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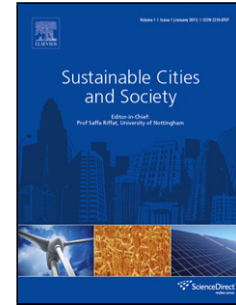
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Building redevelopment as a catalyst for sustainability? - Assessing the renovation of the Pier Arts Centre, along technical, social and economic sustainability indicators.

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Highlights

- A multifaceted assessment of a renovation project on its sustainability and performance.
- A multi-disciplinary approach for development the assessment framework.
- A successfully project making considerable positive contributions to local culture life, building conservation and economy.
- Effective renovation transforming a historical building into a multifunctional, live and active art centre with limited environmental impact.
- Suggestions on improvement of operating the centre and for development of other similar projects.

Abstract

Building redevelopment, even when aimed at greater performance and sustainability, is often carried out in isolation and with a narrow focus on technical and design aspects, with little thought to the building's context and its wider impacts. These wider impacts on cultural, social, economic and environmental sustainability are also often not assessed, or very cursorily so and over a short time frame, which gives little indication of long-term impacts. Taking a case of an art centre which has acted as a driver of wide and enduring positive sustainability impacts in the local community, this study shows possibility of assessing

systematically such impacts of a redevelopment project using a specially developed multidisciplinary methodology over a range of measurable sustainability indicators and a collection of data covering the years before and after the project's completion. The assessment suggests the project has a number of successful outcomes and some areas for improvement over the three pillars of sustainability and building performance as an art gallery. Discussions are given at the end on the lessons to be learned from the project in terms of effective building redevelopment in context, showing that this case study can be an inspiration for redevelopment approaches in other locations.

Key words: building redevelopment; sustainability; design and context; gallery; building conservation; impact assessment; environmental Impact; socio-economic impacts; energy performance; environmental control; multi-disciplinary

1 Introduction

Pier Arts Centre (hereinafter PAC), a redevelopment project in Stromness, Orkney, Scotland, was undertaken by Reiach & Hall Architect. It involved the refurbishment of two listed historic buildings¹, Victoria House and Pier Warehouse¹, and the creation of a new building linking the two (HES, 2016, Fig. 1). These three distinct structures have allowed an expanded centre to offer an entrance/shop, space for the permanent collection and temporary exhibition spaces, a library, meeting room, store, administration offices and service areas. The renovated centre opened to the public in July 2007. Occupying a prominent position in the Stromness conservation area, the original buildings are late 18th Century and firmly rooted in local history. They have formed a key part of the local business and social life throughout their entire life, giving the successful redevelopment project a great importance locally. Indeed, in 1977 the original buildings were purchased by the Pier Arts Centre Trust to house a collection of culturally-significant artefacts gifted to the people of Orkney by Margaret Gardiner (1904-2005). The buildings were converted at that time by Levitt Bernstein

1. They are the 2nd and 3rd Categories in Scotland for historical buildings of international, national, regional and local importance; or major examples of some particular period, style or building type, various degrees of alternation are allowed

Associates and provided space for the permanent collection, temporary exhibitions, a meeting room, reception area and an artist's flat. Since then the centre had seen increased use, and has acquired a central position in the social and cultural life of Orkney, which is seen by local

authorities as a key emphasis for the island's sustainable development. Thus, any redevelopment needed to offer guarantees of adequate building performance in terms of preserving the heritage of Orkney. This also included the need for the centre to become a community hub, capable of supporting a range of cultural and social activities through adequate design principles. Furthermore, islands such as Orkney are largely dependent on tourism, and an iconic arts centre was seen as a potential driver of increased visitor numbers, and therefore as a central component in long-term economic and development policy. Lastly, within the framework of current UK and Scottish policies, the redevelopment of a building such as PAC had to address matters of environmental impacts and offer better performance than its predecessor.

1.1 Context of the study

Indeed, the PAC renovation project has made an impact even just at its completion. Praised for conservation of the two listed buildings, it has received numerous awards, including the Royal Incorporation of Architects in Scotland, Andrew Doolan Award for Best New Building in Scotland 2007; RIBA *National Award* 2008, RIBA Award 2008, RIBA *Stirling Prize* 2008 longlisted and others. A recent review commissioned by Highlands and Islands Enterprise (HIE) emphasised the growth of visitor numbers to Orkney and public welfare and considered the project a success in terms of strengthening cultural life and artisan skills in the local community. The project was seen as a valuable contribution to local sustainable development, whilst fitting in with the unique natural and architectural context of Orkney. The study highlighted how some approaches could be transferrable to other areas of Scotland and beyond (Matarasso, 2012).

However, these studies covered only a short time period after the building renovation was completed, meaning that a more recent appraisal, taking into account a significantly longer time period, as provided in this article, is needed.

1.2 The need for a comprehensive assessment method

Like all projects, renovation will not necessarily perform as intended and contribute positively to local sustainable development, and therefore needs to be assessed along carefully selected parameters and over a sufficient time period. There are several cases in the literature of redevelopment projects leading to negative impacts as shown by Mangold et al.

(2016) . In this study, the negative effect is reflected in the cost of renovation, energy retrofitting and rent are examined in different time period to assess the economic and social impact of renovating and retrofitting a multi-family dwelling stock in Gothenburg. This is just one of many similar studies carried to assess renovation projects of various types of buildings, at different scales and on different parameters, some social, economic and some environmental (Thanvisitthpon, 2016, Raak, 2014, Serrano-Jimenez et al., 2017, Musa et al., 2018).

Retrofitting of residential buildings was assessed in a neighbourhood of Seville (Serrano-Jimenez et al., 2017), in which the regional social and economic effects were presented with the level of satisfaction and affordability through a survey. The study showed that considering the effectiveness of incentives at an aggregate level can help achieve greater social and economic benefits. The same was found in other studies (Waintrub et al., 2016, Greene et al., 2017). These studies also suggest that a well-designed project can improve social integration, a positive contribution to social sustainability.

A mathematical model, proposed by McArthur and Jofeh (2016) analyses potential improvements brought by a series of retrofit investments. Based on the scoring system this assessment approach is bespoke and easily customised to fit the redevelopment project profile. Although the model can be adapted to assess non-commercial buildings by replacing key factors in the evaluation formulae, the proposed evaluation method is not applicable to PAC as it is a pre-assessment approach and primarily relies on expert judgment to determine key factors rather than on an objective and systematic approach. Moreover the change in demographics and number of employees should be considered as indicators to scale the impact of a redevelopment project on local social and economic sustainability (Thanvisitthpon, 2016).

The assessment studies reviewed above focus on social or economic sides of the impact. On the environmental side, *BREEAM UK Refurbishment and Fit-out* (BREEAM, 2014) for non-domestic buildings appears to be an adequate tool to assess the impact of a project on the aspects such as energy and water consumption, waste discharge and carbon emissions. The problem is that these methods often focus on supporting or guiding innovation work on the planning, development and construction rather than on operation after project completion. They are often carried out at design stage or soon after, the actual performance and operation

is not included in consideration. In addition, the challenge of using this tool is that the exercise requires large sets of historic data and information. Unfortunately such data is not easily available due to the fact that data collection is time-consuming and involves a large amount of parties. A new and feasible method was to be developed to assess the impact for this historical building project.

As the Centre functions as a gallery that houses valuable collections, its indoor environmental control is vital to ensure its conditions are compliant with a standard of collection care that meets the conservation requirements of the artefacts. There is a wide range of standards applied in the industry from different parts of the world. Standards, such as BS 5454:2000 (British Standards 2000), PD5454:2012 (British Standards 2012b), PAS 198:2012 (UK, British Standards 2012a), EN 15757:2010 (European Standards Committee 2010), and ASHRAE Handbook: (US, ASHRAE 2011), are very rigorous with the indoor environmental control specifications and others are less stringent. These variants are used even in buildings of significance, including The National Trust, London and Victoria and Albert Museum (Blades, 2010), the Scottish National Portrait Gallery control specifications (Harley Haddow, 2014), Manitoba Museums Canada (Alcántara, 2002), and Smithsonian Institution (Mecklenburg et al., 2004). PAC applies two levels of standards to its spaces, a very strict one in Collection Rooms and a less stringent one in the gallery spaces. After a decade of operation, it is now appropriate to survey the indoor hygrothermal conditions and check if the design targets have been met. A quality control and indoor hygrothermal condition would benefit PAC with an international status, which could open up opportunities for joint exhibitions with other galleries and inter-gallery loans. This would also help to raise the Centre's profile and consequently benefit the Islands' cultural significance, while boosting tourism further, thus contributing to greater social, cultural and economic sustainability, whilst reducing the environmental impacts of the building.

As strict environmental control involves modulating latent heat, this inevitably leads to intensive energy consumption, especially when the gallery spaces are running 24/7. There is thus a need to strike a balance between benefits to the arts collection and wider environmental and energy cost impacts when assessing this aspect of a project (Wang et al., 2013). Many old galleries are housed in historical buildings built with heavy masonry and with no purposely-implemented insulation layers, and the buildings are often able to moderate fluctuations of the indoor air temperature and humidity. As a result, the gallery and

museum industry are questioning the need for rigorous controls where the thermal mass and moisture buffering effect would be utilised for energy saving purpose without sacrificing indoor environmental quality (Harley Haddow, 2012). The PAC gallery and collection spaces are located in both the old Pier Warehouse, with internal insulation that could reduce thermal mass, and the new building built to more recent regulations. Therefore there is a need to carry out a test on energy performance of PAC in addition to the environmental control and indoor quality.

Overall then, there are questions regarding both “how good” the Centre is, and “how to assess” it after over 10 years of operation, taking into account the building performance aspects as well as wider issues of social, cultural, economic and environmental impacts. Therefore this paper asks whether the physical renovation and expansion of an existing flagship cultural centre in an area of outstanding natural beauty and cultural heritage can act as the linchpin for wider environmental, social/cultural and economic benefits for the local community. Indeed, in contemporary urban development projects, design of ‘high quality’ environments is often seen as a catalyst for the wider ‘regeneration’ of an area, a ‘build it and they will come’ approach that is not always borne out by facts. There is a lot of faith put into flagship developments as a way of ‘pulling up’ an area and creating a virtuous circle of development around them. This has been particularly pronounced in the UK over the last 20 years, starting with the famous Rodgers report on the ‘urban renaissance’ (Urban Task Force, 1999), which emphasised high quality design and flagships as anchors of urban redevelopment. Numerous successful examples have emerged to buttress the theory, such as the successful waterfront regeneration of Dundee, Scotland (Smith and Ferrari, 2012). However, there are many examples of design-led redevelopment failing to reach the goals originally contemplated. Such was the case with the 20-year design-led redevelopment of Cardiff (Punter, 2007), which led to isolated, expensive mega-structures that failed to foster a sense of community and did not act as the expected engines of development.

1.3 Aim of study and structure of the paper.

It is clear that there is a need for an approach for assessing the PAC renovation. It is a multifaceted assessment over a number of aspects that characterise the Centre as a flagship for local sustainable development, including the indoor environmental quality and energy efficiency, as well as economic and social impacts. This approach assesses the redevelopment of PAC along several interconnected lines. Firstly, in terms of the building’s contribution to

local sustainable development around cultural, economic and environmental lines. Secondly, in terms of the performance of the building itself across a set of physical and environmental parameters. These aspects are rarely taken into account in a holistic way in building design, construction and assessment. Indeed, building briefs often emphasise technical parameters during construction, and reviews of building performance, when they occur, only focus on a short period of operation and do not take into account issues arising over long terms of occupancy. Furthermore, the assessments of impacts on sustainability are often limited to physical aspects such as emissions and sometimes visual impacts on the local context. This study offers an evaluation of the building and its impacts that is much broader, since it addresses physical, environmental, social, cultural and economic factors. It also offers a much more realistic picture of the building's true impact, as it covers the first 10 years of the redeveloped building's occupancy.

Therefore the aim of this study is to develop a multi-faceted assessment approach and apply it the PAC renovation project in a systematic manner, which provides some lessons that could help other similar projects achieve better results in terms of conservation, redevelopment and a range of sustainability impacts.

To achieve this goal there are a series of objectives

- To review and revise the common methods assessing the impacts of a project on the local environment, economy and society (including culture),
- To define indicators that measure the key benefits brought by the redevelopment on economic, social and environmental aspects using as much as possible quantifiable variables.
- To combine them into one systematic assessment for PAC, covering all the aspects that are widely accepted as the three pillars of sustainability (Brundtland, 1987).
- To collect the data for the indicators and analyse them and complete the assessment.
- Finally to explore how this could be used to evaluate the contribution of a renovation construction project to local sustainability in a cost-effective manner.

This paper presents firstly a literature review of the common assessment methods used for the similar purpose. The review identifies a number of key indicators for this assessment exercise. It then describes the framework developed for this multi-faceted assessment, including quantifying indicators of the impacts of the project on the social, cultural, economic

and environmental aspects of the local development. Section 3 presents the results and discussions over all three aspects of cultural, economic and environmental sustainability. Lastly, the conclusion section shows that PAC, by combining technological, building design and community outcomes, contributes to the social, economic, environmental and cultural sustainability of Orkney, with some important caveats. Following on from these, suggestions are made to further advance these goals.

2 Methodology of the study

There are assessment methods available for various purposes. This section discusses those that are commonly accepted and relevant to this study, and combines them into an assessment package to conduct a multifaceted analysis of the key indicators of social, economic and environmental impacts of the PAC renovation project, after 10 years of operation. These indicators, including changes in revenue, costs, job opportunities, visitor numbers, educational and charitable activities and others allow us to assess the economic and social and cultural impacts, whereas the energy consumption and carbon emissions guide the environmental impact assessment. The gallery environmental control is considered as a cultural impact (due to the necessity of preserving valuable artefacts) and variables used include room temperature (T) and relative humidity (RH) compared against two selected standards. Hygro-thermal fluctuations are also used for the interpretation of assessment results.

Fig. 2, shows the structure of the assessment with 22 indicators (indoor environment is measured separately by T & RH) in four categories, the social and cultural, economic, environmental elements as well as building performance as an art gallery

2.1 *Social and economic impacts*

As explained, survey, data analysis and scoring systems were not easily applicable to the assessment of the social and economic impacts of the Pier Arts Centre renovation. In addition, scores resulting from assessment or models cannot reflect the difference brought by the renovation itself. However, results from long-term tracking assessment will clearly show the changes along the timeline. Therefore, an assessment method applied in this study is revised

from the Sustainable Development Indicators (SDIs) (ONS, 2015). The SDIs provide an overview of long-term progress towards a sustainable society and economy nationwide. To present a picture of the socio-economic impacts along multiple lines, both qualitative and quantitative analysis were applied to assess the long-term effects of the redevelopment. Additionally, to simplify the assessment that covers the entire period from the year before the renovation and up to 2017, only key indicators suggested by the SDIs were revised and applied to the project, taking into account the local circumstances.

The revision of the SDI took significant consideration of the data available from various resources from the Centre, as well as local and regional council reports. The assessment of the social impacts examined the changes over the years of three groups of indicators: the exhibitions and visitors, education events and partnerships and charitable activities and participants. The annual numbers of exhibitions and visitors illustrates the popularity of the centre. Education events and participants counts can reflect academic and professional functions of the Centre. The indicators for the charitable activities and partnerships can show the the impact of the renovation on local society and the centre's rising status. The assessment of economic impacts includes the three groups of indicators: the employment profile, incomes and costs. Tracking the employment profile, both the number of the employee and costs illustrate the major economic contribution brought by the renovation. To give a realistic assessment, the incomes and costs are considered as the most immediate way to reflect the Centre's economic performance. Here the income consists of both the grants and sponsorship received from various sources, and sales associated with various activities taking place in the Centre. The data was collected from various resources, including the latest internal documents from the Centre and council reports and compared over the long term to see if there had been improvement, deterioration or little overall change.

It was difficult to provide a decisive verdict on each of the aspects examined, as there were always fluctuations, resulting in no clear trend towards improvement or deterioration in some indicators. Therefore, the verdict was drawn based on the trend over the ten years period covered, from 2006, the normal operation before the renovation, until the most recent year when annual data was available. Also only three grades were used in the verdict for each of the elements: increasing or good; no change or fair; and decreasing or poor. This data was selected to reflect the changes in the performance of the Centre on various facets from the pre-renovation period to the latest available data. However, due to accessibility issues, some

of the measures for a certain year were not available. Furthermore, the rating system did not reflect fluctuations during the intervening period and so it only shows the overall change from the start year to the end year.

2.2 *Indoor condition and control quality*

As mentioned before, indoor physical environment has a long term, direct and significant impact on the display, storing and preservation of the artefacts housed in galleries, and often light control is much better achieved than hygrothermal control (Cassar, 1994). Hygrothermal control is also associated with intensive energy consumption. This aspect was therefore the focus of this assessment study to reflect the status of the Centre as a gallery, for storing, studying and displaying valuable artefacts and as a renovation project for energy efficiency. Three standards were used as the criteria for the assessment, British Standards BS 5454, PAC design target and the relaxed control with seasonal variation (Table 1). British Standards BS 5454 is the most stringent, representing the tightest indoor microclimatic control for both the preservation of collections and human thermal comfort. The third standard is a result of long discussion in the industry, with a relaxed control floating within a seasonal change for energy efficiency without sacrificing quality to meet the requirements of housed collections (Ganguly et al., 2015).

This control strategy is to allow the two environmental variables, the temperature and relative humidity, to float in response to outdoor conditions but to limit the rate of change in the variables. Typically the room temperature would float between 18-23C and relative humidity (RH) 40~65% and the RH is limited to 3% change in 1 hour and 15% in 24 hours (Harley Haddow, 2014). Making subtle changes to the space temperature to offset fluctuations in RH is far more economical than running humidifiers or de-humidification cycles. Similarly, allowing the gallery spaces to float within this wider control band maximises the benefit that can be gained from the thermal mass of the building.

The two key environmental variables, room temperature and relative humidity, were measured in two spaces selected as representative from the two zones: Area 10 (Collection 4) in the old pier warehouse, representing a high quality environment and Area 12 (Gallery 4) a two-level space, also used as a multi-function space in the new building link on the first floor of the new building (Fig. 1d). The parameters were recorded using TinyTag sensors with a sampling rate of 15 minutes over the period of October 2014 to November 2015. The data

was checked against BS5454 to secure PAC international status in gallery and museum industry. Then the data was checked against the design standards for see if the target was met. When the ‘relaxed’ seasonal strategy for control was applied, the extra variables were used to reflect quantitatively the fluctuations in time of the indoor temperature and relative humidity, the two common variables. They are the hourly fluctuation parameters: ΔT_{1H} and ΔRH_{1H} , and the daily fluctuation parameters: ΔT_{24H} and ΔRH_{24H} and are defined as follows:

$$\Delta T_{1H} = T_n - T_{n-1}$$

$$\Delta RH_{1H} = RH_n - RH_{n-1}$$

$$\Delta T_{24H} = T_{d,max} - T_{d,min}$$

$$\Delta RH_{24H} = RH_{d,max} - RH_{d,min}$$

where T_n and RH_n are the temperature and relative humidity at n^{th} time interval; T_{n-1} and RH_{n-1} are the temperature and relative humidity at the $(n-1)^{th}$ time interval; $T_{d,max}$ and $RH_{d,max}$ are the daily maximum value for temperature and relative humidity, respectively; $T_{d,min}$ and $RH_{d,min}$ are the daily minimum values for temperature and relative humidity respectively. They quantify the environmental stability of a gallery space, when the T and RH are allowed to gradually move out of the safe zone that are defined by the stringent standards (Ganguly et al., 2015).

2.3 Energy Performance Assessment

A comprehensive assessment of environmental impacts was far beyond the scope of this study, which focused on the main environmental impacts due to energy consumption and its consequent carbon emissions for running the building and its activities. This focus was justified by the fact that galleries are always energy intensive, as it was explained earlier, and also numerous projects are assessed mainly using these two indicators for measuring their main environmental impact (Niemelä et al., 2017, Serrano-Jimenez et al., 2017). Hence only energy performance and carbon emissions were considered. The assessment was derived, in part, from a review of European methods (Corgnati et al., 2009, Corgnati and Filippi, 2010) and was used to gauge the Centre’s energy impact as well as to identify issues that could be causing the gallery to consume more than necessary.

The majority of the analysis focused on the centre's HVAC system, since energy use in this area was expected to be high, due to the stringent indoor environmental conditions required as an art gallery (Mazzei et al., 2005). The review of assessment procedures identified four tools to be used in the Pier Arts energy performance assessment: benchmarking, energy performance modelling, degree-day analysis, and thermal imaging.

The energy data of the PAC was compared with the benchmark figures for similar buildings (43 galleries and museums in the UK) published in CIBSE Guide F (2012), Energy Consumption Guide 19 (Action Energy, 2003), IAMFA (McClanahan, 2013), and a number of data on gallery buildings from Display Energy Certificates (DEC) in the UK (CIBSE, 1999). Neither the PAC nor the DEC data was adjusted for weather bias, so degree-days were used to normalise the data and provide a more valid benchmarking comparison. This normalisation was achieved applying methods from CIBSE's TM41 (2006). Having determined the Centre's energy consumption, government greenhouse gas conversion factors (DEFRA, 2015) were used to conduct a parallel comparison of equivalent carbon, between the PAC and the DEC data. This national average figure was higher than the actual factor in the area, as Scotland has more renewable input to its national grids.

Due to lack of split benchmarking figures (lighting, cooling, small power, heating etc.), a dynamic thermal model of the PAC was created to simulate energy performance for the service systems in an occupied building (Jradi et al., 2018). The Centre's construction, building services, operation, and location data were input into IES-VE to devise a thermal model (IES, 2018). The benchmarking and energy modelling were devised to gauge and to find broad areas of overconsumption. The degree-days analysis and thermal imaging survey attempted to identify more specific issues, to give the Centre the opportunity to reduce consumption, and therefore energy costs, as well as emissions and other harmful impact on the local and global environment.

Heating degree-days (HDD) were used as a measure of how much heating was required, calculated from the difference between PAC's base temperature and the external temperature, over the analysed time period (Lewry, 2012). By plotting this theoretical figure against the Centre's actual consumption, the efficiency of the heating system was determined, since these two variables should follow a direct relationship (Layberry, 2008). Humidity is not included in the HDD calculation, which was therefore limited to analysing the underfloor heating only, and is not a suitable tool for analysing the latent load or overall efficiency of the air conditioning systems.

3 Results and discussion

3.1 Social and cultural assessment

As mentioned in Section Two, three groups of indicators are used to measure the social impacts: the numbers of exhibitions and visitors, education events and partnerships and charitable activities. Each of them is plotted over the period of time being examined to show its trend.

3.1.1 Social/cultural indicator I: Exhibitions and visitors

The Centre's floor area was about 420m² before the redevelopment. Since then it has expanded to 1,023m² as the new link has been built to connect the two historic buildings. As a result, the extension area made it possible to host more temporary exhibitions in the centre as well as other activities earning rental fees where this economic benefit is mentioned in the economic indicators section. There were only three exhibitions before the renovation in 2006. But the figure rose to eight after the renovation in 2008. Since then, the number of temporary exhibitions has remained at 11 and above, an almost fourfold increase (Fig. 3). This is evidence that the renovation has accomplished the Centre's main aim to a large extent.

The increasing number of temporary exhibitions brings visitor number growth, which is another major achievement for the renovation as the growth promotes consumption in the local area, stimulating a wide range of businesses. The financial benefits are analysed in the economic indicators section. As per TNS Travel & Tourism report (2005), there were 127,200 total visitors spending £26.6m in Orkney in 2004. The annual visitor numbers of the PAC reached 22,000 (Hartley and Peebles, 2004), which is 17.3% of the total visitors in Orkney. During 2008-2009, there were 141,172 total visitors in Orkney, of which 30% had visited the Centre (AB Associates, 2010). The latest Orkney Visitor Survey produced by Scotinform (2014) shows that a total of approximately 142,000 visitors came to Orkney during 2012-2013 due to a series of campaigns and promotion on boosting local tourist industry. As shown in Fig. 3, there were 52,375 visitors to the Centre in 2013, meaning that 36.9% of the total visitors to the region had visited the Centre.

All these figures demonstrate that the visitor numbers grew rapidly between 2004 and 2008. The growing number of visitors can at least partly be related to the redevelopment of PAC, a high-profile project designed as a major tourist attraction in a series of campaigns operated by

the local authority to promote the area. The growth was further enhanced by the promotion campaigns and series of high-profile events and exhibitions during 2011-2013. It can be expected that these extra visitors are also spending locally in ways that benefit the local economy, thereby exerting a multiplier effect on other businesses, as well as increasing the area's visibility in international tourist rankings. The visitor number dropped after 2013 in PAC whilst there were increases in other tourist interest sites such as St Magnus Cathedral and the Italian Chapel, both showing over 30% increase from 2011 to 2015 (Staiano and Matthew, 2017). Thus, it can be concluded that the PAC, as a flagship project, drew people to Orkney as a tourist destination and increased visibility of other notable tourist destinations on the island. Overall the Centre is believed to be making a noticeable contribution to the tourism industry in the region.

3.1.2 Social/cultural indicator II: Education

As stated by the centre's former director, the education and research events played a key role in the re-launch of the PAC. The annual reports in 2006 and 2007 showed that there were more educational and research activities organised or directly supported by PAC after the renovation, including New Artwork Fund, Creative Scotland traineeships, Artists' Rooms, etc. Besides, the Centre co-operates with Higher Education Institutions in Orkney to make its collections contribute to academic research (Fig. 4). These type of events faithfully reflected the nature of the Centre as part of the fabric of a local cultural history of art and craftsmanship. There is also a library, which contains a unique collection of art books and catalogues. All of these facilities support the new service scope of an expanded PAC. Education events and participant numbers, not only of local residents but also outsiders and visitors, are key indicators of PAC's contributions to social and cultural resilience and sustainability. Clearly these increases also suggest a strong enhancement to local cultural life as well as wider influence, and are therefore a positive impact which is clearly linked to the redevelopment.

3.1.3 Social indicator III: Partnerships and charitable activities

The increase of visitor numbers, education events and exhibitions have attracted more partners in the region and far beyond, with collaborations between the Pier Arts Centre and other arts and crafts related organisations and institutes. This indicator shows the number of partners sponsored by the Centre in selected projects. There was only 1 sponsorship before the renovation, which jumped to five in 2007 before full completion of the renovation (Fig. 5).

These sponsorships in turn lead to economic benefits, which are discussed in the following section. Thus, we see a dynamic of building renovation leading to more visitors, greater cultural contribution and economic benefits, illustrating a virtuous cycle of sustainable development among the three accepted ‘pillars’.

Charitable activity is another major contribution of PAC to the local community. After the redevelopment in 2007, the expenditures on charitable activities increased over 1.8 times compared to the previous two years and remained relatively constant. This means the redevelopment led not only to an increase in visitor numbers, but also positive socio-cultural benefits for the local population in the shape of these charitable activities, thus showing that the PAC is ‘giving back’ to the local community and strengthening Orkney’s socio-cultural sustainability and sense of community, which also contributes to community resilience (Sharifi, 2016). As recorded in PAC’s annual reports, there have been volunteer opportunities and workshops for all ages since 2013. Moreover, the PAC also supports emerging and young artists with a number of training and career opportunities. Aforementioned activities help decrease the unemployment rate, as well as up-skilling the local population, a key function in remote and rural areas of Scotland where a large section of the population may lack access to educational and cultural opportunities locally.

3.2 Economic assessment

Three indicators were used to measure the economic impacts: employment profile, incomes and costs.

3.2.1 Economic indicator I: Employment profile

With the increased size and various abovementioned activities, the Centre has created a wide range of jobs to meet the increasing needs in various areas. The redevelopment also created new office space to accommodate more staff members. The number of full-time staff increased in the first five years from five to nine (Fig. 6). After the adjustment period, it stabilised at around ten people up to 2017. The staff profile and annual reports all suggest that there are 2-3 part-time jobs each year, which is also the reason for the decreasing capital income to the Centre. As the renovation expanded the floor area and extended the functions, more part-time working opportunities have been provided. This part-time work is also a socio-economic benefit to the local economy brought by the redevelopment.

3.2.2 *Economic indicator II: Incomes*

The redevelopment provided the buildings a full access to the centre's three units, which not only doubled the display space, but also created a gallery shop. Therefore, with expanded display area, the grants, including the subsidies from the government and funds sponsored by partners, increased rapidly (Fig. 7). In the first two years, the grants were £147K and £257K, but the figure rose remarkably to £292K immediately at the completion of the redevelopment in 2007. After that, the grants reached £348K on average for the following eight years, which is more than the sum of the first two years' core activities income.

The gallery shop established by the redevelopment also increased its sales. The trends of sales and rental incomes reveal the revenue growth after the redevelopment. The average net sales income was above £23K for 2008-2017, double the figure before the redevelopment. The income growth after the renovation clearly shows a positive impact to local economic sustainability.

3.2.3 *Economic indicator II: Costs*

The increased floor area could affect the management fees and utility costs, but the costs were not clearly recorded in the reports and therefore they were considered as general management costs. This indicator shows fluctuations, with a figure of less than GBP1K in 2009 and a peak 5K in 2013, but no overall statistical change in the management fee and utility costs (Fig. 8). The corresponding energy cost will be discussed together with the environmental impact in Section 3.4.

The decreasing expenditure in advertising and publicity reflects the increasing popularity of the Centre (Fig. 8). As the renovation attracted more partnerships and more partnerships brought more funds, the virtuous cycle helped the Centre bolster its reputation. This also suggests that the abovementioned income growth is intimately correlated with the redevelopment instead of publicity activities.

After this analysis of the data on social, cultural and economic impacts, a discussion proceeds on the results concerning the physical and environmental performance and impacts of the building, as these are also key aspects of PAC's contribution to sustainable development.

3.4 Control and Indoor quality

The indoor environmental condition was assessed using the two hygro-thermal parameters, the room temperature and RH as well as their hourly and daily fluctuations in the two areas, Area 10 representing the collection spaces in the renovated old building and Area 12, the built gallery spaces.

The two parameters over an annual period are presented together with the fixed RH control (blue-shaded area) and fixed T control (red-shaded area) corresponding to BS5454 standard in Fig. 9. The data shows clearly both the daily and seasonal fluctuations. In both the recorded areas, apart from the drier winter months, the indoor conditions were primarily very humid and seldom dry with respect to the standards, even reaching an extremely high level of 75% RH for a considerable duration of time. In Area 10, the temperature was at a considerably low level (around 12°C), for almost the entire winter months. This led to high relative humidity, which should be avoided if valuable collections are housed there. In Area 12, representing the galleries, the indoor temperature was better controlled, as it can be seen that much of both the T and RH are within the accepted bands. The results shown in Fig. 9 also suggests dehumidification should be increased in the system during the summer seasons in both areas.

Table 2 summarises the indoor environmental assessment results with three standards and Fig. 10 presents the control quality measured by the percentages of hours when the room conditions fell in the safe zones defined by the two sets of standards: BS5454 and Design specifications respectively. With respect to the tight BS5454 specifications, the indoor temperature and RH in Area 10, the old building, were within the zone only 7% of the time over the period of investigation (the yellow box, top, Fig. 10). This figure raises to 35% in Area 12, the new building, which means the spaces in the new building were much better controlled.

When compared against the design specifications, the percentages are much higher (the two seasonal boxes, Fig. 10). The control was much more successful, 56% in winter and 12% in summer in the old building and 86% in winter and 73% in summer in the new building. In both areas, the control was better in winter as the air contained less vapour and the control was poorer in summer as more moisture needed to be removed. This suggests that the room quality in the collection areas should be improved by removing moisture during the summer time.

As the figure shows, there were hours when the conditions were out of the safe zones, especially in the old warehouse. Such a gap between the design expectation and the actual achieved performance is common, as is pointed out in the literature (Zero Carbon Hub, 2014) due to a number of causes. The major factor is a lack of fine-tuning after the completion, especially in a system where both thermal and moisture need close control. Fine-tuning of the system would take a couple of years to achieve a satisfactory result, and hence it is expensive and often neglected in many projects.

When compared against the relaxed seasonal specifications, the control was fairly satisfactory too (Table 2). The safe condition percentage in the old building was 12%, 41% and 11% respectively in winter, mild seasons and summer. The percentages were even better in the new building, 79%, 43% and 85% for the three seasons.

As mentioned in Section Two, the relaxed control relied on control fluctuation. Hence the hourly fluctuation was applied as an additional indicator in this assessment, the results of which are very encouraging. This indicator in both Areas 10 and 12 was well within the limits specified by the standards (Fig. 10). The daily fluctuation, the other indicator for control quality, shows an excellent fit. Both areas were well maintained throughout the year with just one case of extremity in the daily RH fluctuations in both the areas in the month of May (Fig. 11).

On comparing the control quality in the two areas, the new building (Area 12) is much better than the old building (Area 10). Area 10 experienced more often high humidity and cold with respect to the standards. The major cause was due to the poor condition of the external walls, which featured voids in the joints between masonry work due to weathering and decay. Consequently, undesirable water ingress occurred, leading to interstitial dampness and consequently poor insulation. The effects can be seen clearly in Fig. 12: the room was

constantly under-heated in the winter as a result of poor insulation and with high RH due to moisture ingress. Repointing the masonry work should be the first remedy to be applied.

An overall better control was observed in Area 12, due to the new construction with better insulation (the glazed parts had a U-value of $1.1 \text{ Wm}^{-2}\text{K}^{-1}$) and air tightness in the building envelope. Its interior was therefore relatively less influenced by the outdoor weather and more easily controlled with high satisfaction, when compared with the old building. The gallery spaces in this part would house prestigious collections on loan from important sources.

Area 10, on the other hand, in an old construction could serve as a permanent collection area mainly for local artefacts and less prestigious collections. Such a control of various levels of quality could be a practical solution for best balance between quality control and energy saving. After repointing, other remedies could be tested. A simple basic heating practice, known as conservation heating, could be an effective solution, as low level heating to raise room temperature could reduce the relative humidity, even though it would inevitably raise heating costs. Revising the control of the Air Handling Unit (AHU) should be carried out to increase dehumidification in summer seasons. All of these measures would, however, inevitably increase energy costs.

3.4 *Environmental impact*

3.4.1 *Energy performance*

The results of the energy benchmarking show the Centre to be close to typical consumption, with a value of $10 \text{ kWh}\cdot\text{m}^{-2}\text{yr}^{-1}$ below the CIBSE Guide F figure (Fig. 13). This suggested that the Centre was performing well in terms of energy efficiency, particularly since the total energy use was $127 \text{ kWh}\cdot\text{m}^{-2}\text{yr}^{-1}$ below the gallery-specific DEC data.

The thermal dynamic modelling confirmed the energy benchmarking results, although the actual PAC consumption was 11% below that estimated by the modelling (Fig. 14). This low value of the actual consumption was primarily caused by less under heating and insufficient dehumidification, as previously discussed. The difference between the actual and model estimation would be unnoticeable, when the room control is improved.

A closer look into Fig. 13 suggests that PAC consumptions are $30 \text{ kWh}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$ and $33 \text{ kWh}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$ higher than good practice benchmarks, which would suggest some effort could be made on heating to reduce RH, and on lighting to reduce this part of consumption.

3.4.2 Carbon emissions

Comparison of PAC's energy performance and carbon performance with 43 the buildings with DEC data reveals the PAC being the 13th best in the energy efficiency, a very good results. Its position dropped to the 28th in the list for carbon emissions, despite its low energy consumption. The position was calculated using the UK average carbon conversion rate of $0.41 \text{ kgCO}_2\text{e kWh}^{-1}$. It drops further to the 29th, when the local conversion rate, $0.46 \text{ kgCO}_2\text{e kWh}^{-1}$ is used (Orkney Islands Council, 2016). This shows a poor performance in terms of carbon emissions due to full reliance on electricity for the entire system operation, including space heating. However the rating will be improved in the future as the region is increasing its use of renewable sources for power generation, as a result the conversion factor should be potentially lower than the national level.

3.4.3 Monitoring Heating Performance

The degree-days analysis of the submetered heating found a poor relationship between HDD and energy consumption (Fig. 15). With all 11 available values considered, the correlation is very poor, suggesting the heating was affected not only by the weather, but also a number of factors, from change in temperature setpoints, air changes, variations in internal heat gains, and above all, occupancy and usage. Having noted a gap in the consumption of 1,327 kWh between the weekly heating loads corresponding to HDD 30 and 32 degree-days, an inquiry revealed that the week of 32 degree-days with a much lower heating load was before Christmas and the Centre was only partially open and heating was shut down deliberately in those unoccupied spaces. The other week, was after New Year, a lot more activities taking place, which resulted in a high heating consumption. This suggests those common and simple measures for energy saving could make a significant difference in optimising operation for quality condition and energy saving. Monitoring system load together with HDD could allow the management team to act proactively to apply those simple energy saving measures to improve energy efficiency.

3.5 Summary of Assessment

Table 3 presents the appraisal that summarises the discussions above and the verdict is made for 22 indicators in three grades: increasing or good; no change or acceptable or fair; and decreasing or poor. No scoring and rating were attempted.

4 Reflections and Conclusions

Based on the wide range of data collected and analysed, this paper now draws the following conclusions. Firstly, it is possible to have a method for the multifaceted assessment of the impacts of a renovation project of historical buildings in relation to local economic, environmental and social/cultural sustainability. The assessment approach can be developed tailored to the nature of a project that focuses on art and culture as well as to the existing literature and existing methods. The overall assessment is based on an exhaustive collection of data and examining the trend of each of a number of quantifiable variables as indicators of sustainability over three widely-accepted aspects, social, economic and environmental. Secondly the assessment applied to the PAC shows how the physical and architectural redevelopment of a ‘flagship’ building in a rural and remote community can support wider community development and sustainability goals. Also it suggests how the building renovation and expansion project itself stands as a catalyst for a number of local benefits. Furthermore, discussions of the assessment exercise suggest how PAC’s approach can be used as a source of inspiration for building redevelopment in other places is provided, so as to emphasise the wider lessons from this case study. This is another contribution of this paper to the literature on building redevelopment in context.

Social, cultural and economic impacts: our study clearly shows a positive contribution to local social, cultural and economic indicators, measured through employment figures, and increased visitors to the island and its attractions, providing a multiplier effect on local businesses. According to Andersson (Andersson, 2014), there is a ‘halo effect’ from this flagship project that has beneficial repercussions for other attractions on the island. The cultural benefits also include putting Orkney more firmly ‘on the map’ within the increasingly-competitive Scottish and international tourist market, where localities need to provide clear USPs (unique selling points) to differentiate themselves within a context of competition between places for people’s attention. Cultural projects such as PAC also fit into current discussions on the ‘creative class’ (Florida, 2004), whereby nurturing local cultural

assets and attracting new talent in this field is seen as crucial. Socially and culturally, PAC also provides a point of pride for the local community, on the one hand, and can help in retaining educated staff in a specialised field of employment, as well as training future experts in the fields of arts and conservation, on the other hand. Functioning as a gallery its role is evident in social and cultural resilience, either in promotion of the appreciation of the local art and craftsmanship to outside world and engaging local residents in various education activities to enhancing these unique traditions. These social, cultural and economic aspects are clearly correlated with the redevelopment of PAC and its successful operation for a decade now, showing that the physical renovation of an iconic, flagship building can indeed be a linchpin for wider sustainability benefits, especially in a rural and remote community. Due to the relatively modest sums expended on the project, it is suggested that this approach is indeed replicable in other locales in Scotland and abroad. Key factors in a successful replication include:

Sensitivity to building integrity and cultural context: prioritise preservation as much of the old structure as possible, whilst deploying vernacular architectural approaches and mobilising local building materials, to ensure a good fit within the local and historical context. This can also contribute to reduced emissions from the building process, due to lesser use of virgin and/or imported materials. Approaches to building design based on vernacular knowledge are also likely to be more environmentally sustainable within their local context, as evidenced by hot country designs that incorporate design elements such as shading, reduced glass surfaces and proper orientation to wind patterns (Hebbert and MacKillop, 2013). Lastly, place-based design including using local materials may also contribute to greater local acceptance and pride vis-à-vis the building, which can become a local icon.

Prioritising the core mission of the building: many building development and redevelopment projects aim for the spectacular, sometimes at the expense of the day-to-day mission of the building, with sometimes awkward shapes or poor building performance as a result. This has happened with a number of ‘starchitect’-led projects (Kozłowska, 2015). On the contrary, PAC prioritises the good preservation of historical buildings and valuable artefacts, whilst providing new community and office spaces to support an expanded mission in the community. In this sense, the renovation will be more sustainable in the long run, whilst requiring fewer costly maintenance measures. This is particularly relevant to developing

country contexts (or low-income areas of developed countries), where building maintenance costs can be crippling and can compromise the building's mission in the long run.

Flexible design approaches: the renovated PAC features multi-use spaces that can support gallery, retail, office and community activities. In this sense, it has moved beyond being 'merely' a museum to becoming a more vibrant, open and inclusive space, where a large section of the local and external community can feel welcomed for a variety of activities. A flexible approach in renovating a building can ensure greater impacts on the social, cultural and economic sustainability, as previously unforeseen activities can take place when other need to be scaled back due to funding or other issues that will inevitably occur over time. As time passes, new generations can also find their place within the building, which is not necessarily the case with buildings narrowly-defined around a single function. Lastly, this flexibility can contribute to environmental sustainability too, as it will require fewer demolition/construction operations, which have adverse environmental impacts.

Building performance aspects: the indoor environmental control assessment shows that the new building was performing satisfactorily and significantly better with respect to the old building although not up to the strict standard for art collection care. When looked through the relaxed seasonal specifications, the indoor environmental performance is very good, especially during the summer and winter months in the new building and during the mild months in the old building. Although this standard seems a little unsuited to a gallery space, this is considered as an optimal balance between the needs for quality control and energy economy. This also suggests that it is an effective way to maintain good indoor standard for the Centre whilst minimising energy consumption if the gallery spaces are zoned for different levels of standard, i.e. some under tight control and the rest under relaxed control. Finally, the control in the old section would surely be improved with repairs to its fabric and fine-tuning of the AHU. Thus, the building performance itself is good as a result of the redevelopment.

Environmental: the energy performance assessment provided positive results, as well as identifying some areas of improvement. The PAC outperformed the DEC UK museums and galleries benchmark by 39%, but was closer to typical consumption when compared to CIBSE guidelines. Its energy performance was listed on the top 13 among the 45 galleries and museums in the UK. Additionally, the Carbon Benchmarking of the PAC against the DEC dataset highlighted the negative impact of having electricity as the building's only

source of fuel. The thermal dynamic modelling suggested that the Centre was operating in an efficient manner. The actual performance, especially the room hygrothermal condition would be improved when the fabric repair is done. Therefore, while the verdict is mixed on some parameters, the renovation can also be described as successful in terms of environmental impact, thus contributing to greater sustainability, alongside the social, cultural and economic aspects discussed above.

Limitations and areas of future study

Some missing data is considered as a slight drawback in this study. Collecting the data is normally a part of the feasibility study for a redevelopment project, an essential part on the inspection at the project's completion, and often a part of management during the operation. Hence it is possible to gather all relevant data if such an assessment is agreed in the early stages of the redevelopment project and follow-on action is taken over a few years of operation.

The assessment approach consists of a dozen individual assessment issues spanning four core categories: the social and cultural, economic, environmental elements as well as building performance as an art gallery. Each of the assessment parameters has a simple verdict of three grades and no overall scoring is attempted. This is because devising such a weighting system itself would need an in-depth study and the system is apparently case dependant and each project would have its own main interests (ALwaer & Clements-Croome, 2010). A public building project or preservation of a historical building would place more weight on the social and cultural considerations, whilst new construction project would have different focus over those elements of sustainable considerations. Exploring weighting for assessment is suggested for further study.

An area that could benefit from further research and data, both for this specific case and other redevelopment initiatives, is a better understanding of the socio-political context of decision-making. Indeed, it is necessary to gain a fine-grained understanding of who decides the parameters of building redevelopment, and through what processes, such a procurement, tendering etc. Who are the specific actors in the local community (and maybe beyond, such as national and other levels of government) defining what the building will look like, at what

cost, and to serve what purposes? An understanding of these actors and processes, such as whether community feedback is requested or not and taken on-board can help us understand why certain projects deliver better sustainability results than others, and why some fail or present very narrowly-defined objectives. These aspects, in the case of PAC, would require further literature review, such as on the governance of urban renewal projects (Zhang et al., 2016, Peyramale and Wetzel, 2017) and more tailored literature (e.g. with reference to island, remote and rural communities for instance) and in-depth qualitative studies (such as interviews and focus groups) in Orkney.

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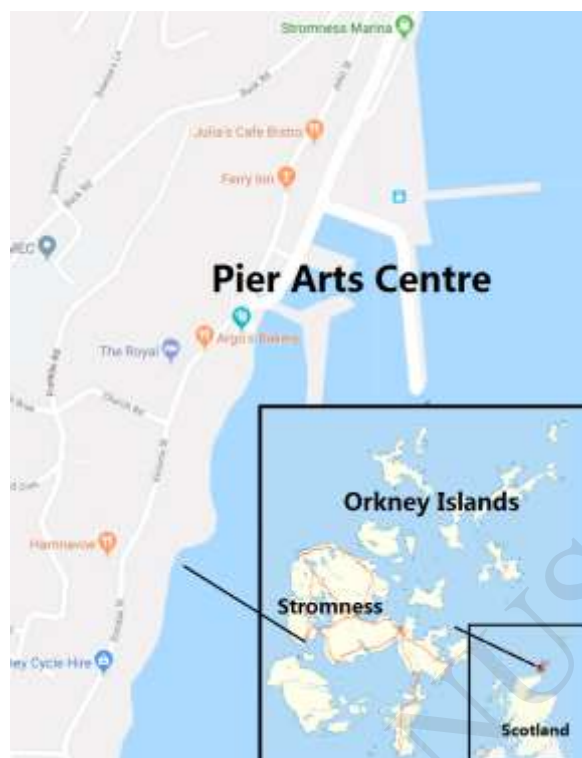
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Figures captions



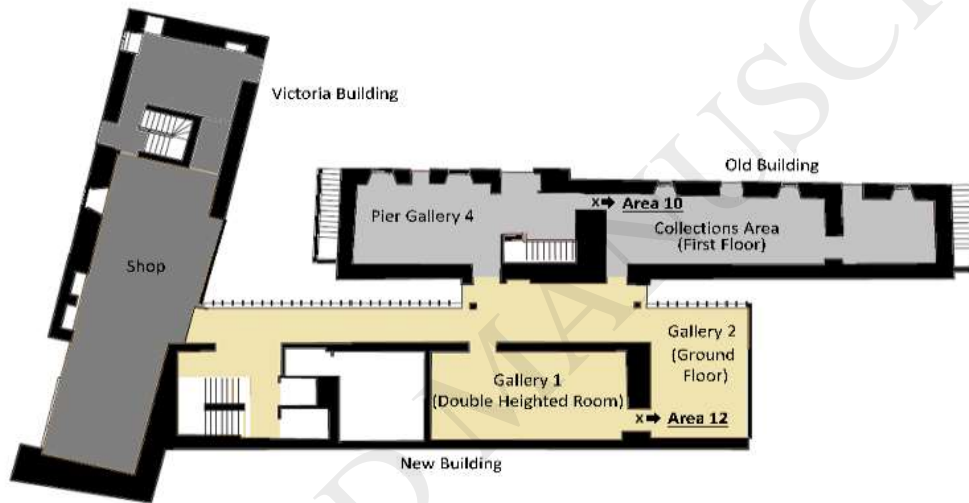
a) The location maps



b) The original buildings in 1930



c) The Centre in 2007 (Pier Arts Centre, Achieves)



d) The ground floor with the new building as a link (“x” marks the locations for the monitoring sensors)

Figure 1. Pier Arts Centre

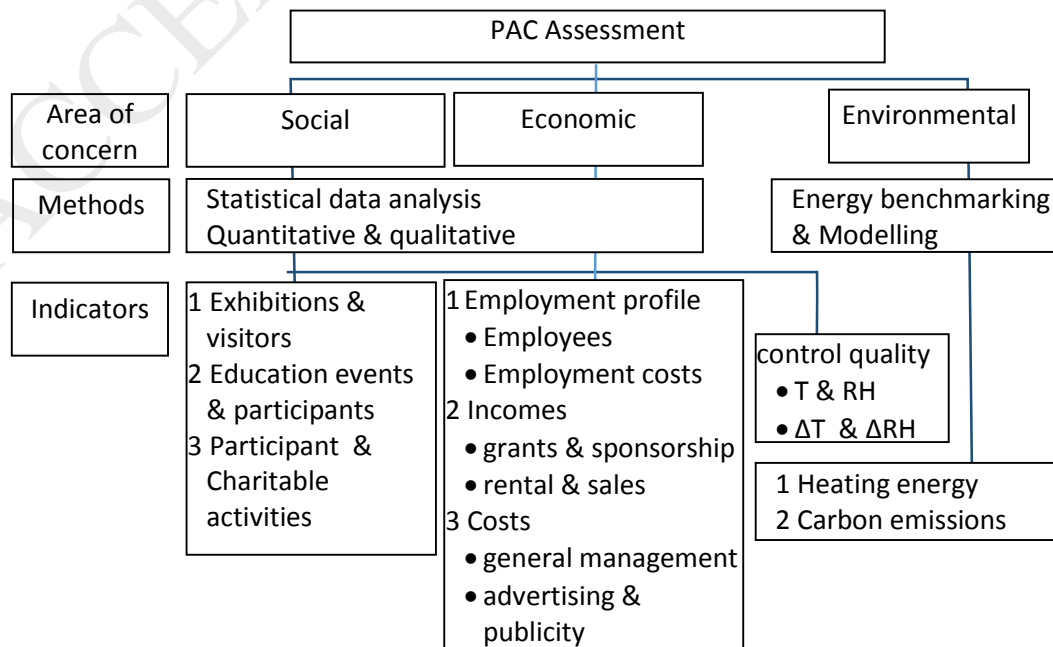


Figure 2. The structure of the assessment approach

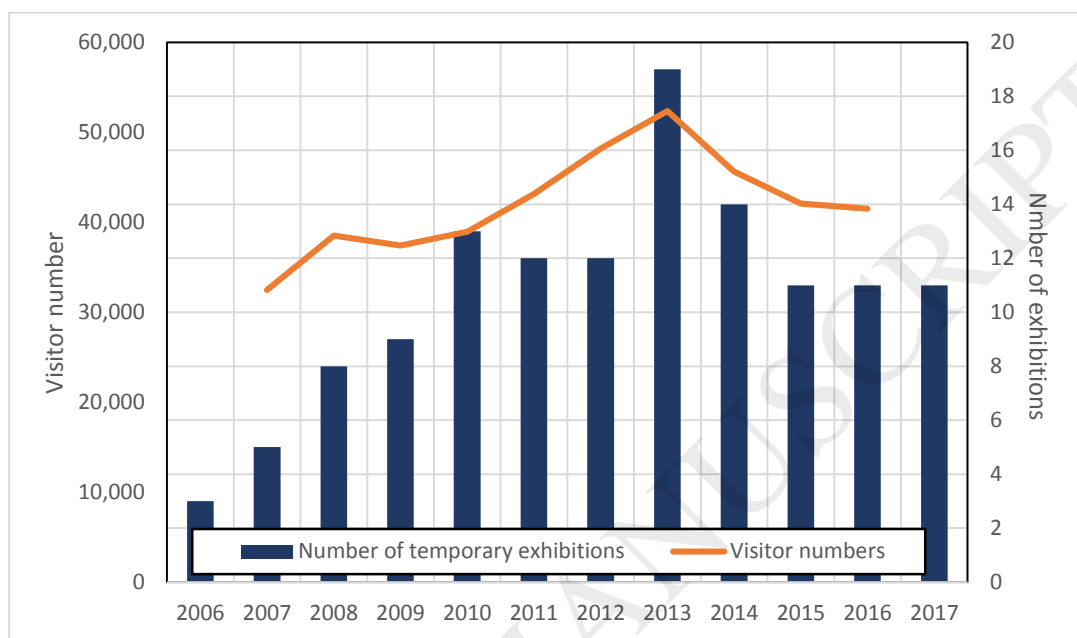


Figure 3. Visitor numbers and number of temporary exhibitions

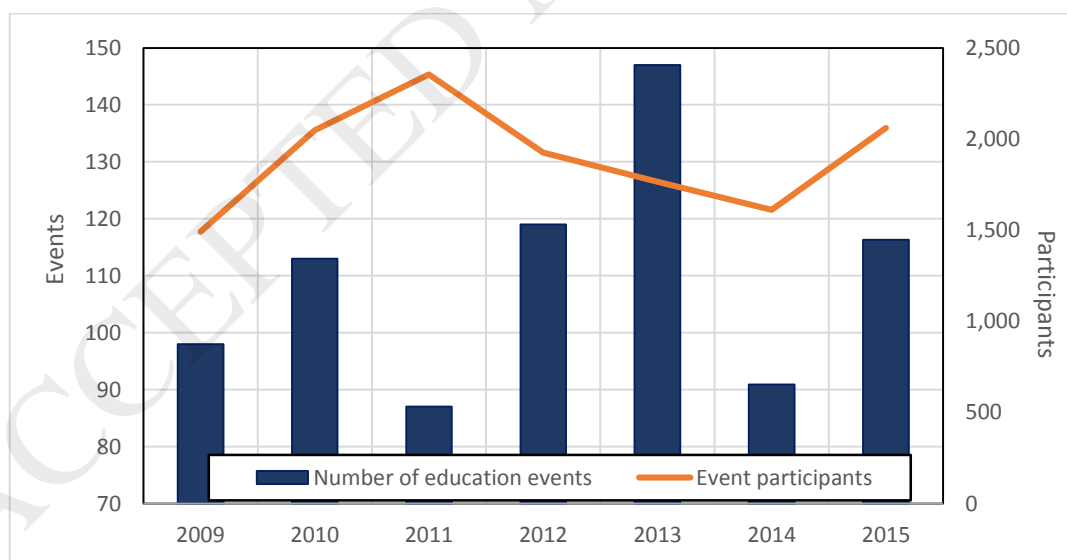


Figure 4. Number of education events and participants

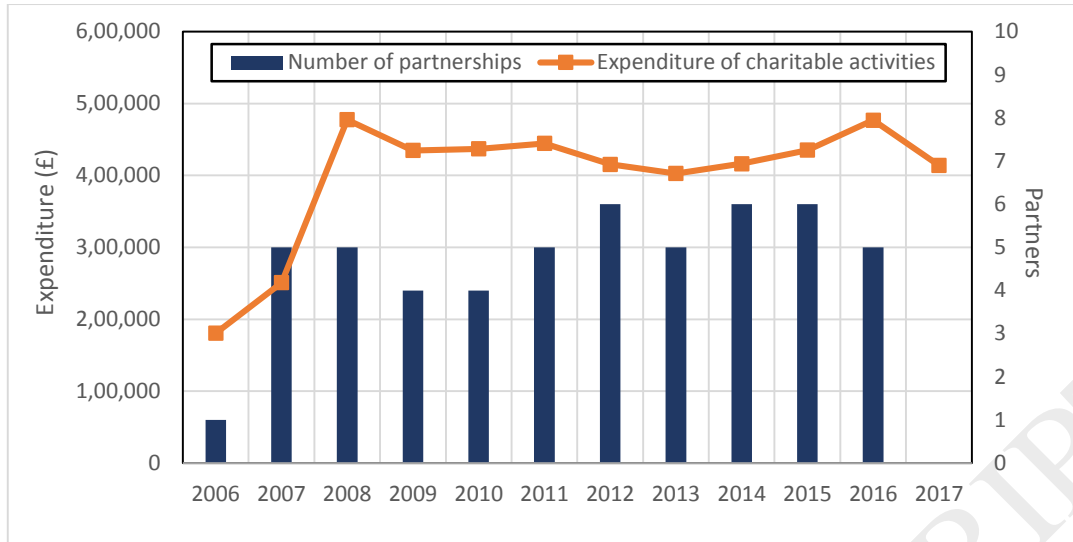


Figure 5. Number of partnerships (co-operated institutions, art associations or other authorities) and expenditure for charitable activities

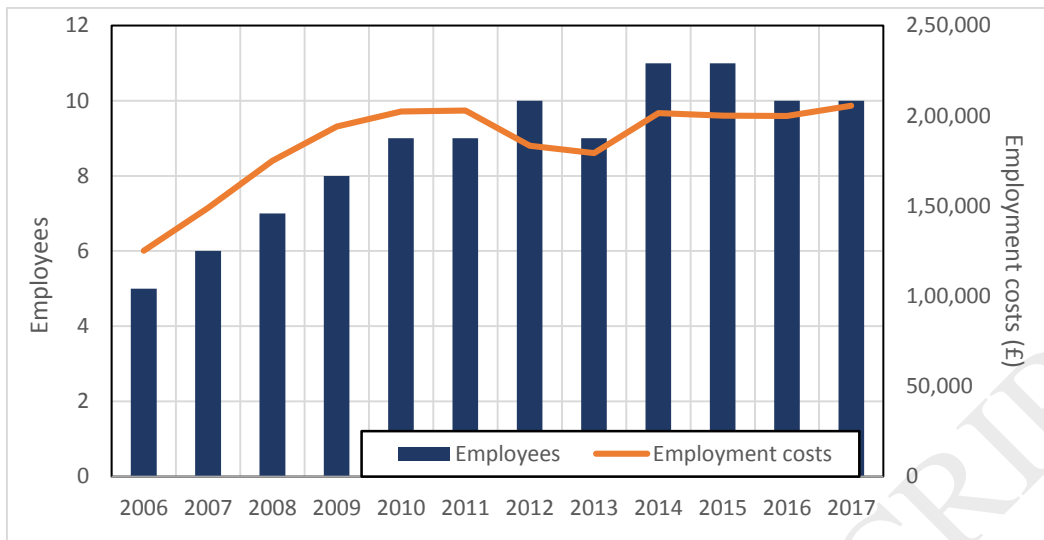


Figure 6. *Employees and employment costs*

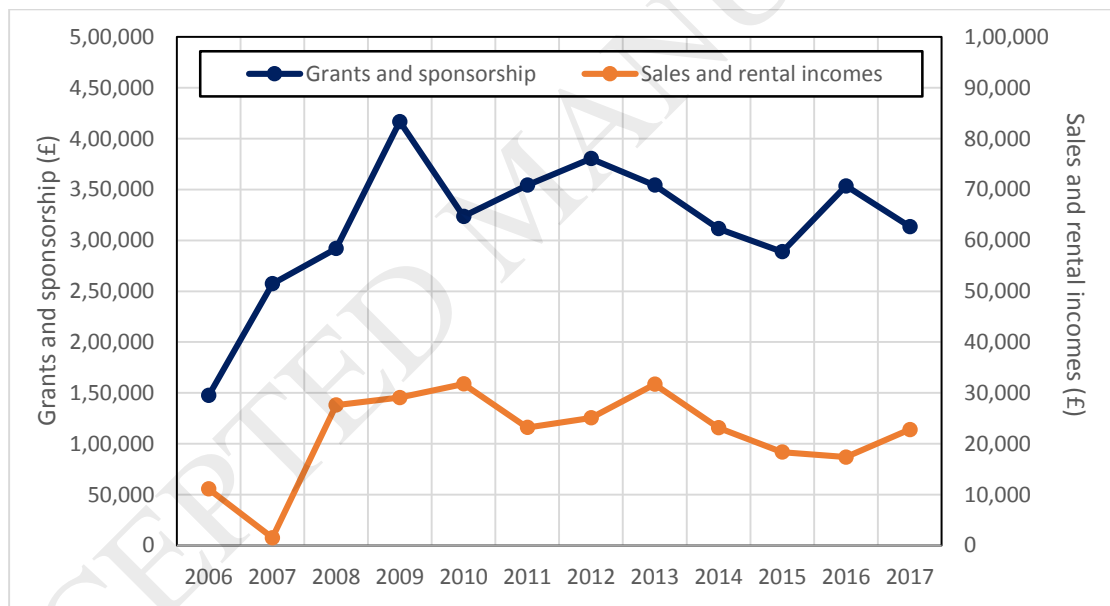


Figure 7. *Grants and sponsorship, sales and rental incomes*

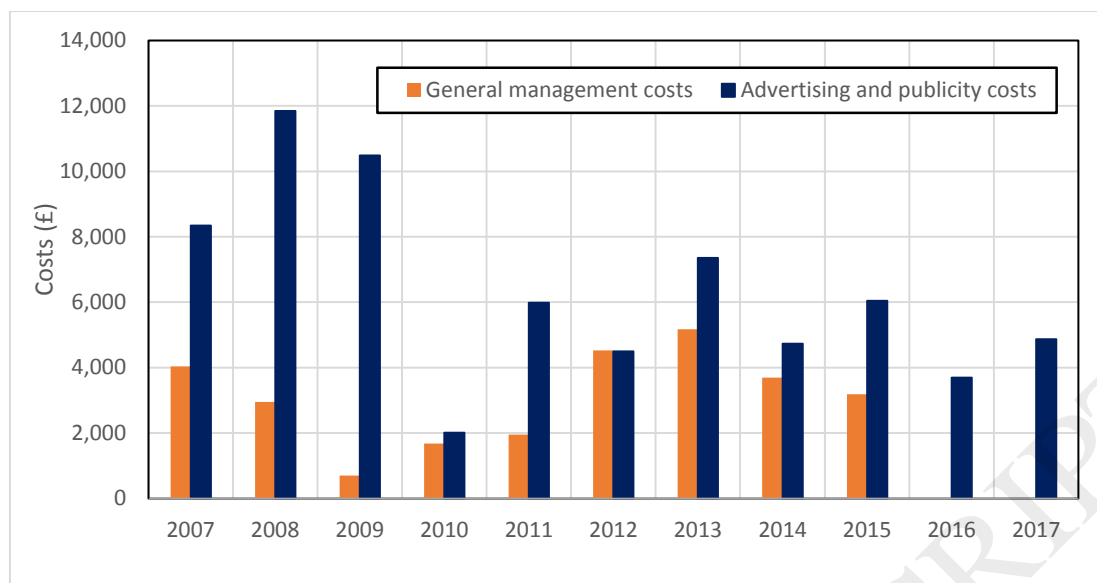


Figure 8. General management costs, advertising and publicity costs

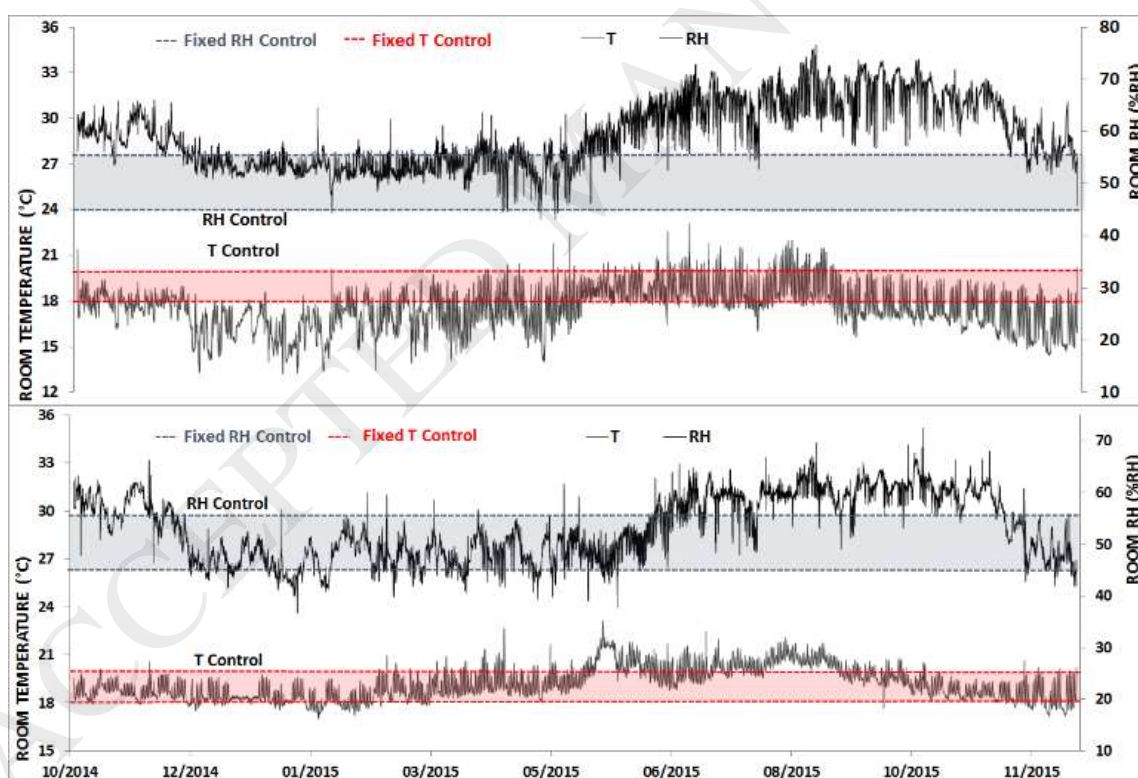


Figure 9. Indoor T and RH at gallery 10 (top) and 12 (bottom).

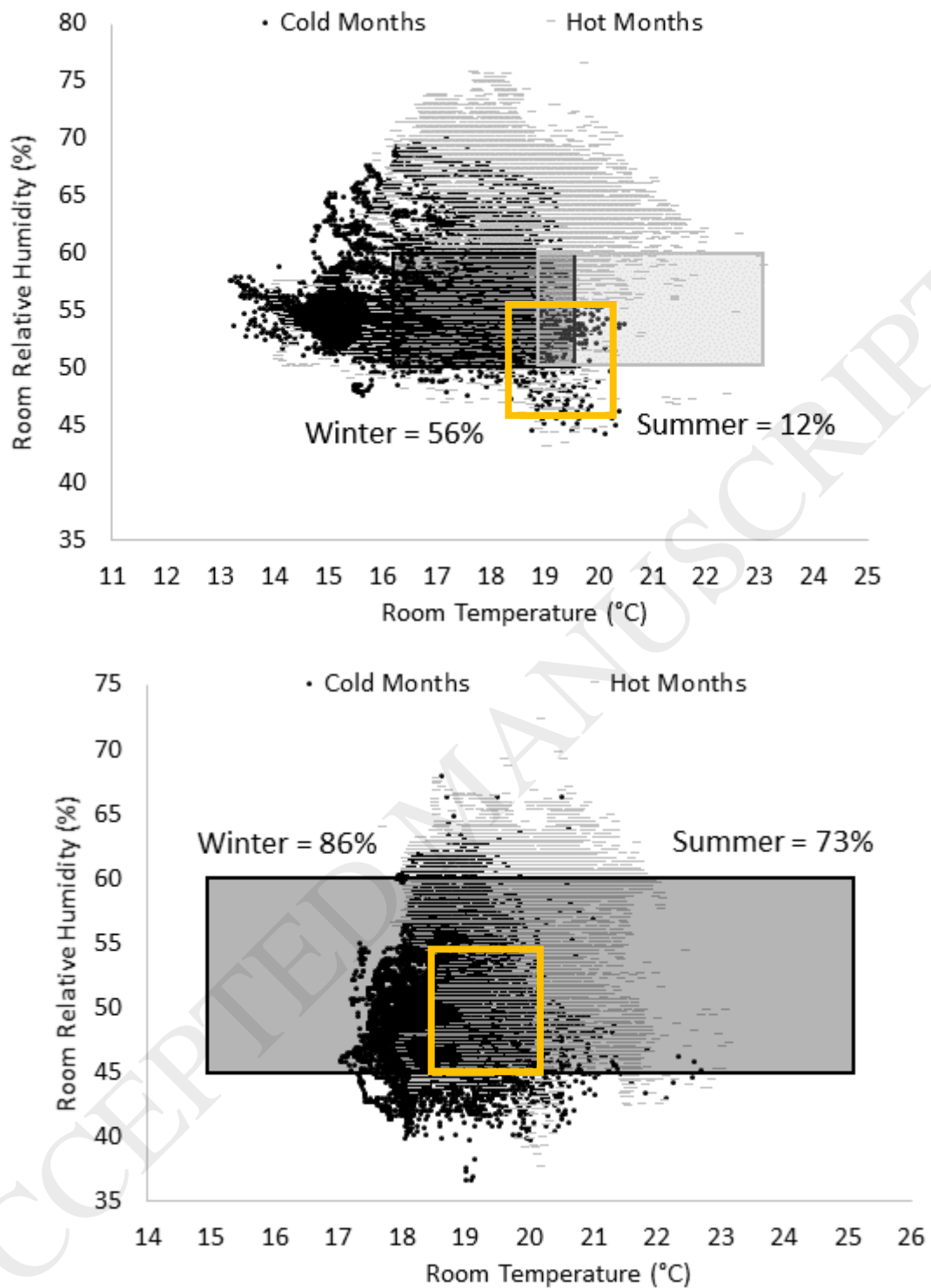


Figure 10. Measured indoor T and RH in Area 10 (top) and area 12 (bottom) against the Safe Zones defined by the strict specifications (yellow boxed) and the design one.

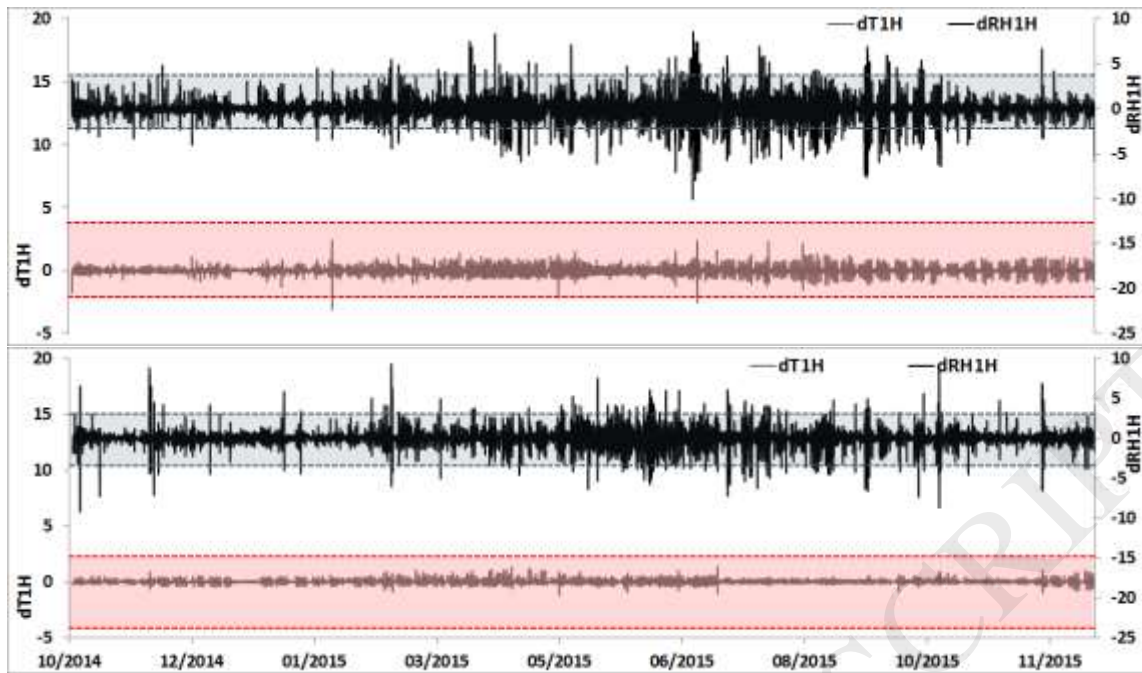


Figure 11. Hourly T and RH fluctuation parameters in Area 10 (top) and 12 (bottom).

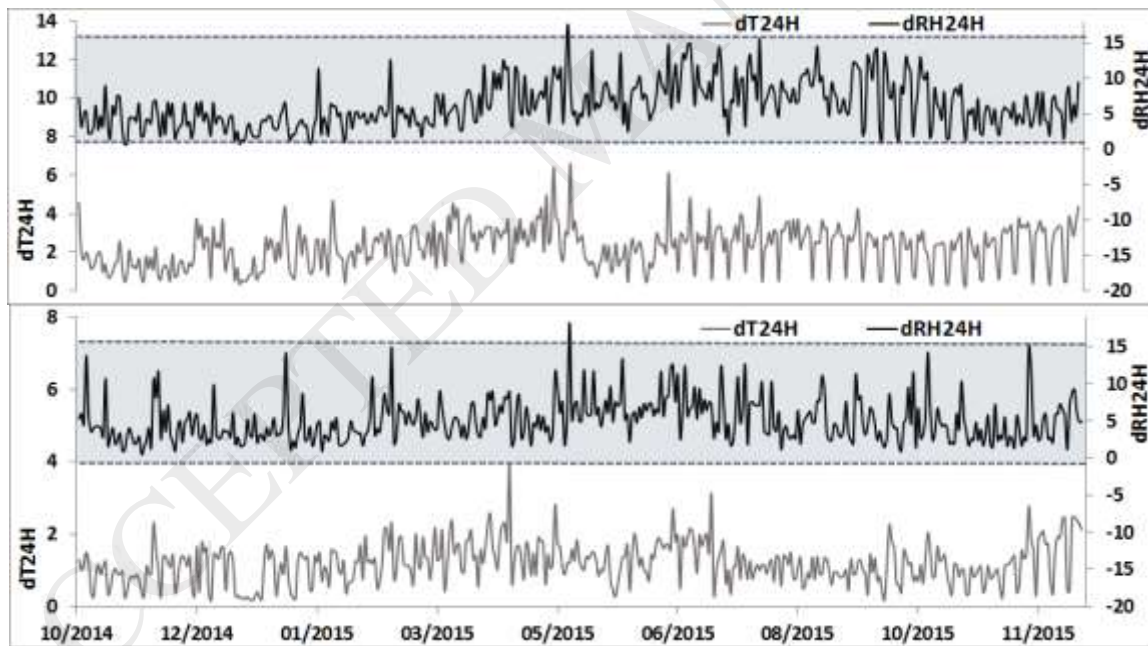


Figure 12. Daily T and RH fluctuation parameters in Area 10 (top) and 12 (bottom).

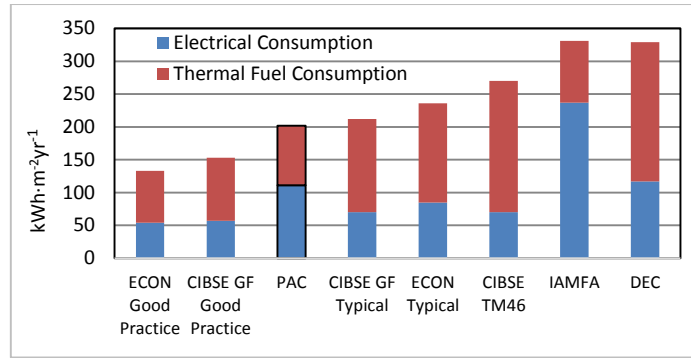


Figure 13. Energy consumption comparison to benchmarks

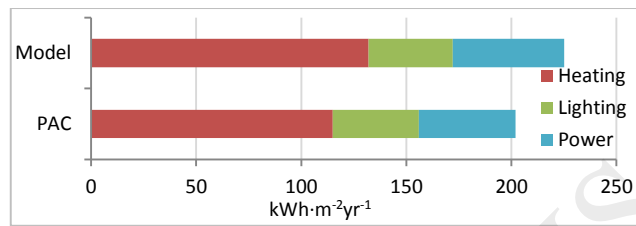


Figure 14. Energy consumption components derived from environmental model and PAC split.

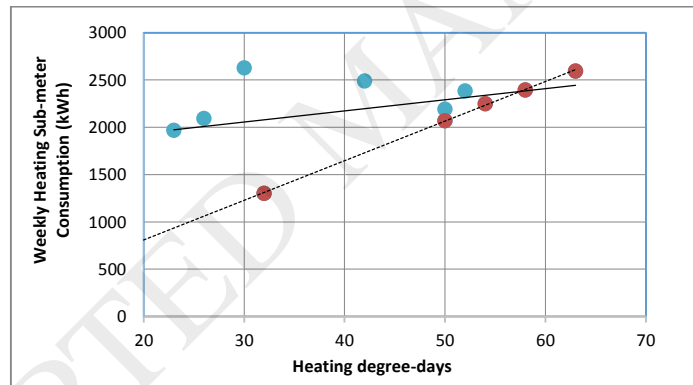


Figure 15. Heating sub-meter consumption against degree-days.

Tables

Table 1. Three sets of Safe Zone defined by the specifications for the three standards for Indoor hygrothermal conditions

| Standard | BS 5454 | Design Standard | | Relaxed Control |
|----------------|---------------------------|---------------------------|-------------------------------|---------------------------|
| | | Area 10 | Area 12 | |
| Annual (Fixed) | T: 18-20 °C RH: 45-55% | - | - | - |
| Summer | - | T: 15-25 °C RH: 50-60% | T: 19-23 °C RH: 45-60% | T: 18-21 °C RH: 41-55% |
| Mild | - | - | - | T: 19-22 °C RH: 45-60% |
| Winter | - | T: 15-25 °C RH: 50-60% | T: 16.5-19.5 °C RH: 45-60% | T: 20-23 °C RH: 47-63% |

Table 2: The percentage of the measured indoor T and RH within the Safe Zones defined by the three sets of specifications

| Standards | BS 5454 (%) | | Design Standard (%) | | Relaxed standard (%) | |
|----------------|-------------|----------|---------------------|----------|----------------------|----------|
| | 10 (old) | 12 (new) | 10 (old) | 12 (new) | 10 (old) | 12 (new) |
| Area | | | | | | |
| Annual (Fixed) | 7 | 35 | - | - | - | - |
| Summer | - | - | 12 | 73 | 11 | 85 |
| Mild | - | - | - | - | 41 | 43 |
| Winter | - | - | 56 | 86 | 15 | 79 |

Table 3. Summary of the overall assessment of the PAC.

| | | Indicator measures | Verdict |
|-------------------------------|---|-------------------------|------------|
| Social/ cultural Impact | Indicator 1: Exhibitions & visitors | Temporary exhibitions | Increasing |
| | | Visitor numbers | Increasing |
| | Indicator 2: Education | Education events | Increasing |
| | | Events participants | Increasing |
| | Indicator 3: Partnerships & charitable | Partnerships | Increasing |
| | | Activities expenditure | Increasing |
| Econo mic | Indicator 1: Employment profile | Employees | Increasing |
| | | Employment costs | Increasing |
| | Indicator 2: Incomes | Grants & sponsorship | Increasing |
| | | Sales and rental | Increasing |
| | Indicator 3 Costs | General management | No change |
| | | Advertising & publicity | Decreasing |
| Control quality | BS5454 standard | T & RH | Poor |
| | Design Standard | T & RH | Acceptable |
| | Relaxed Standard | T & RH | Good |
| Environ mental Impact | ECON | Energy & Carbon | Poor |
| | CIBSE | Energy & Carbon | Fair |
| | DEC | Energy & Carbon | Good |
| | IAMFA | Energy & Carbon | Good |