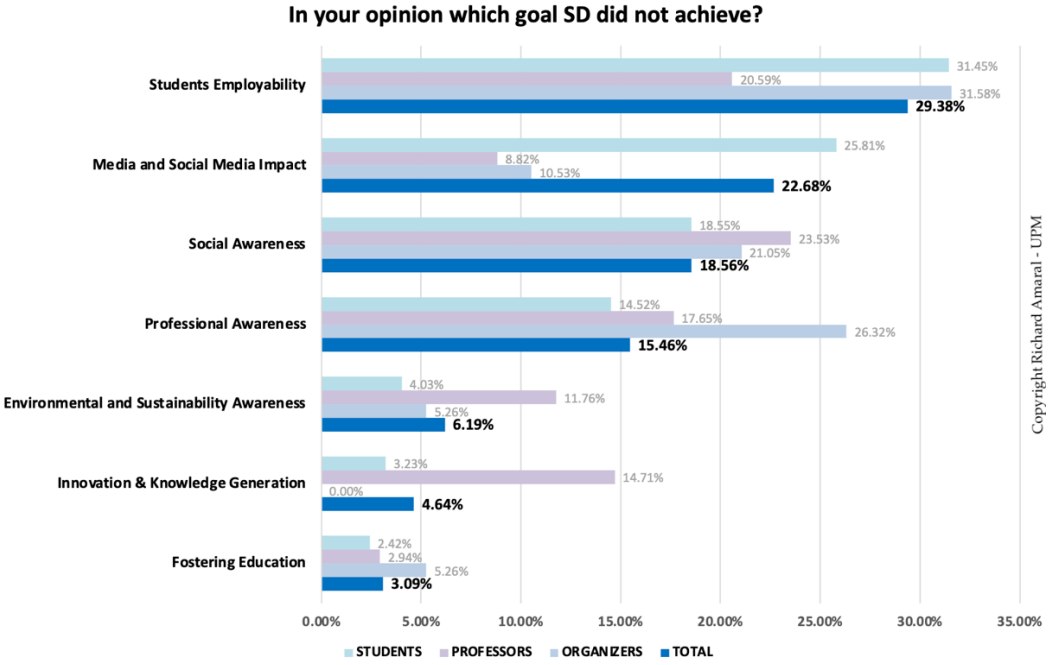

Figure 102 – Respondents' assessment of which objective the SD did not achieve. Source: Richard Amaral.

5.4.2. Discussions Category "Satisfaction"

After developing an analysis of the results related to the satisfaction of the Solar Decathlon participants, what can be concluded is almost unanimous the contentment of these people with the event, which demonstrates that the objectives are being achieved. Nevertheless, it is important to emphasize the negative aspects of the competition according to the participants, which in this case is the students' employability and the media impacts. This information serves as impetus to seek guidelines on how to improve these weak points.

5.5. Media and Social Media

Being aware that the visiting public is the best guarantee to arouse and maintain the interest of public institutions and private companies, the organizing teams have a specific media planning to be able to attract the visiting public. This topic will address and analyse the media organization strategies adopted by the competitions in addition to the parallel activities and events created with the purpose of attracting more people to visit the competition.

5.5.1. Media and Social Media Strategies

To better understand how the event communication strategies are executed, it is first important to understand how the competition organising skeleton works. To this end, in the Factsheets developed for the organisers of the SD competitions, it was requested to explain how the organisation of that event in question worked. According to Figure 103 below, where the SDE 2010 organisation scheme is shown, what can be observed is that there are four main groups, which are: Economic and Services; Communication; Infrastructure; Competition. Each of these four groups has a person in charge and in addition, there is an internal division in each of these groups of specific subareas. According to the interview conducted with the organizer of the SDE10, Sergio Vega, these subdivisions are important in order to categorize and prioritize the main needs of the event. Moreover, according to Figure 103 below, all these groups are controlled by a Project Manager and assisted by Competition and Event Managers.

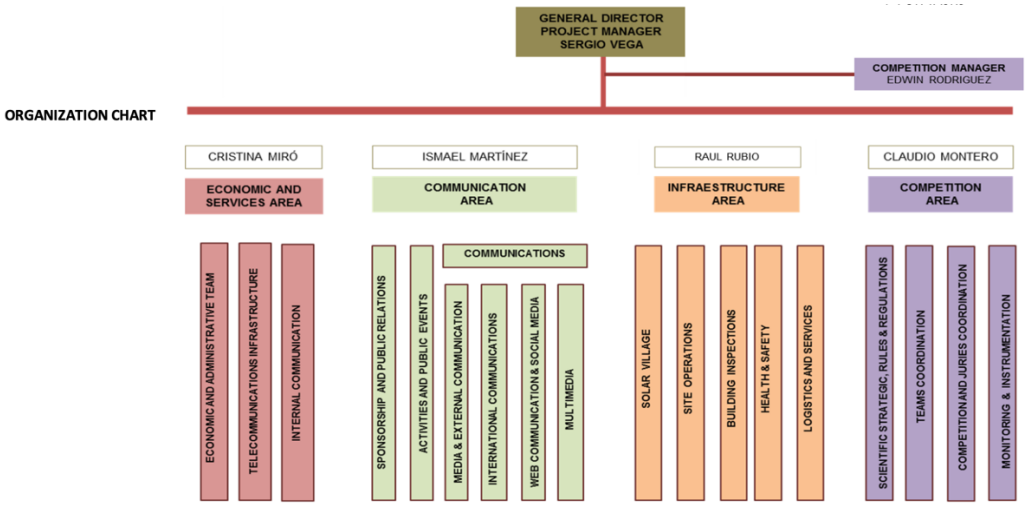

Figure 103 – SDE 2012 Organization Chart. Source: SDE 2012 Organization Team/Sergio Vega.

The organization of media strategies is situated within the "Communication" group and it is very important because it directly influences the relationship/impact of sponsors, the development of activities for participants, the relationship teams/universities with the organization, the promotion of the event, etc. According to the information given through the Factsheets and the interviews with the organisers, it is not possible to carry out a comparative analysis of each edition on the media strategies adopted because besides much of this information being unknown, many editions had to cut the funding allocated to this theme due to unforeseen events during the organisation. In the following paragraphs the strategies of some editions acquired through the methodology of this thesis will be exposed in order to have a basis to be able to suggest new premises for the conclusions of this work.

The US SD 2007 used as main base the TV, radio, newspapers and magazine as the main way to divulge the event and according to the organizers the following strategies were adopted:

- Media advisory for reporters, producers and PR;
- Newswire via e-mail to announce and promote the competition;
- Publicity in the home cities of the participating teams;
- Personalised emails to key editors in the genres: energy/solar, architecture/household, environmental/green, construction, business, science/technology;
- Telephone follow-up to press secretary recipients emailed during and after the event;
- Creation of national and local media interest;

- Management of the event's social media;
- Coordination of interviews.

As for the first two European editions, the media strategies adopted were based on two main tools: the website and the workplace area for teams (SD WAT). This second tool was a collaborative work space for the organisation of the event that served as a mean of communicating with the teams and companies involved. The web page, on the other hand, served as a showcase for consulting the scores of each team, the competition scoreboard, technical information for each house, activities planned for the children, professionals, the public, photos, publications, etc., which were updated daily. In addition to these two tools, the organisation of the competitions followed the following strategic premises:

- Closeness between the main media through calls for activities, presentations, press conferences, etc;
- Providing material produced for the press under the guise of organising conferences, trade fairs, summer schools, etc;
- Inviting influential people such as the King of Spain, ministers, presidents of autonomous communities in order to intensify media coverage through these entities;
- Invite ambassadors, mayors and regional councillors from the participating countries;
- Planning and developing the competition's social networks in order to disseminate information, photos, videos and news in real time.

According to the organisers, the number of media appearances at the SDE 2010 exceeded 2,000, with an audience of more than 172 million citizens and an economic value of more than 4,350,000 Euros. In addition, according to the organisers, the competition also moved the social networks where:

- 124,000 consults of the Competition on Facebook
- 120,000 mentions of the Competition on Twitter
- 148,213 visits to the website during the Competition
- 7,810 videos on the web
- 156,000 EDS images available on Google
- 59,700 results in blogs

- 2,810 results in debate forums
- 200 videos on Vimeo
- 291 videos in Youtube

The media impact of the 2013 and 2018 Chinese competitions was very important as both competitions had a high number of total visitors. According to the organisation, the 2013 SDC competition was widely covered by the media through reports and advertisements. According to them, there were more than 1200 reports on the Internet, more than 600 reports in newspapers, almost 100 reports on TV and radio, and the official website of the competition had a total number of 148,799 visits. For SDC 2018, the most visited competition to date, the competition's official website had a total of 3,300,000 visits. Also according to the organisation, the impact on the national media was estimated at 60 million people reached.

With regard to the African competition, media strategies have been created and as a result, more than 600 impacts on the national media and around 150 international media have been measured, with more than 100,000 visits to the competition website. More than 500 written media were impacted, more than 100 of them in the international press. In addition, according to the organisers, more than 250,000 photos and 50,000 videos were produced.

5.5.2. Activities and linked events

Attracting the public to Solar Decathlon events is not only about a good location, communication strategies and sponsoring companies. Getting a high number of visitors does not mean the success of the event. The main objectives of the event is to educate and raise awareness about energy efficiency and sustainable living, and finding ways for this to be executed is a complex task that requires a smart and effective strategy from the organizers. Creating activities and tasks for the visiting public (students, young people, children, families, companies, industries) in a way that is attractive and educational to convey the main message that the event stands for is essential. The strategies adopted by some competitions with regard to these activities will be discussed below.

North American competitions had the main focus on attracting and taking as much audience as possible to visit the event and the houses, without developing any specific or educational activity for these people. Among the few activities carried out, some were

aimed at children but were not of an educational nature. For students and professionals, activities were developed that were limited to guided and informative tours.

In a scenario completely opposite to the North American competitions, in the European events several strategies and possibilities were thought out in order to attract and educate as many visitors as possible, thus broadening the scope of the competition. As previously mentioned, the creation of the 10Action project that had as its main objective to create activities for children, teenagers, university students, professionals and the general public in order to promote education and social and professional awareness about the need for more efficient and sustainable buildings and cities. Moreover, many of these activities were adopted by several teams making possible the dissemination to other countries (12 in total) having a reach not only "inside" the event but also internationally. Figure 104 below shows the schedule of activities carried out along with some photos of its realization in the 2012 competition.

Figure 104 – SDE 2012 Activities Program. Source: EBC Annex 74, Subtask B (Sergio Vega, Beatriz Arranz and Richard Amaral).

According to the organisation of the first two European editions, the result of the impact of this project (Figure 105) was very positive and in total 180,514 European citizens from 12 countries of all ages actively participated in the 10ACTION activities, and had the opportunity to reflect and learn about the responsible use of energy and how

to contribute to making cities and buildings more sustainable. As proof of this success the project released the following figures:

- 9,350 children actively participated in the activities planned by 10Action;
- 6,967 adolescents took part in debates and competitions organised in various countries;
- 2,086 university students from 12 European countries participated in workshops, conferences and debates organised by 10Action;
- 43,854 construction industry professionals participated in exhibitions and conferences organised across Europe;
- 142,803 citizens participated in the model exhibitions, visits and demonstrations held in the various European countries involved in the competition.

Figure 105 – 10Action Impacts. Source: EBC Annex 74, Subtask B (Sergio Vega, Beatriz Arranz and Richard Amaral).

Subsequently, reaping the fruits of this project, several books, scientific articles, doctoral theses have been published in addition to an award from the European Union in the Sustainable Energy Week in 2011. There is no information available regarding these activities in the 2014, 2019 and 2022 European editions but what can be stated is that the

numbers speak for themselves. It is notable that the 10Action project was a major driver in the number of visitors to the 2010 and 2012 European competitions and by comparing the final numbers with those of other editions, what can be concluded is that this project directly (positively) impacted on the final performance of the events.

The Chinese and African competitions were also concerned with developing activities with the aim of promoting education and awareness. According to the Chinese organisation, there were a total of 27 activities organised in the host city, and some 42 other activities were organised in other cities in China. In addition there were 27 activities aimed at university students and professionals and 12 for the general public. Reaping the fruits of this, according to the organisation, there were more than 50 publications on SDC, of which 35 were scientific articles in journals with scientific impact. According to the African organisation, about 10 activities were organised for university students, generating the visit of about 10,000 students. In addition 5 activities were organised for professionals resulting in the visit of about 6,000 professionals in total. Another 3 activities were aimed at children and teenagers impacting 5,000 people in total. Another 14 activities were developed for the general public and 10 activities were developed in other Moroccan cities.

Clearly the creation of activities to foster education and sustainable awareness during Solar Decathlon events is a success and the numbers don't lie. The fact that the North American competitions have not developed these activities does not mean that the competition has not been successful, as several of them have had high numbers of visitors, but definitely the lack of these activities have made the events less attractive and successively the fruits harvested have been reduced and above all the objectives are incompletely achieved.

5.5.3. Discussions Category “Media and Social Media”

Concluding this fourth category, it was possible to see the importance of communication to develop an SD competition. With an adequate media strategy it is possible to attract a large number of people. However, communication is an area that has little impact on information about it and furthermore, according to the participants and the organisers, when there is cost containment, it is the first area to be affected. It was also found that the strategies are very similar between the competitions, with standardized and outdated characteristics, without any innovation over these years.

However, there were not only negative points observed in this topic. The activities and events created with the intention to promote the principles of SD and to attract visitors to the competition are successful strategies. The 10Action project that was created for the 2010 and 2012 SDE competitions proved to be a great example of a successful strategy that can serve as a basis for new ideas and strategies for future competitions.

5.6. Outreach

In relation to what has been analyzed so far about the results obtained by this thesis, it was already possible to see some improvements and impacts caused by Solar Decathlon, such as

- -The longevity of the event and its expansion to several continents reaching new people and cultures;
- Data about the publication of articles, books, researches, etc, about the competitions;
- The satisfaction of the participants;
- The impact of the prototypes on the market and their viability for commercialization;
- The insertion of SD into the daily life of citizens, companies and industries affected;
- The employability and leverage in the professional career of its participants.

However, there are other possible improvements caused by the competition and that will be studied in the following topic, which are: The improvements and impact on the knowledge and experience of the students involved and examples of appropriate and successful uses of post competition prototypes.

5.6.1. Students Improvements

In order to assess the impact of the competition on the "decathletes", according to the opinion of the participants, in the 2020 worldwide survey questions were asked (for all respondents) to find out specific data on this topic. For this purpose, four questions were produced related to the awareness, experience, knowledge and skills that the SD developed in the participating students. The answers to these questions will be analysed below and have the intention of knowing which areas were more and less impacted by the students and seek strategies and solutions for improvements in future editions.

The next question concerns about the areas of awareness that the SD improved in the students' lives. In this question, there were a total of 14 categories and each respondent had to choose 4. The option of "all of the above" was intentionally withheld, so that the respondents had to choose the four best proposed categories.

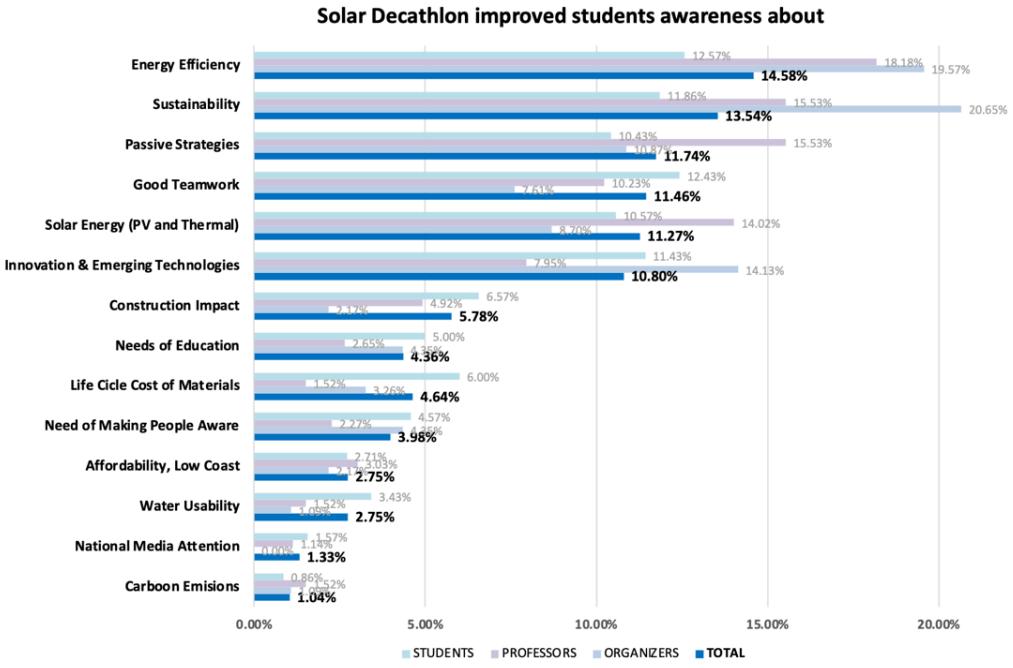

Figure 106 – Respondents' assessment of areas of awareness that the SD improved in students. Source: Richard Amaral.

According to the overall average represented in Figure 106, the four categories with the most votes were: energy efficiency, sustainability, passive strategies, and good teamwork. However, analysis of the responses by participant typology showed that opinions differed between some categories. For example, from the students' responses, the four areas with the most votes were energy efficiency, good teamwork, sustainability, and innovation and emerging technologies, respectively.

Still on Figure 106, according to the professors' responses, the four options with the most votes were energy efficiency, passive strategies and sustainability (tied), and solar energy (PV and thermal), respectively. In the organizers' opinion, the four most improved areas of awareness were sustainability, energy efficiency, innovation and emerging technologies, and passive strategies, respectively.

The topics of sustainability and energy efficiency appeared in the top four of all three categories, so they were the most relevant in the opinion of the interviewees, as illustrated in Figure 106, which shows the consistency of the responses.

Overall, the category with the worst rating was carbon emissions (1.04%), even though the rating was not unanimous among the three voting typologies. Another category presenting a negative highlight was national media attention, with a vote percentage of 1.33%. As was seen in the analysis of the responses to previous questions, this is a topic that is always negatively highlighted by respondents.

For the next question the respondents had to choose four of the ten categories related to the areas of experience developed by students participating in the SD.

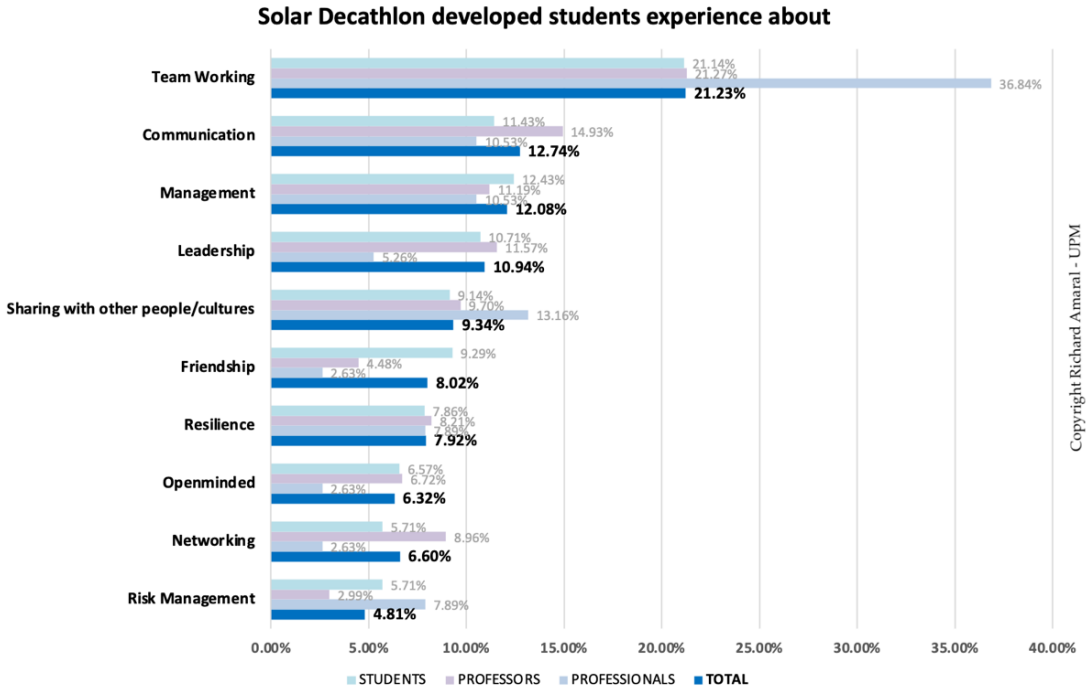

Figure 107 – Respondents' assessment of the areas in which students' experience was most improved by the SD. Source: Richard Amaral.

Analyzing the general average of responses presented in Figure 107, the four highlights were team working, communication, management, and leadership (21.23%, 12.74%, 12.08%, and 10.94%, respectively). Team working scored considerably higher than the category in second-best position, so it is the area in which students developed the most experience in the opinion of the respondents. The answer that had the lowest average rating was risk management, with 4.81%.

The results of this question (Figure 107) confirm the importance of an event with a non-formal education approach. Team working, communication, management, and leadership are skills that are not learned in the classroom. Participation in an event that lasts two years can provide all the participants with these valuable skills that they can apply in their future jobs, benefitting their professional lives.

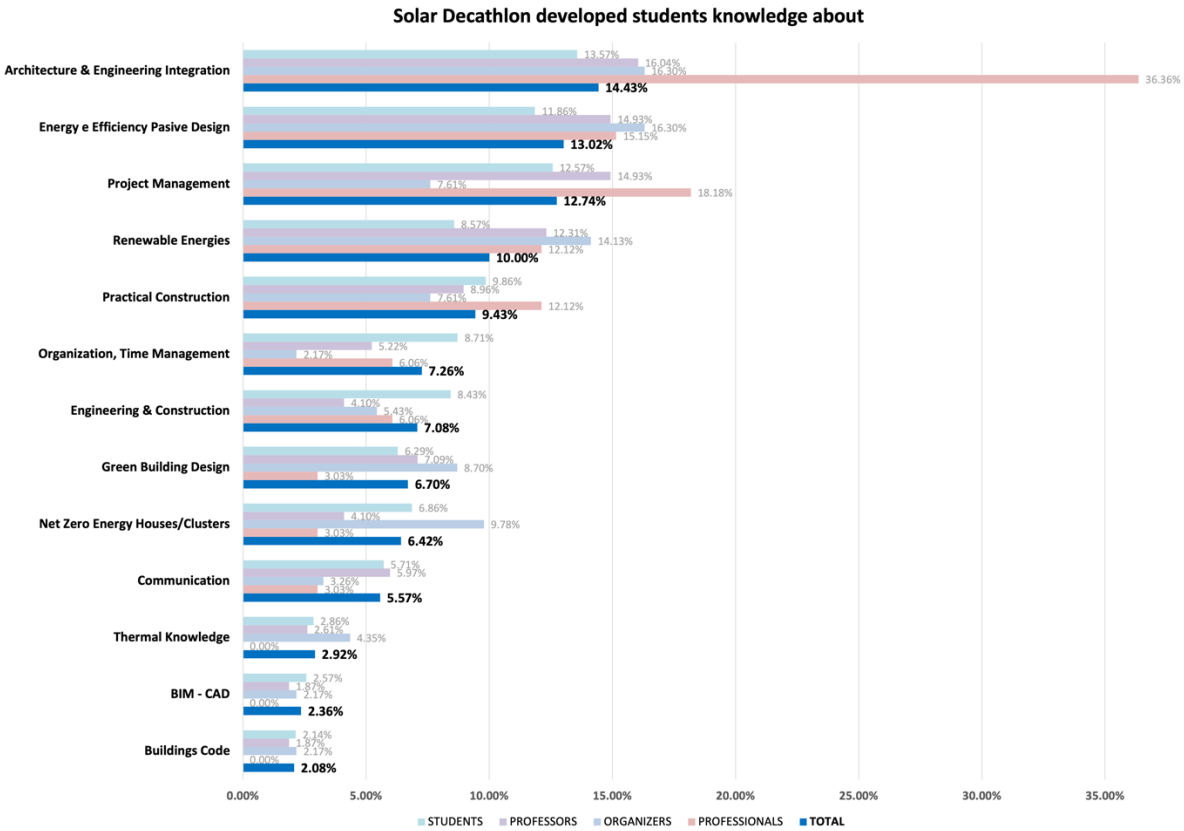

Figure 108 – Respondents' assessment of areas of knowledge that the SD improved in students. Source: Richard Amaral.

The purpose of the question presented in Figure 108 was to know the opinion of the respondents on the development of knowledge that the SD has developed in students. Of the 13 options given, the four most relevant were: “Architecture & Engineering Integration”, “Energy and Efficiency Passive Design”, “Project Management” and “Renewable Energies” with 14.43%, 13.02%, 12.74% and 10.00% respectively.

The three categories that received the least response (Figure 108) were “Thermal Knowledge”, “BIM – CAD” and “Buildings Code”. The three had a close result so they are the ones that students developed the least knowledge.

As regards the skills developed by the students (Figure 109), nine categories were presented to be evaluated on a scale from 1 to 6. All nine categories were well evaluated and had a high average. The one that stood out the least was modelling and simulations, with a score of 4.55 out of 6. In the opinion of the respondents, the skill that was most developed in students was team working, with an average score of 5.43. This category was also a highlight of the responses to other questions, which shows that it is a positive aspect of the SD environment.

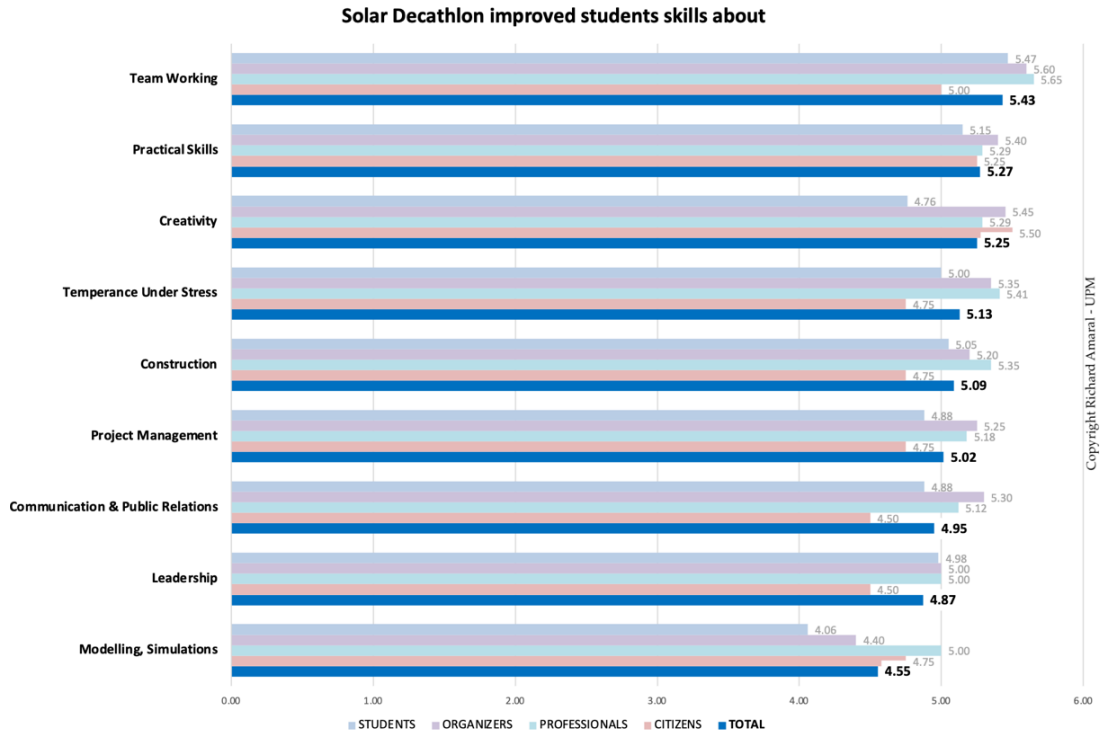

Figure 109 – Assessment of the skills that the SD improved in students. Source: Richard Amaral.

The last four graphs presented showed the areas more and less affected by SD in the participating students. This information is very important because from them, modifications can be made in the rules/contests of future competitions in order to polish the strategies and objectives of the same.

5.6.2. SD Contests Impact

Besides the knowledge generated to the students through the event, there are other aspects that should be considered, such as the knowledge generated by the competition itself through the ten contests. For that, questions were asked in the 2020 worldwide survey with the purpose of obtaining information regarding this theme. The next four figures are related to the impact of the SD contests not only in the students' lives but also in the market, sustainability and media.

These were multiple choice questions, and the interviewee had to choose two contests as the answer to each question. The 10 contests evaluated were: architecture; engineering and construction; energy efficiency; electrical energy balance; comfort conditions; house functioning; communication and social awareness; urban design, transportation and affordability; innovation; and sustainability and circular economy. The evaluation of the contests was very important because, from the results we obtained, it was possible to consider each one individually and create solutions to improve the next

editions of the competition. In addition, it was important to know the opinion of the students, professors, and organizers individually, because the contests impacted each category in a different way.

In Figure 110, the two most frequently selected contests with respect to their educational contribution were the engineering and construction contest and the architecture contest, with voting percentages of 26.19% and 20.51%, respectively. There was a considerable gap between the first two contests, with the engineering and construction contest having a greater perceived contribution to education, although it was not chosen by the professors and organizers as the first option. It is worth mentioning that the energy efficiency contest also obtained a high number of votes and should be emphasized as well.

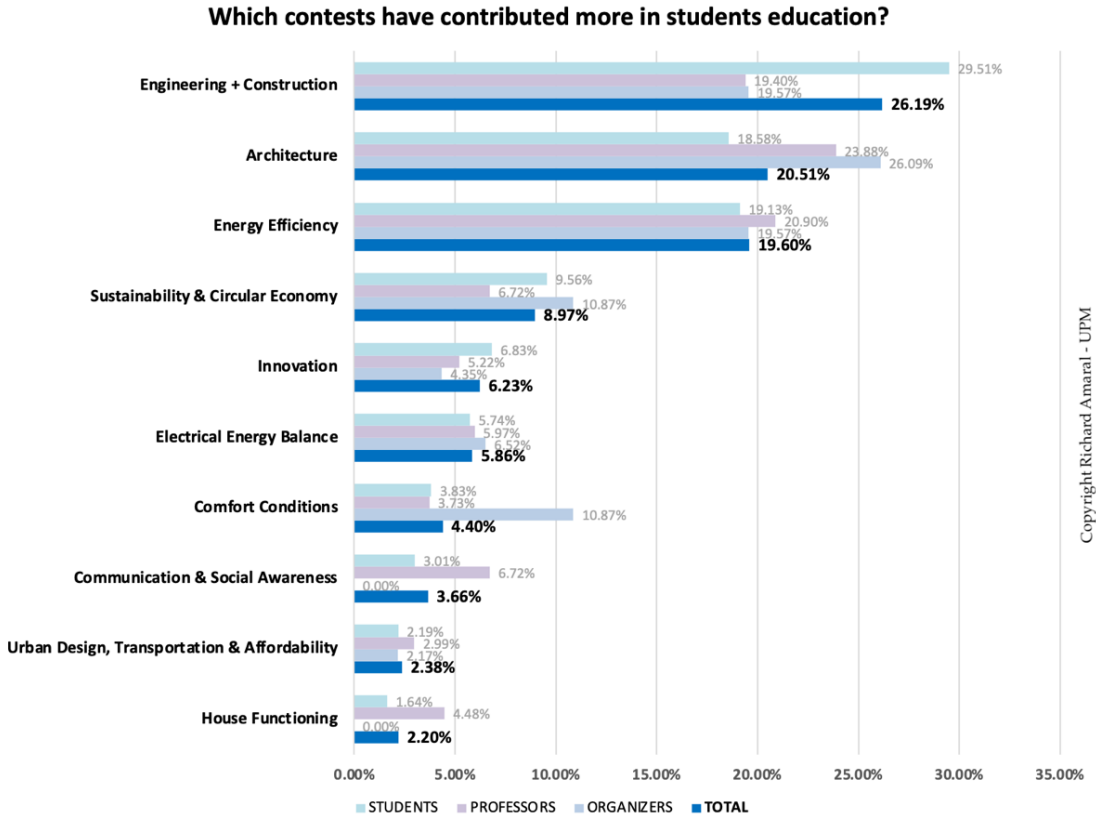

Figure 110 – Assessment of which contests contributed most to the students' education. Source: Richard Amaral.

Event participants usually come from the fields of architecture, engineering, and construction. The results presented in Figure 110 show that although the SD is a parallel event to university life, the content learned/experienced is always related to the scope of architecture/construction.

The two contests that had the worst performance in this question were the urban design, transportation, and affordability contest and the house functioning contest. Both had a very similar percentage of votes, 2.38% and 2.20%, respectively.

As regards the question about the contests that contributed the most in relation to the market and professional technical innovation (Figure 111), the answers came only from two types of audiences (professors and organizers), as shown in the graph below. It is possible to see that the opinion varied between each audience. According to the average of the responses, the innovation contest and the engineering and construction contest were those with the highest number of votes (22.73% and 20.45%, respectively). According to the responses of the organizers, the energy efficiency and electrical energy balance contests were tied for second place, which shows that they are also significant in the scope of the market and professional technical innovation.

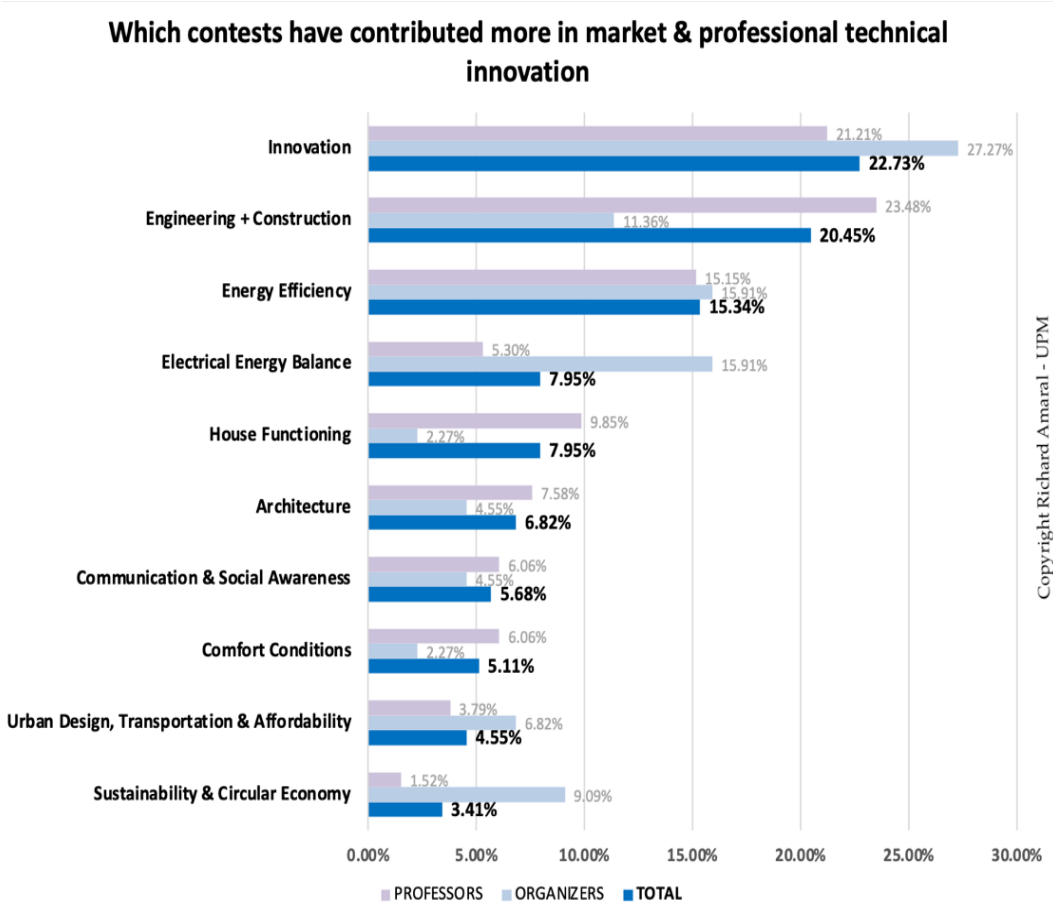

Figure 111 – Assessment of which contests contributed most to the market and professional technical innovation. Source: Richard Amaral.

The contest that had the worst percentage of votes in the overall average was the sustainability and circular economy contest. Although this contest was the fifth-best-placed in the opinion of the organizers, it still had the lowest number of votes in the

overall results, as the majority of the responses to this question were from professors (75% versus 25%).

According to the Figure 111, the contests that had the greatest contribution in the scope of sustainability and energy awareness were “Energy Efficiency” (28.86%) and “Electrical Energy Balance” (21.14%). The difference in percentages is also notable, and it can be concluded that “Energy Efficiency” is the contest that had the most prominence in this regard. The contest that had the lowest performance was “House Functioning” again with 2.57%.

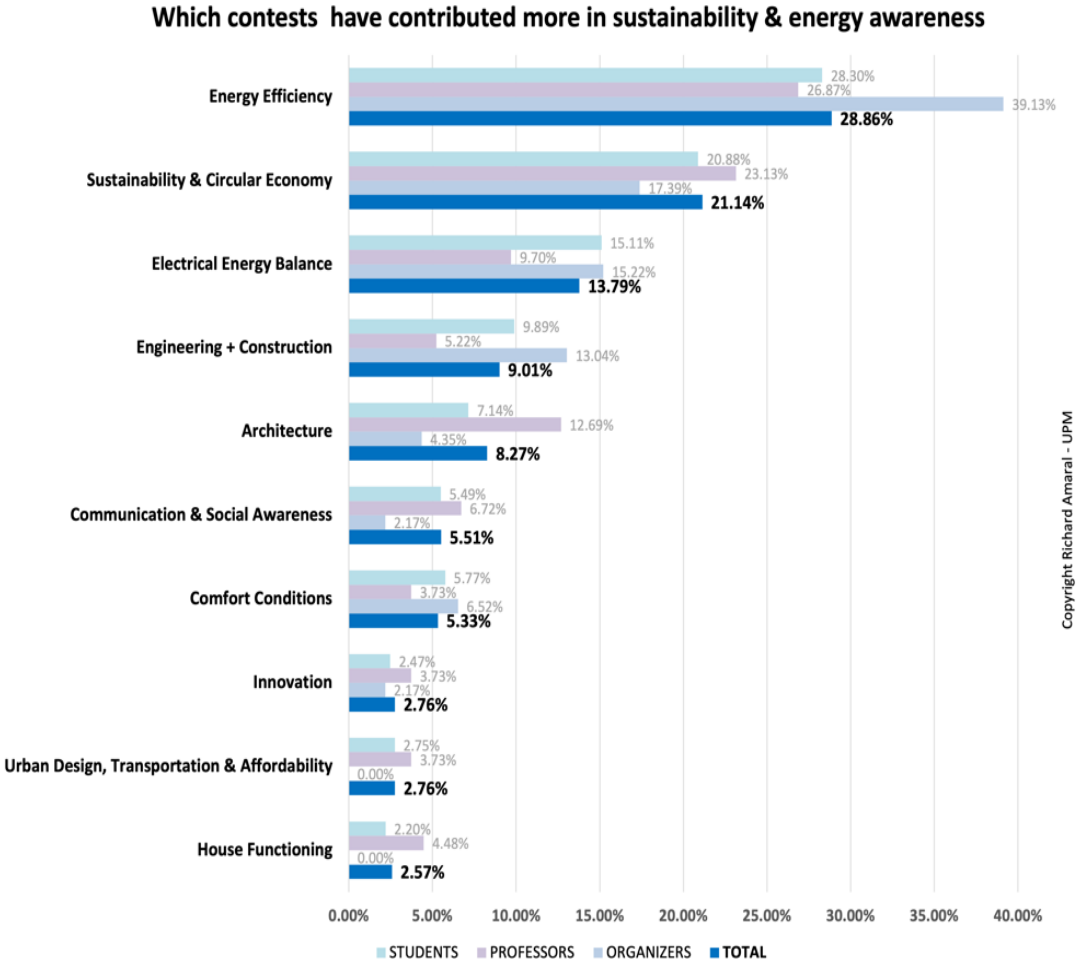

Figure 112 – Assessment of which contests contributed most to sustainability and energy awareness. Source: Richard Amaral.

According to the opinion of the interviewees about the media impact and social awareness presented in Figure 113, the “Communication & Social Awareness” contest had the best percentage (34.74%). The least significant contest on this point was “Electrical Energy Balance” (1.47%).

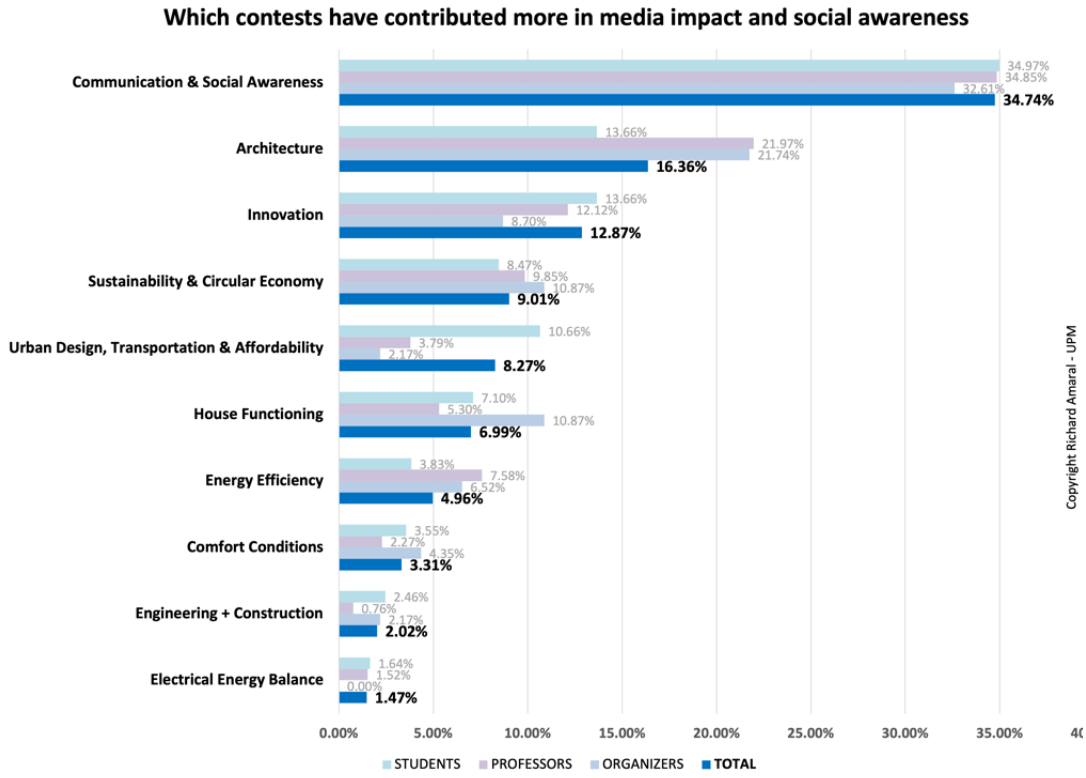

Figure 113 – Assessment of which contests contributed most to the media impact and social awareness. Source: Richard Amaral.

5.6.3. Impact on Educational Innovation

Through the results that are being presented throughout this chapter, it was possible to have evident proof about the greatness of the event and its countless benefits, mainly for the students. As mentioned previously in Chapter 2 (2.3.1), when references to motivational strategies in the education of university students were addressed, it was possible to get an idea of the importance of this theme within the institutions and how positive it can be for the students. Despite having already been reported in the final report of the project Annex 74 on educational innovation provided through the SD competitions, it was considered important to bring this theme to the thesis since this is one of the main benefits acquired (along with the impact of the contests and the knowledge generated in the area) as by the participating students.

As this is a very important theme, during the application of the methodology of this thesis, the participants were asked, both during the two interviews carried out, and through the questions of the 2020 worldwide survey, to cite words that potentiate opportunities and synergies that arise from the educational potential. Figure 114 shows all the words cited through a word cloud where the ones with greater prominence are the ones that were repeated most often.

Figure 114 – Respondents answers when they asked to name words that leverage opportunities and synergies which arise from educational potential. Source: Richard Amaral.

According to Figure 114 above, the most echoed words were: experience, teamwork, learn-by-doing, design thinking, service learning and hands-on. Based on the words mentioned above, the main trends in educational innovation will be identified, based on bibliographies, linking them to the Solar Decathlon competition. Making a comparison with the graph in Figure 115 below, which shows the responses from the survey conducted for the 2012 European competition, when asking respondents to name words that exemplify students' personal gains from participating in an SD competition, many of them are repeated in both surveys, such as teamwork, leadership, opportunities, etc.

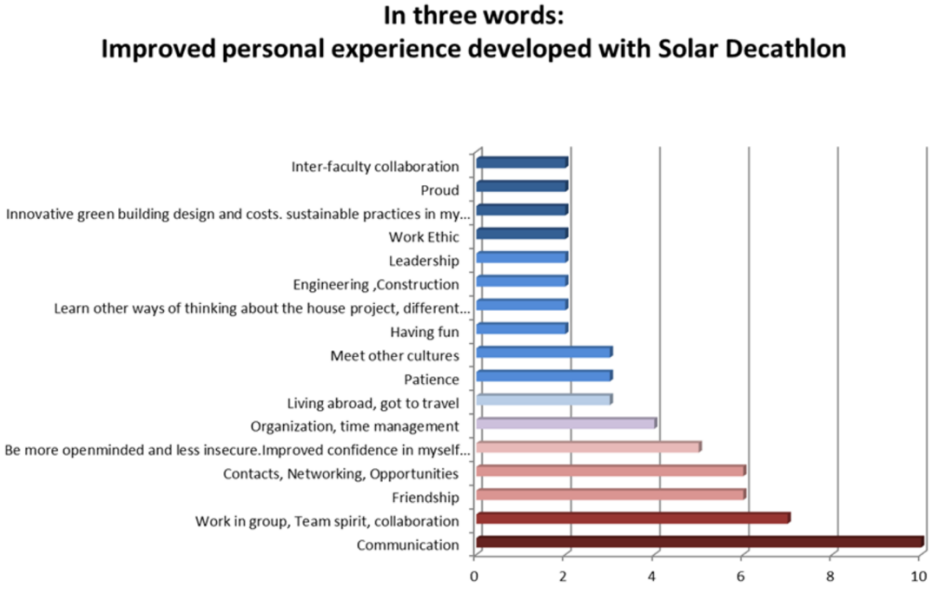

Figure 115 – The responses from the 2014 survey when asked to name words that describe their personal experience with SD. Source: Annex 74.

In addition, it can be observed in the 2020 survey (Figure 114) the use of more modern words. To better understand their meaning, their definitions are explained below. According to ALVES (2014) and CAMPONETTO et al., (2014), gamification can be adopted in different contexts and for a variety of purposes, including learning. According to BUSARELLO (2016), gamification uses game mechanisms for motivation, engagement and problem solving. Also according to BUSARELLO (2016), the mechanisms found in games and contests serve as a motivational engine for their participants, contributing to engagement at various points. In the case of SD, through the competition itself (playing), students learn the practical application of the knowledge acquired in addition to improving other aspects such as reasoning, creativity, problem solving, critical analysis, etc.

Challenge-based learning and design thinking is also another innovative educational method that, according to LEIJON et al. (2022), is an approach that encourages students to harness the technology they use in their daily lives to solve real-world problems. Also according to LEIJON et al. (2022), this method is collaborative and practical, fostering group work in order to develop a deeper knowledge of the area, accept and solve challenges, act and share their experiences. In the case of SD, this method focuses the student's interest in solving a specific purpose (in this case, the prototype) favouring interdisciplinary collaboration, knowledge integration and knowledge of techniques such as: marketing, communication, creativity, etc.

As seen in topic 2.3.1, learning by doing is an action-oriented methodology of educational innovation where it is emerged through the action of putting into practice the ideas designed by a team of people. According to the final report of Annex 74, in the case of Solar Decathlon, learning is done by applying the knowledge studied and putting it into practice in a tangible and authentic context, facilitating the resolution of the problems of each team in the ordering of ideas to achieve the proposed objectives. Hits and misses are the basis of this methodology, which finds in experimentation a way to discover which elements work and which do not in each case.

ERICKSON & ANDERSON (2005) introduce service learning as a form of experiential education, but it does not necessarily involve students reflecting on their product, but on their acquired experience. According to PRENTICE & ROBINSON (2010), this methodology is collaborative where the student performs a service to the community, promoting critical analysis, understanding of social problems and stimulating

the proposition of solutions. In the case of Solar Decathlon, students learn a lot by observing the real performance of the house through the challenges exercised by the event contests.

OLIVEIRA (1999) demonstrates that Learning in collaborative can be an innovative education method since it promotes collective intelligence. Solar Decathlon and teamwork are words that go together since the competition fosters collaborative dynamics among its participants.

In order to find out if any particular competition had a below average educational impact, the graph in Figure 116 below shows the indicator of improvement in teamwork skills in students by competition. In blue is shown the average rating among respondents. The standard deviation between scores is shown in orange. Competitions that have a lighter colour in the graph mean that they had less than five responses, so they can be considered unrepresentative. What can be observed in this figure is that competitions, regardless of their continent, had good ratings on team working (skill cited in both graphs of Figure 114 and Figure 115).

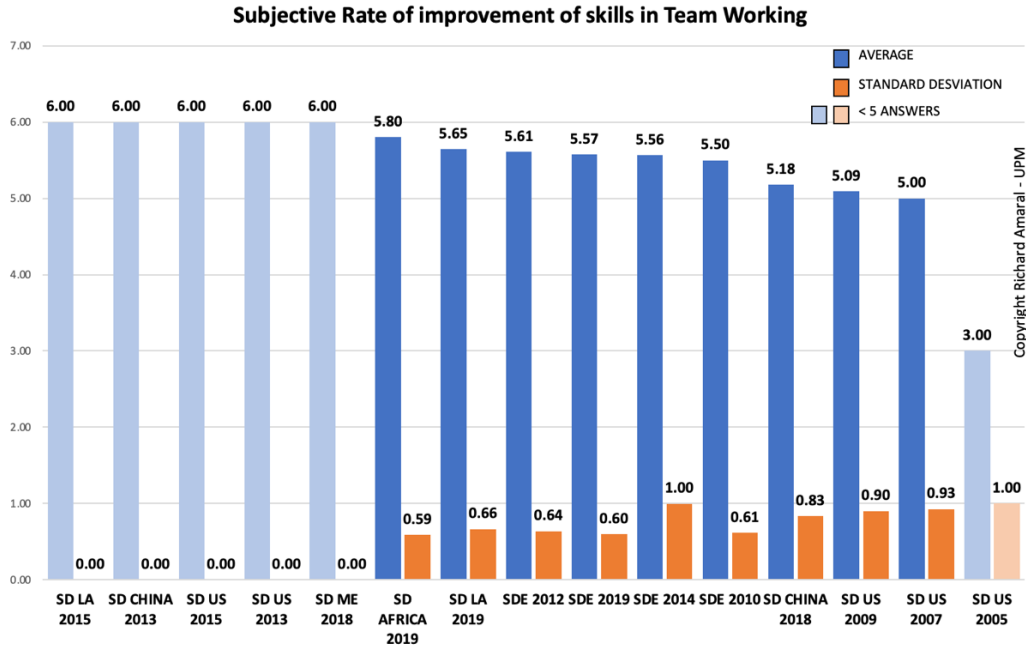

Figure 116 – Average assessment of the improvement of teamwork skills. Source: Richard Amaral.

This topic described with examples, through the participants' opinion along with the application of the concept, the power of Solar Decathlon by its dynamic process, assisting students in experiential and collaborative learning, proving to be more effective than traditional teaching methods (where a lot of knowledge is transmitted but no soft skills are developed), and complementing the constantly needed theoretical knowledge.

5.6.4. Outreach of the Post Competitions

In the topic 2.6 of this thesis, was explained that the teams are instructed and motivated so that the prototypes after the competition participation have a use. According to the interviews with the organisers and to the final report of the EU international project, there are cases where teams choose to dismantle the prototypes (when the material provided is borrowed) but normally the use given by them to the prototypes is intended to:

- To be used as Living Lab for awareness, student, research and educational purposes.
- To be sold to a company or somebody;
- To be used as an office or for special events;
- For dissemination and awareness purposes.
- As a demo for new technologies, systems, site and devices.

It was asked to the participants through the worldwide survey of 2020 about the use given to the prototypes after the competition and according to the graph of Figure Figure 117 below, what can be observed is that the vast majority of prototypes were intended for Living Labs (56.50%), with different purposes (for students, for visitors awareness, for education and for research).

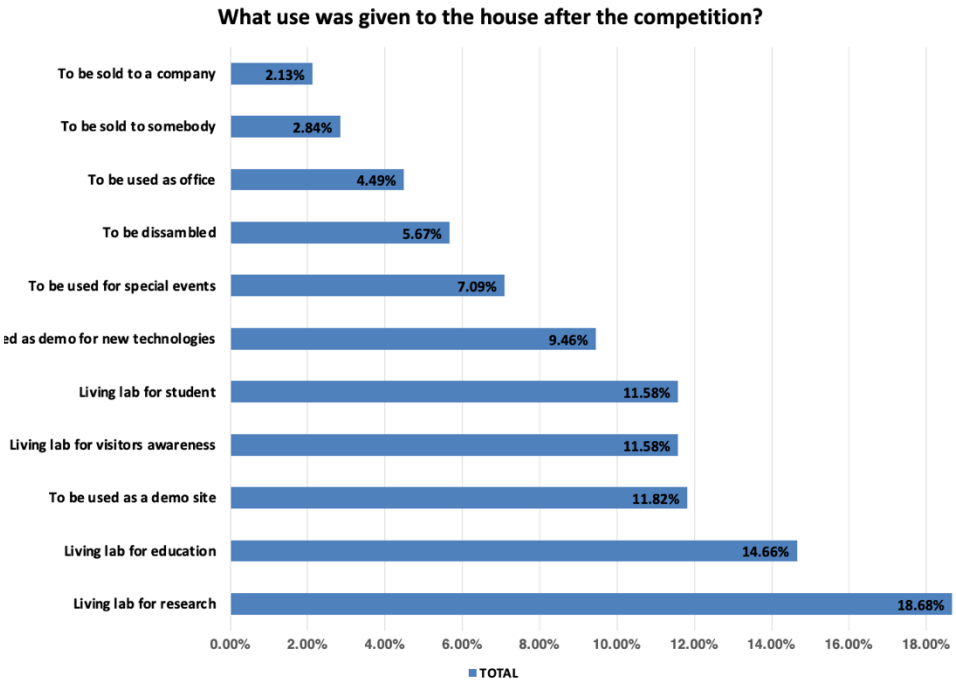

Figure 117 – Assessment of what was the given use to the house after the competition. Source: Richard Amaral.

According to STEEN & VAN BUEREN (2017), the term 'Living Labs' refers to a variety of experimental projects that have a participatory nature. According to FEURSTEIN et al. (2008), Living Labs can be considered a research and development methodology where innovations are created and validated collaboratively in real world environments. The uses presented previously by Figure 117 demonstrate how SD can impact several generations of students and people besides affirming that its legacy is not only in the 15 days that a competition lasts. Next it will be exemplified some existing prototypes in European countries that are still active and successively impacting other people (Figure 118).

Figure 118 – Examples of European houses used as Living Labs post competition. Source: SDE Teams.

After viewing examples of prototypes that have a successful utility even after many years since their assembly, what can be emphasised is the size of the impact of the competition as a function of:

- The longevity and continuity of the impact of the competition through the optimal use of the participating prototypes
- The extent to which this impact is achieved as there are prototypes being used in various parts of the world.

However, the author of this thesis considered it necessary to know the participants' opinion on what is the best use of the prototypes post competitions as there may be cases

where the final destination is not ideal. According to the graph of Figure 119 below where it brings answers about the participants' opinion, what can be observed is that the vast majority considers ideal the use of Living Labs (66.87%).

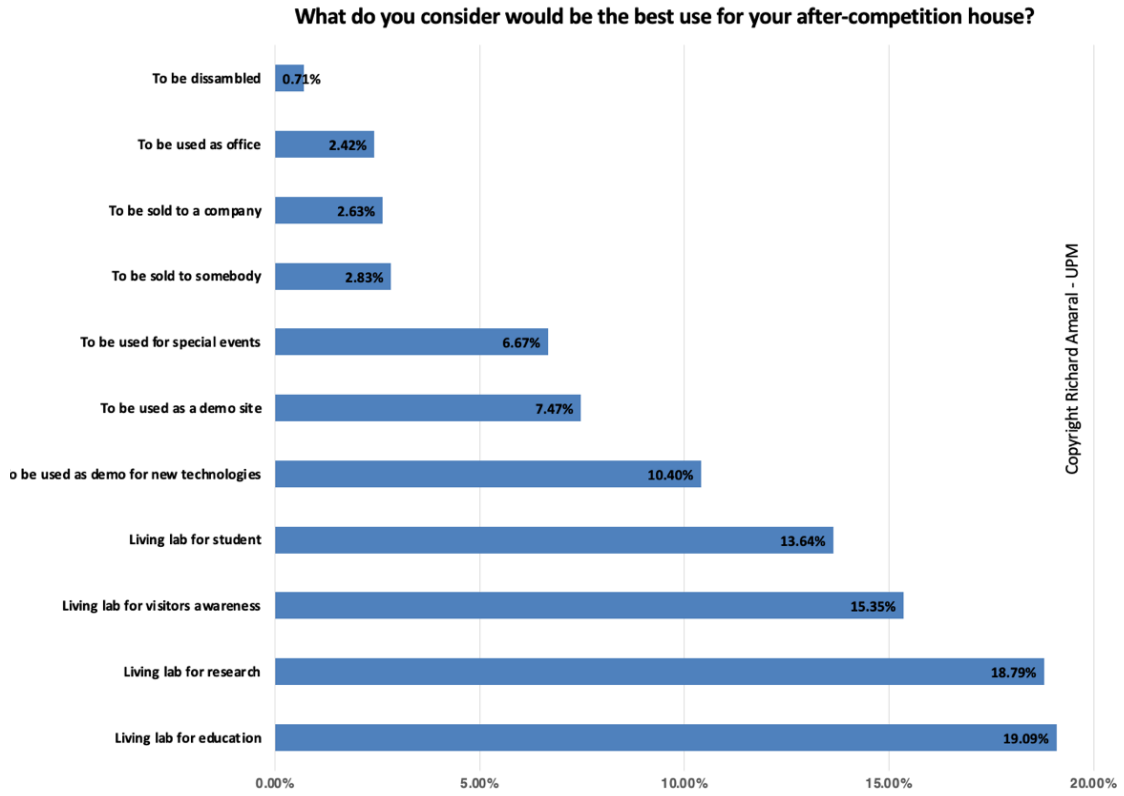

Figure 119 – Assessment of the opinion of what is the best use to the house after the competition. Source: Richard Amaral.

Finally, it was shown that the use of prototypes as Living Labs after the end of the competition is an effective example that can be applied and encouraged in future events. The creation of new strategies to perpetuate this use is a point that can possibly increase the impact of the competition.

5.6.5. Discussions Category "Outreach"

The results analysed in this category brought important information and that its use can bring improvements for future events. The positive and negative points in several areas of knowledge that SD affects students were presented. It was also understood that the educational potential is not limited only to new knowledge linked to the disciplines of architecture and engineering. According to the participants, there are other areas that are impacted by SD, such as Teamwork; Learn-by-Doing; Design Thinking; Service Learning; etc.

Examples of successful uses of the prototypes after the competition were also presented, as well as the participants' opinion on what would be the ideal use in order to seek alternatives to encourage their use in future editions.

5.7. Cost Effectiveness

The last category to be analysed will be the relation cost effectiveness in function of the interest in developing future competitions. For this, two areas will be analysed, which are: Innovation and Social Awareness.

5.7.1. Innovation

The more innovative the event, the greater the emergence of new technologies, directly impacting the market. Therefore, the strategies adopted to develop the competition directly influence the innovative/educational potential of the competition. To analyse this first area (innovation), it is important to understand how these strategies work, therefore an analysis of the evolution of the rules and of the contests of the competitions in the United States and Europe will be presented next.

There is a document of rules and regulations that all teams must agree to in order to participate in the competition, under the fulfillment of penalties or even disqualification if they are not fulfilled. This document is divided in three parts which are:

- I - Definitions. This part is destined to the specific terminologies of Solar Decathlon with the intention of introducing the participant, be it student or academic, in the world of the competition. This first part keeps growing as over the years, new terminologies are added to the rules.
- II - General Rules. This part has the intention of promoting a fair and interesting competition. In this section are exposed information and rules about the Authority, the SD Goals, the Organisation, the Administration, the participation, the site Operations and the houses design.
- III - Contest Criteria. This last part specifies the ten contests of the competition. The contests cover all aspects of the sustainable built environment, including renewable energy integration and social awareness and communication efforts.

The contests are divided into three categories which are: Juried, Monitored and Task Completion.

The construction process of the houses, generally has limitations because they are conditioned to this document. Solar Decathlon is in continuous evolution and over the years, this document has been changed and information has been added/deleted in order to make the competition more democratic and adapt it to the conditions required over the years. Most of these changes were made to target only a specific competition but brought an innovative impact to the competition that were kept in the regulations. Next, the most relevant changes in North American and European competitions will be described, punctuated by time period, through comparative analyses made in the competition documents (U. S. DEPARTMENT OF ENERGY).

Following the time line of the competitions, presented previously Figure 59, the main adjustments made from US SD 2002 to US SD2011 were basically under the contests. In 2002 the contest that had the highest score, therefore considered one of the main ones, "Design and Liveability" underwent a change in its name and from 2005 onwards it was called "Architecture". This change was made due to the principle that architecture is much more than just aesthetics. Teams must design and build attractive, high-performance homes that seamlessly integrate solar and energy-efficient technologies. This change reverberates to this day.

The number of points distributed among the ten competitions has also changed, where the 2002 and 2005 competitions had 1100 points, in 2007 1200 points and in 2009 the total score was 1000 points. The "Getting Around" competition present in the first three editions where teams used the electricity generated by their solar electric systems to "fuel" electric vehicles, was eliminated.

The first three competitions (2002, 2005 and 2007) had their energy stored through individual batteries. From 2009, the houses became part of a Solar Village Grid.

Between US SD2011 and US SD2017 there were significant changes, the main one, as seen earlier, the change of the event location from Washington DC to Irvine (2013 and 2015) and then to Denver (2017). For the first time the teams were competing for prize money. Regarding contests, in 2013 the contest "Hot Water" was added and in 2015 the contest "Commuting", this last one was removed for the following contest (2017).

The year of 2010 was marked by the first competition held in the European continent and this addition brought significant changes and adaptations to the event's history. The event changed from Solar Houses Competition to Competition of Sustainable Houses Competition, focusing on a wise use of energy, in line with the energy efficiency policies of the European Union.

SDE categorizes the contests into five themes (Architecture, Solar, Comfort, Social-Economic and Strategic) and creates two new contests and renews seven existing ones. The SDE also creates sub-contests, increasing the level of requirements and successively making the competition tougher.

For the 2012 competition some significant changes were made such as increasing the maximum height of the houses, allowing the creation of a second floor. The use of energy generated through photovoltaic systems was limited in order to promote the use of innovative systems. The monitoring of the teams was intensified through the organisation of two workshops.

In the 2014 competition, in addition to the location factor (moving from Madrid to Versailles), the event sought to reach new areas by incorporating urban contests. In addition the event had a greater focus on density, mobility, sobriety, innovation, affordability. The limitation on the use of energy generated through photovoltaic systems was more restrictive than previous competitions.

The 2019 competition had significant changes (compared to the previous three) which ranged from the main focus being renovation, where teams could choose from four different project proposals (Renovation of the traditional building model; a roof-top apartment built; renovation project; any other proposal to solve specific local challenges that could enrich the EDS Community) to the duration of the event where the houses remained on display for two months after the closing ceremony.

After describing a series of changes in the Solar Decathlon competitions over the years, what can be noted is that many of them happened through the geographic change of the location where the event was being hosted. Of all these changes, it is worth highlighting the moment when the competition migrated to Europe (2009-2010) where the contests "Innovation" and "Sustainability" were created. The creation of these contests gave the main focus of the competition new premises that directly impacted the final result.

Figure 120 – Evolution of contests. Source: EBC Annex 74, IEA (Beatriz Arranz, Sergio Vega and Richard Amaral).

It was also noticed several changes related to the contests and their scores bringing a greater complexity to the event. Since the first Solar Decathlon, depending on the evaluation method, there are three different ways of scoring: Juried, Monitored and Task Completion (EASTMENT et al., 2022).

Juried Contests are evaluated by experts in their field. The jury's assessment is based on the documentation submitted by the teams, the information shared by the teams during the project tour and on-site corroboration of the project characteristics.

The Monitoried Contests are related to the success of the projects in providing comfortable indoor conditions and their energy performance. Organisers install a monitoring system in each of the projects that records their behaviour in real time.

Task Completion Contests are evaluated based on the teams' success in completing the tasks required in the competition rules. The organisers assign people to supervise and record the teams' results as they complete the tasks. These people are known as "Observers".

The table in Figure 120 shown on the previous page, developed for the Annex 74 report, shows the evolution of contests and the scores of each of the competitions held until the year 2019. Through this table it is possible to analyse the evolution of the proposals implemented over the years in Solar Decathlon.

5.7.2. Social Awareness

Several times it was commented during this thesis the importance of the event reaching a high number of people. What has not yet been analysed is the relationship of the total budget with the competition income (total number of visitors). The values in this graph are updated to the year 2022 according to the inflation rate of the United States (THE WORLD BANK) and the exchange rate realised to unify to the US dollar was made according to the average annual exchange rate established by the European Central Bank (ECB). According to the graph in Figure 121 below, the SDE 2019, US SD 2011 and US SD 2017 competitions had the highest rates, which means that the money invested could have been better used if these editions had more teams and a larger audience of visitors. Against this thought, SDE 2010 and 2012 had the lowest rates, which is a positive finding.

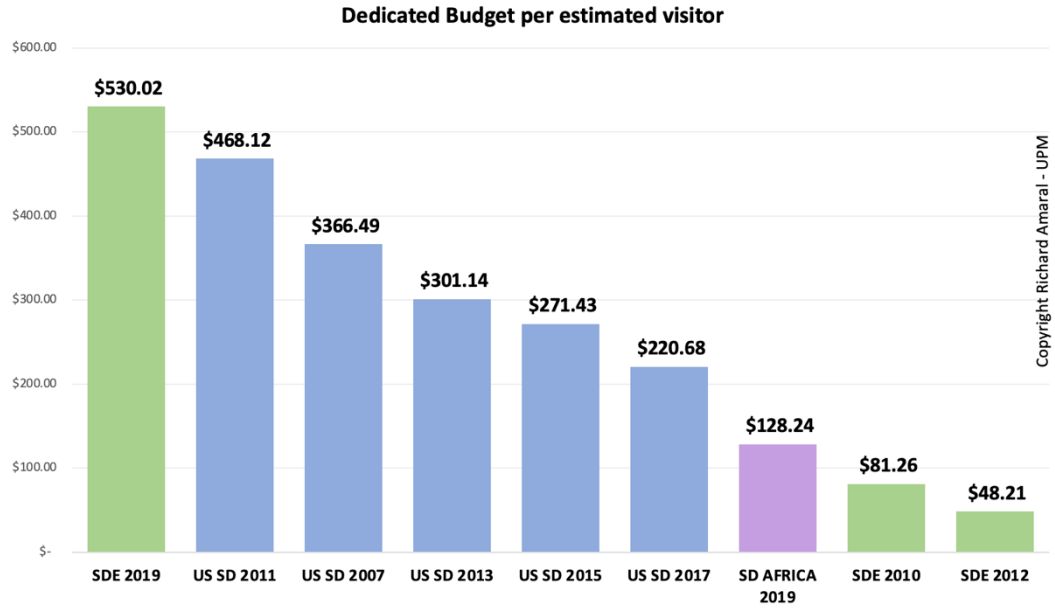

Figure 121 – Budget per estimated visitor. Source: Richard Amaral.

Still on the graph of Figure 121, what can be stated is that there is an element in common between the European competitions of 2010 and 2012 and that may have helped to influence the low figures of this graph, which was the 10Action project. This analysis emphasizes the importance and success of this project, as with efficient communication strategies, it is possible to attract a large audience, and successively, the effect on the money invested is better.

Still talking about 10Action, the chart in Figure 122 below shows the percentage of the project over the total budget for SDE 2012. What can be observed is that the amount of money to organize a project like 10Action is very low (1.21%) and that its impact on the competition is extremely high. Therefore, it is feasible to carry out a project like 10Action within the Solar Decathlon competitions as its benefit and impact on them is very high.

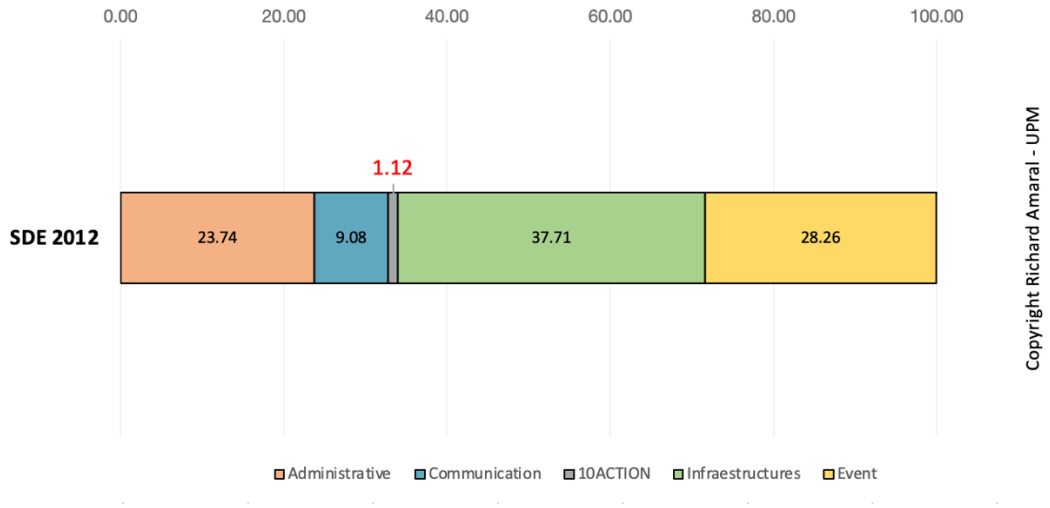

Figure 122 – % of budget spent per area in SDE 2012. Source: SDE 2012. Adapted by: Richard Amaral

5.7.3. Discussions Category "Cost Effectiveness"

Making a summary of everything that was analysed in this last category, what can be stated is that the greater the amount of people visiting the event, means that the investment was well made. Furthermore, the creation of strategies such as 10Action's significantly boosts the final result of the event.

Therefore, the strategies adopted by the event organisation directly influence with the educational and innovative potential of the competition and there are more positive than negative reasons to consider developing future events. It is a matter of applying some successful measures (such as 10Action) for the event to have a better outcome.

5.8. Results Final Considerations

This chapter provided information through comparative and qualitative analyses of the competitions held to date. As seen in Topic 5.1 above, in order to evaluate the success of an event, it is necessary to perform a consistent analysis of different aspects of the event. In this comparative analysis it was possible to obtain useful information to evaluate the success of a Solar Decathlon event.

Information about the participants of an event is basic and important data to perform this analysis. In this chapter it was possible to compare the total number of visitors of different competitions on various aspects and to come up with possible reasons why some events performed better than others. The comparative analyses performed on the locations and situations of the events, the evolution of the event over the years, the universities on each continent in terms of participating teams, the time of the event in terms of visitors, and the comparison of strategies to carry out specific activities and events for visitors helped to find the best ways for a Solar Decathlon event to attract a large audience and at the same time meet its main objectives of spreading and teaching people about energy efficiency.

As previously reported, information related to profitability can also be used to be able to evaluate the success of an event. In the case of Solar Decathlon, profitability is related to money used to run the event. As said, the collection of this money can be done through public agencies and corporate sponsorships and in function of the comparative analysis performed in the topic 5.3.3 of the budget of some competitions, the amount of sponsoring companies and the comparison of these figures in function of the total visiting public served to visualize which competition managed to attract more funds and the answers to the reason for the success obtained can be found through the correlation with the data presented previously about the organization, evolution and execution of the events.

Another factor that helps when measuring the success of an event is people's interest and search/demand on that theme. In the case of Solar Decathlon this approach is related to the main target audience, which are the students, teachers and universities related to architecture, engineering, urbanism, design courses, etc, besides the companies and professionals of the construction and sustainability sector. The comparative analysis developed in the topic 5.2.4 about the existing universities in each continent in relation to

the participants, the population comparison of the host cities, the comparison of the interest of the universities in participating in the competition throughout the years, along with the novelty factor can be used to analyze the demand and the feasibility of the competition in the future.

The repercussion of an event, mainly in the social networks, also serves as data to evaluate its success. In the case of Solar Decathlon, this impact can be measured through the numbers obtained as a function of the strategies adhered to by the organizers of the competitions in relation to communication and media. The information presented in the topic 5.2.4 that brings the strategies used by organizers of some competitions along with numbers and data from the application of this methodology adopted. Although the information that was presented is about few competitions, it served to emphasize the success of some competitions through the correlation with the total number of visitors.

The return obtained through an event is also a factor used to measure the success of an event. In the case of Solar Decathlon competitions this return is not only related with the total number of visitors but also with the impact of the competition on students, teachers and universities, on the population, on the market, on the scientific community, on the use of the prototypes after the event, etc. The information presented in topic 5.3.1 where it brings data about works (thesis, articles, books) published after the competition, the use of the houses after the event and the scope of the activities performed in the competitions can help to emphasize the success of the event. It is a fact that there is a deficit of information on the return obtained, which makes it necessary to search for more information on the subject.

The analyses presented allowed for the categorization of the most successful competitions. The strategies adopted by these successful SD competitions will serve as a basis both to conclude this thesis and to develop suggestions for improvements in future editions. This analysis also served to find data that are not yet existing and that must be discovered before developing the final conclusions of this work. In the opinion of the author of this thesis, there is an absence of information related to the opinion and satisfaction of the people who participated in the competitions, be they students, teachers, organisers, professionals or even the visiting population itself. This information obtained through the feedback of these people serves not only as performance indicators but also gives reason and veracity to the data already available and that have been previously analysed.

The feedback from the participants may bring answers to several questions that are still open, such as the evaluation of the positive and negative points of the competition, the description of the experience, the opportunities obtained through this experience, the impact caused in the educational, social, innovative, technological and market fields, suggestions for improvement, etc. The correlation of these answers under the look of who experienced the competition together with the analyses already developed may define the strategies of how to create an "ideal" Solar Decathlon competition and possibly be able to prolong the vitality of the competition.

According to the diagram in Figure 123 below, the next and final chapter will conclude this work by reflecting all the information that has been found and analysed in this chapter.

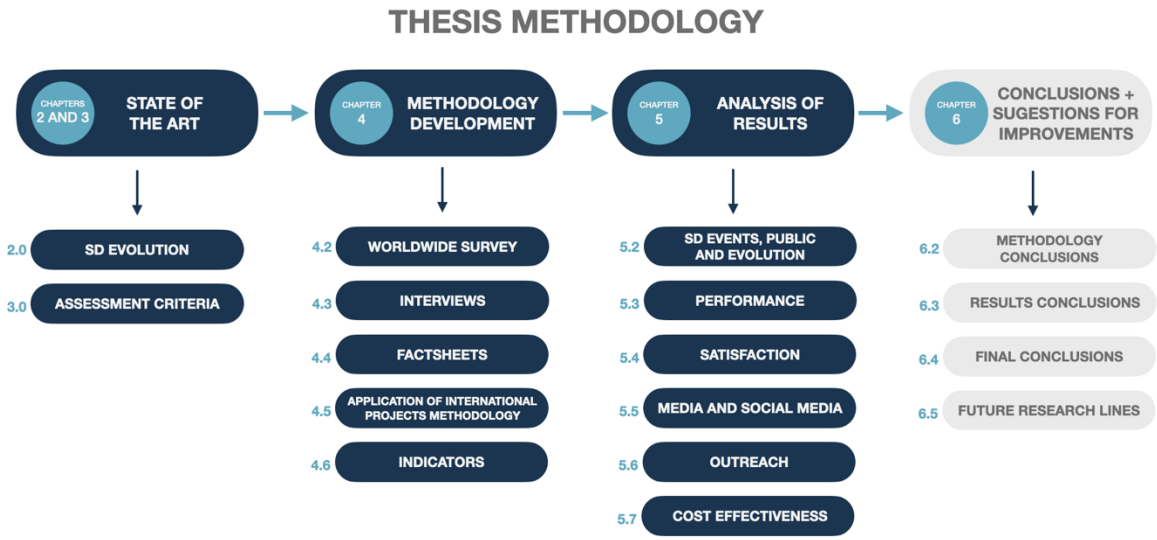

Figure 123 – Timeline of completed chapters. Chapter 05 done. Source: Richard Amaral.

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6. CONCLUSIONS

6.1. Introduction

In this chapter, the conclusions of all the research work documented in this thesis will be presented. Next, some preliminary conclusions on the theoretical foundation used for this thesis will be pointed (Chapter 2).

The numbers do not lie. With almost twenty-five years of history, Solar Decathlon has had a clear impact on millions of visitors and thousands of students, teachers and professionals, innovated the market and implemented a new way of learning. It is clear the need for the vitality of this project for more and more years to come, as its impact directly influences the environment in which we live. Like any other great and successful project, the event showed its weaknesses and, through the comparison of editions, it was possible to visualize these flaws. By resorting to particular mechanisms, it was possible to understand what these problems are and seek alternatives to improve them through examples of successful and effective solutions.

Due to the dispersion of the existing information together with the "degradation" of important data about the past editions of the Solar Decathlon, it was necessary to develop a compilation of information about the editions, teams, countries, objectives, rules, etc in function of the timeline of the event. Through this execution, it was possible to visualize the development of the competition during all these years and question the discrepancies between editions detected through this compiling. This approach was necessary in order to be able to understand such absences and create strategies to analyse the problems deciphered. Moreover, this information serves to situate future researchers.

The conclusions on the execution of the methodology used in this work, together with the concepts contributed on the conception of scientific research and the validation of its results (Chapters 3 and 4) will be presented in topic 6.2. Next, in topic 6.3, the conclusions drawn through the analysis of the results developed in Chapter 5 will be presented together with suggestions for improvement. In section 6.4 the final conclusions of this work will be presented. Finally, in topic 6.5, proposals for continuity linked to this research will be offered.

6.2. Methodological Conclusions

This work offers a comprehensive study of all the Solar Decathlon competitions held to date. The main objective of this thesis was to make a global analysis of the

competition in order to create appropriate strategies to improve its impact from an economic, social, educational and scientific innovation point of view. The information used to develop this analysis came from existing and available references together with new material that emerged from the application of the methodology developed for this work. Based on the concept of scientific research and its quality criteria together with effective data collection tools, a worldwide survey, semi-structured interviews, performance indicators, factsheets and the application of the methodology of other international projects were developed to collect all the data required.

The results obtained through the worldwide survey complement and enhance the existing surveys developed in the past for other projects. Even though it was answered by almost 400 people, this was the first Solar Decathlon survey that received answers from participants of all the competitions held until 2020. It was also a systematic survey and brought new information about the satisfaction of the public involved in the competitions. Together with this, it was possible to obtain data about the positive and negative aspects and the areas of SD with the greatest/least impact.

The survey also highlighted problems such as the employability of the participants and the low media impact of the competition and, through these, it was possible to study patterns of success in order to implement them in future editions. Furthermore, this survey collected relevant recommendations and opinions that can be used in favour of the organisation of future events.

Students and teachers participating in the 2019 SDE and organizers of various competitions held over the years were interviewed and from these interviews it was possible to emphasize and confirm several results obtained by the 2020 worldwide survey. These interviews allowed to have different points of view (from those who participated it and those who organized it) and brought elements regarding the opportunities obtained through the participation of the competition. Due to this, it was possible to find weaknesses concerning the organization of the event due to the lack of involvement of universities, which are leveraging factors for the success of an event of such characteristics.

Regarding indicators, 138 were initially defined, but due to lack of information, it was possible to execute only 58. KPIs related to budgets, costs and effectiveness made it possible to visualise a continuity of the competition in the future. Indicators on the

evaluation of the competitions according to the SD impact areas made it possible to improve the weaker competitions. The KPIs on the evaluation of the impact of the competition on each type of public made it possible to seek improvements in this aspect.

The factsheets answered by the organisers were fundamental to have correct data on amounts, values and totals related to the budget, the visiting public, teams, students, contests, etc. These data, in addition to bringing veracity to the analyses, also enabled the execution of the KPIs and quantitative analyses developed throughout this work.

Adding further importance to this work, the fact that this thesis is part of two large international projects, developed by IEA and EC, helped to concretise and highlight the information projected by the analysis of this thesis. The use of the surveys of the 2012 and 2014 European competitions and the North American competitions adopted by the international projects helped to develop comparative analyses on the evolution of the competition over these years.

Contemplating the methodological process adopted in this work together with the concepts of quality in scientific research, where the uses of different methods (quantitative and qualitative), literature, theories, as a way of validating of results, it can be seen that the use of these different strategies (surveys, interviews, indicators, factsheets, bibliographies, etc.) helped to validate the results achieved since they corroborate each other since the weaknesses of each particular strategy do not overlap with those of the others and, on the contrary, their strengths add up. And, successively to this, it substantiates the analysis developed through these results found.

Therefore, it is possible to conclude that the results obtained through the methodology created for this thesis were fundamental for the execution of the analysis on the competition made in this work. Even if the worldwide survey has not reached a high number of answers and that only one third of the indicators have been executed, the information obtained met the planned results. Another point to be highlighted is that these elements are new and did not exist in any other work developed on Solar Decathlon.

6.3. Conclusions - Results and Proposals for Improvement.

The analysis carried out through the results obtained by the methodology applied in this study pointed out positive and negative points related to competition. In general, there is a unanimous opinion that the competition is beneficial and positive for those

involved. The analysis demonstrated that the competition has been renewed over the years, adapting to new needs, hardening and diversifying its dispute. The analysis also found and emphasized that this event is unique and that there is nothing similar in the field of architecture and sustainability, so its continuity in society would be really positive. Taking these premises into consideration, the analysis found negative points that must be improved to enable this desired vitality. For a better understanding, such points have been divided into four categories which are:

Location/Visitors

It was shown that the final public of an event is the main indicator to evaluate its success. Contextualizing this concept in the Solar Decathlon context, the more people involved, the greater the impact of the event in society. Therefore, considering this main premise, we detected some points that directly influence the total number of people and successively to that, the impact of the event.

After comparing the location of past events, it was found that in order to run an SD competition the event must be situated in a place that has a higher movement of people (centrality). In a private event, visiting people are "forced" to travel to get to their venue, regardless of where it is located, because there is a bound and desired interest about that event. In the case of Solar Decathlon, it was shown in Figure 58 that the vast majority (over 96%) of its audience is composed of citizens/visitors, therefore students and professionals linked to the area of architecture, technology and sustainability that are willing to travel to visit the event due to interest, are not able to hold an event of this size. It is fundamental that the event be centrally located, as it would be close to basic infrastructure such as bus/metro stations, restaurants, etc. In addition, a central location also serves as a "shop window" for people who are unpretentiously passing by and successively to this, it allows for cost savings and great strategies in publicizing the event.

Other aspects found after performing the analysis of the results and that directly influence the total visiting public of the event are: the time of the year when the competition is held; the university influence (mainly in the areas of architecture and engineering), Figure 67 and Figure 75, respectively, and the total population of the host city. These factors must be considered when choosing the location since, according to the analysis of this study, they directly influence the total audience of the event.

Communication

This work found that this is an extremely fragile and weak point about the event. Through the (little) existing information on this theme, together with the results of the interviews and survey, it was possible to conclude that it is necessary that the organization of future events give greater importance to this aspect. The success of an event in terms of its visiting public is conditioned to adequate communication strategies. It was found that the strategy adopted by the organization of the SDE 2010 and 2012 competitions in creating a project (10Action) aimed at promoting education and social awareness through activities served to attract people of different age groups to visit the event. Moreover this project crossed borders and reached thousands of people. Therefore, the author of this work believes that this can be an example to be followed for future editions. Moreover, it was also found that for the execution of the 10Action project it was used little more than 1% of the total budget of the event, as appreciated by Figure 122, which demonstrates the viability of the execution of this plan.

Event Organisation

The organization factor was also a question that was extensively addressed during this thesis and some important points were found to be highlighted. The first of these is the deficit of universities involved in the event's organization. During the analysis of results, in several points some negative aspects about this theme were found, such as the absence of content/disciplines related to SD within the universities, as shown in Figure 81. Another relevant point found was the lack of recognition by universities of the teachers participating in competitions. Or even the lack of control over everything that is published (scientifically or not) about the competition. This means that these problems may be related to the absence of university bodies as organizers of SD competitions. As it is an academic event and aimed at students, it is extremely important to have institutional representatives organizing the event.

The budget of the event was a topic that was questioned a lot by the participants. It is clear that to organise an event of this size, it is necessary to raise a large amount of money. Regardless of where, when or how, the sums are millions of dollars. This is a fact. What should be taken into consideration is the way in which the event should be organised, with effective strategies (especially in communication and location of the

event) to reach as many people as possible so that the large sum invested can be well spent.

Opportunities and Post Competitions

Two other factors parallel to the organisation of the competition that were encountered during the development of this work are: the opportunities generated for the students and the use of the houses after the competition. Both are related to what happens after the event. During the results analysis in Figure 82 and Figure 87, it was observed the dissatisfaction of the students regarding the work opportunities obtained after having lived the competition experience. It is important to have an efficient plan for a greater connection between the students and the companies involved since many students participate in the competition with the interest of having better job opportunities.

Regarding the future of the houses, it was found that more than half of them are being used as Living Labs, which is a positive fact. What is worth to be highlighted about this aspect are pre-competition recommendations to foster the use of these prototypes after the event. The previous definition of the use and location of the prototype facilitate this process. Involving the university in this process by appointing a responsible person and creating a research and maintenance team are also factors that can help foster educational use.

6.4. Final Conclusions

Answering the question raised in the introduction of this thesis, there are more positive than negative reasons to consider holding future events. It is a matter of implementing some changes to make better use of the event.

The educational potential generated by the event is one of the main reasons for a university to participate in a Solar Decathlon competition. UPM's leadership has had a positive impact on the history of SDE competitions through its direct involvement with the project. This competition has a high educational potential not only for the students but also for their teachers, organisers, professionals and the public involved. It's important to consider the high cost of holding the competition, so a high number of visitors is essential in order to dilute the price and make the event worthwhile. The overall balance is positive and it is advisable to organise future editions of the event.

Therefore, the hypothesis of this thesis has been validated, as it has provided criteria for improving the impact from various points of view through the more than 150 graphs acquired by the proposed methodology. The objectives set for this work have been fulfilled as it has been possible to measure the impact of various competitions, carry out a comparative analysis between them and define appropriate strategies so that it is possible to make the most of the potential of future competitions.

It is shown that the impact of the different Solar Decathlon competitions can be measured and that these can be useful for improving the performance of future editions. As a final result of the analysis of this thesis, for the Solar Decathlon Europe 2022 competition, the indicators/outcomes of the methodology of this work were implemented and the performance in many aspects surpassed the performance of previous competitions.

6.5. Future Research Lines

Regarding the proposals for continuity, the methodology of this project can be employed in other situations in which it can be useful to evaluate other large-scale events such as concerts, sporting events, etc.

This work has mostly information, data and analyses of the competitions in the United States and Europe due to the fact that they are more accessible (both in literature and in volunteers for surveys/interviews). Nevertheless, it is known that the Solar Decathlon China competition, in which three editions were celebrated, has a high potential for the development of a scientific work similar to this one, but with exclusive content for these competitions.

The information provided by this work can also serve as a basis for further scientific work on the impact of future editions of the Solar Decathlon. Furthermore, this work can be used to compare the performance of these future events.

This study enables the design of new exclusive scientific works on the use of post competitive prototypes. Through this thesis it was proven that there are several prototypes spread around the world with multiple uses. It is a subject that covers numerous topics.

During the development of this work, it was used several materials from the areas of pedagogy and sociology related to educational innovation and motivation of students. This work can add new information for new scientific researches related to this area.