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Optimizing Luminous Environments in Bahraini Handicraft Centres: an Exploratory Case Study Using DIALux Software

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Abstract: This study explores the critical role of lighting design in creating the desired ambiance, enhancing productivity, and optimizing energy efficiency within traditional handicraft workspaces and display. A well-designed lighting system can significantly influence our perception of the working environment. However, achieving the optimal balance between aesthetic, energy, and functional requirements necessitates strategic planning. Given the inherent link between light and various physiological aspects and rhythms of the human body, lighting serves as a bridge connecting the natural and interior spaces within the realm of Sustainable Development Goals achievement. Successful lighting design in handicraft rooms requires a collaborative approach involving architects, lighting experts, and end-users. This research explores the implementation of lighting technologies in the traditional handicraft workspace of the Al Jasra Handicraft Centre in Bahrain. The study aims to utilize diverse lighting techniques, fixtures, and control systems to generate the desired illumination, reduce energy consumption, and promote sustainability. This is due to the limited research related to the illumination in handicraft rooms. Based on this research study, analysis is carried out based on physical data and DIALux evo lighting simulation software which enable to evaluate different handicrafts units with different visual task difficulty level, and various working planes height depending on nature of craft produced which allows the craft rooms to achieve the optimum illuminous flux and visual comfort level while achieving efficient electricity consumption.

Keywords: Illuminance, luminous environment, DIALux evo software, handicraft, visual comfort

1 Introduction

Over the past few decades, lighting design has been the subject of extensive research worldwide. Researchers have studied the influence of natural and electrical lighting on various environments and spaces, exploring its potential to impact user mood and enhance the overall aesthetic appeal of a space [1] [2] [3] [4] [5]. In Bahrain, research on this topic is growing as well, especially in critical spaces, such as hospitals, educational buildings, and cultural heritage related institutions. In parallel to that there is a growing demand for the Sustainable Development Goals (SDGs) achievement in several aspects of life. The United Nations Sustainable Development Goals encapsulate a comprehensive and integrated approach to addressing the complex challenges confronting societies and their development in the 21st century [6]. The key to this approach lies in recognizing the interdependence between the various goals and the necessity of a holistic strategy to achieve sustainable progress. Before moving forward to consider the space and conditions that foster creativity, it is necessary to further clarify the term "sustainable", which has become widely used in recent times. In the context of handicraft centres, sustainability encompasses environmental, social, and economic dimensions, as it does in other fields. Environmentally sustainable design for handicraft centres prioritizes the use of locally sourced, renewable, and non-toxic materials, as well as energy-efficient systems that minimize the centres carbon footprint [7]. Socially, these spaces should be designed to promote inclusivity, accessibility, and community engagement, serving as incubators for traditional crafts by providing workshops, training, and resources to empower artisans and ensure the intergenerational transmission of skills and knowledge [8]. Additionally, the economic sustainability of handicraft centres is crucial, as they must generate

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sufficient revenue to support the livelihoods of the artisans whose work they showcase [9]. Cultural institutions are working to sustain handicrafts, protecting them from extinction and preserving these crafts as core elements of national heritage. For example, the "Crafter's Expo" initiative, emerged in 2012 by the Pakistani Crafters Guild and Firefly, it was supported by Dastkari. Pk, Pakistan's premier marketplace for crafters [10]. Another example, the "London Craft Week" festival, started in 2015 to celebrate the outstanding British and International creativity [11]. Also, the "Made in Bahrain" initiative, launched in 2020 by the Bahrain Authority for Culture and Antiquities, aims to promote and preserve these traditional arts and crafts [12], and other initiatives of the same nature. Within the Arab Gulf region, the discovery of oil in the late 1950s led to an economic boom, prompting the construction of new structures to meet the needs of contemporary society. Several historic houses were demolished to make way for modern homes with more efficient and flexible layouts, as the significance of traditional buildings in defining the region's character was recognized [13][14][15]. Research supports the benefits of preserving historic architecture as a source of inspiration and learning from past experiences. Additionally, new buildings were created to reinforce the presence of arts and crafts [16][17]. Among the GCC countries, Bahrain, a Middle Eastern nation, has recognized the significant importance of preserving its cultural heritage. Furthermore, Bahrain's Economic Vision 2030 is aligned with global concepts of sustainability and the achievement of Sustainable Development Goals (SDGs) , serving as a fundamental principle underlying the nation's strategic plans [18]. This vision encompasses a range of key focus areas, including sustainable environmental and resource management, urban development, water, energy, transportation, urban growth, and more. In recent years, Bahrain has undertaken substantial efforts to safeguard its tangible and intangible cultural treasures. For instance, Bahrain has implemented various measures to protect its cultural heritage, including transforming restored traditional Bahraini houses into museums and cultural centres, as well as constructing new visitor centres to educate and showcase Bahrain's rich cultural heritage [14] [19]. In addition, cultural centres and institutions dedicated to the preservation and promotion of traditional arts and crafts, such as the Bani Jamra Weaving Textiles Factory, Aali Pottery & Ceramic Industries, The House of Basket Weaving and on top the Al Jasra Handicrafts Centre, which acts as one stop shop for all crafts in Bahrain, were established. These platforms are lined with space for local artists and craftspeople to practice their traditional crafts, such as metal embroideries, wood carpentry, basket weaving, and pottery making, in the presence of visitors, and they offer space to display handicraft collections for sale. In addition, some of these centres offer training programs for the public to learn and engage in traditional crafts, ensuring the transmission of these skills to future generations. By preserving and promoting its cultural heritage, Bahrain not only ensures the continuity of its traditions but also offers a unique and authentic experience to visitors. Handicraft centres should also prioritize sustainable design practices, especially given the current climate emergency and commitment to Agenda 2030's goals. As outlined in a study on preserving cultural heritage embodied in traditional crafts, design professionals must support the skilled artisans who keep these traditional crafts alive [17]. Handicraft centres can make a vital contribution to realizing Bahrain vision by serving as hubs that simultaneously promote traditional crafts and sustainable practices. Now that the background on handicraft centres in Bahrain has been presented, and from the literature study conducted it is important to highlight that there is limited research exploring the interior environment of these centres. Therefore, it is crucial for researchers to examine interior environment conditions at these centres, since they are at the core of Bahrain's tourism and heritage preservation. Based on the author's observations in these hubs, all lights will be switched on throughout the day and shut off after the centres close. In handcraft centres, the lighting environment is critical for human needs and environmental sustainability. The aim of this study is to analyse the indoor lighting environment in handicraft centres in Bahrain. These are the main objectives.

1. To evaluate the existing lighting conditions in several handicrafts units
2. To identify the different factors that influence the lighting environment in handicrafts units.
3. To propose a general recommendation to improve the lighting environment for had handicrafts units, when limited daylight sources are available.

Following that, the focus can shift to discussing the design considerations for these centres and its synergies to the Sustainable Development Goals (SDGs) with a particular emphasis on indoor lighting [17] [20]. Followed by the lighting design consideration that will be employed in the proposed design.

1.1 Lighting Design and Sustainable Development Goals

Effective design can enhance the visitor experience and foster an environment that supports the sustainability of traditional arts and crafts. Within the realm of architectural design, lighting is a crucial component in several of the Sustainable Development Goals, particularly those focused on energy, infrastructure, and urban development. For example, Goal 7, "Affordable and Clean Energy" directly addresses the need for universal access to modern energy services, including energy efficient lighting design [21]. Furthermore, Goal 9, "Industry, Innovation, and Infrastructure" highlights the importance of developing resilient and sustainable infrastructure, which encompasses lighting control systems [22]. Similarly, Goal 11, "Sustainable Cities and Communities" emphasizes the need for sustainable urban development, which includes the efficient and equitable provision of lighting services [23]. Lighting is a core element of energy systems, and its impact on sustainable development is far-reaching. Furthermore, it can enhance the development of more liveable and equitable urban environments, supporting economic growth, social inclusion, and environmental protection. Recognizing these intricate connections, policymakers and urban planners must adopt a holistic, systems-thinking approach to fully unlock the transformative potential of lighting as a catalyst for sustainable development. However, Light pollution is now a widely recognized term for the adverse effects of electrical lighting on nature and humans, and it has become a significant environmental and public health concern in many regions globally, including the Arab Gulf region [24]. In response, many countries, regions, and communities in the Arab Gulf are now developing innovative lighting programs and concepts that prioritize energy efficiency and reduced greenhouse gas emissions [25]. The GCC countries have embraced leading green building certification programs such as LEED and the WELL Building Standard, which aim to enhance occupant health, well-being, and energy efficiency in their indoor environments. Incorporating these principles, these nations are increasingly focusing on lighting designs that optimize natural light usage and incorporate energy-efficient technologies [26]. This dual approach promotes healthier indoor environments while simultaneously addressing energy sustainability concerns through innovative practices and policies related to lighting. While these efforts represent important steps forward, but a more comprehensive policy approach is needed to fully address the challenges as humans spend large amount of time inside building, and subjected to illumination level noticeably varies from the ones existing in the natural environment.

1.2 Lighting Design Considerations

Lighting is essential for human activity. Good illumination allows for efficient and precise visual tasks without fatigue or discomfort. Lighting can change a place, provide a feeling of beauty, and serve a variety of roles [3]. The concept of visual comfort, as defined by the European Standard EN 12665:2011 'Light and lighting,' is a complex and multifaceted aspect of the built environment that has significant implications for the well-being and productivity of occupants [2][6][27]. A successful lighting system must meet three requirements: quality, quantity, and light settings [2][3][4]. The standard sets criteria for colour temperature, intensity, uniformity, and glare control. Proper illumination can increase the capacity to accomplish visual tasks and minimize visual discomfort, leading to improved performance and productivity [28][29]. Studies suggest that the implementation of a lighting system with illumination levels exceeding 500 lux, and a warm colour temperature can substantially enhance productivity [30] [31]. Furthermore, 590 lux is regarded as the most comfortable and optimal light level for occupants [32][33]. For lighting to be carried out properly, the lighting standard must meet the requirements stated in the guidelines of the Illuminating Engineering Society (IES) and the lighting handbook discussing lighting planning on a building. The lighting standard for art-related studios varies between 300 and 750 lux [30] [34]. The lighting in the standard spaces should be designed in a way that provides visual comfort and minimizes glare using the Unified Glare Rating (UGR) index of 19 as a standard, while in special spaces, such as the art technical related classes, this index should be lowered [2]. Furthermore, the Average Daylight Factor (ADF) performance range should range between 4-6% as recommended performance criteria for tasks in the art studios and crafts units [2]. Qualitatively, the recommended Illuminance Uniformity on the working plane is utilized E min/E max ¿0.5 for acceptable and E min/E max ¿0.7 preferable performance [35]. In standard art spaces, the light should be distributed to achieve a uniformity level of 0.6 and a color rendering index of 80. However, in visual art-specific spaces, these parameters are increased due to the specialized nature of the artwork, where accurate color representation is critical [32][33]. For visual art spaces, the color rendering index can be increased to over 90. Table 1 outlines the specific lighting requirements and criterion of different crafts based on the level of task difficulty. Insufficient illumination in an area

Table 1: Recommended illumination level vs. task difficulty, adopted from the lighting handbook [30]

Task/activity difficulty level	Light intensity (lux)	Light Uniformity (Uo)	Unified Glare Rating (UGR)	Colour Rendition (Ra)
Moderately easy visual tasks	300	≥ 0.6	19	80
Moderately difficult Visual tasks	500	≥ 0.6	19	80
Difficult visual tasks	750	≥ 0.6	16	90

might hinder activity, while high brightness can impair vision [30]. Therefore, the lighting level must be adjusted to meet the user's demands, and each space requires a unique size and brightness based on its activities and needs [3]. To provide a satisfying and appealing setting for visual art related spaces, these rooms require enough natural and electrical lighting. Lighting in art and crafts rooms may be challenging to manage. When natural lighting is insufficient in an area, electrical lighting is utilized to increase the level of light. Electrical lighting has a key role in art-related settings and exhibitions, prompting several studies on the subject [1][2][5][36]. However, the research did not provide a clear image of illumination in craft studios from the user's perspective or of its impact on their craftsmanship. Several studies have examined the deterioration of parts, lighting qualities, thermal comfort, and natural versus artificial illumination. Compared to traditional lighting, LED lighting offers a larger range Correlated Colour Temperatures (CCT), leading to improved performance, visual comfort, and preference [31]. Furthermore, LED lighting is widely used due to its great efficiency, energy savings, and ease of control over colour, temperature, and illuminance [24][31]. In addition, when designing a space to make and exhibit traditional handicrafts, it is critical to consider the orientation of the windows and how natural light will enter and interact with the area during the day. Good lighting can increase craftsperson productivity and enhance the quality of produced products [2][4][30]. Therefore, lighting should provide adequate brightness while also reducing energy use [3]. The application of electrical lighting in handicraft-related spaces is critical because it is used as a tool for nonverbal communication, and the author suggested that lighting design should be customized to meet the task difficulty requirements to boost craftsman satisfaction and create a sense of identity.

2 Methods and Materials

This section is intended to detail the methodology and procedure used to conduct the study. As stated earlier the aim of this research is to evaluate the existing lighting conditions in handicrafts units with different activities and compare whether the lighting in the spaces under exploration meets the recommended illumination standards illustrated in Table 1.

2.1 The Exploratory Case Study

For this exploration, the Al Jasra Handicrafts Centre was selected as a case study (Figure 1). The centre has 2 levels: the ground level is designated for craft making and display, while the first level is used for administrative purposes. For the sake of the study, the exploration will be limited to the ground level only.

The center-making and display space forms a configuration with a limited size room (average area of 43 square meters) and limited size windows, some of which look upon the service corridor, while other fenestrations (double swing glazed doors) look upon the center garden. Previous studies have shown several problems in similar spaces that involve sensitive artifacts and displays, such as art studios and handicraft workspaces. These problems are related to the existence of a high illuminance level that damages the displays and produces an uncomfortable visual environment [1][5][20][37]. This research paper intends to evaluate the lighting environment in three craft units with different activities to compare whether the lighting in the three rooms meets the lighting standards in the handicraft room; hence, the crafting and display functions occur at the same time. Moreover, this study also aims to provide details regarding types of handicrafts where the existing lighting condition is below standard. The DIALux evo program is used to simulate design outputs and determine lighting levels that meet the standards.

Fig. 1: Different views of the Al Jasra Handicraft Centre, Bahrain (Source: Author)

2.2 Method

The study employed an exploratory case study approach, focusing on the lighting system at the Al Jasra Handicrafts Centre in Bahrain. It involved surveying the ground-level craft units, taking photographs, conversing with craftspeople [38], and conducting computer simulations using DIALux Evo software[39][40]. Figure 2 portrays the exploratory case study approach, research methods, data collection tools, and the aim of the gathered data for analysis and informed decisions based on evidence.

2.3 Procedure and Data Collection

Initially three visits were made to the Al Jasra Handicrafts Centre during March 2024 (Figure 1) at 8:00 am, 12:00 pm, and 5:00 pm to evaluate the impact of daylight on the crafts units. Architectural design data such as dimensions and geometry of the crafts units were collected and analysed based on surveys of building images and on-site measurements of floor areas, overall height and the Window-Wall-Ratio (WWR), Table 2.

Next, the lux meter (illuminometer) was used to measure the brightness of an illuminated surface by

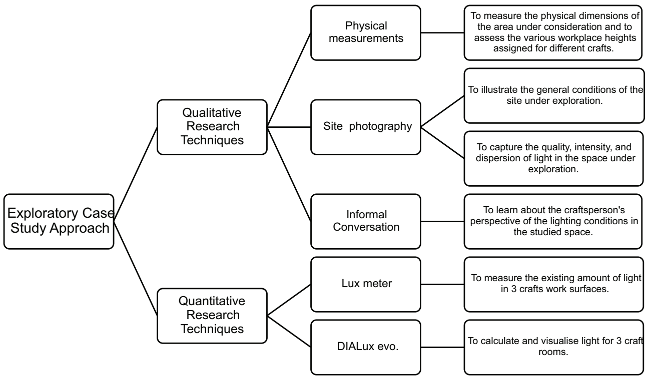


Fig. 2: Research Methodology. (Source: Author)

Table 2: Design information of the crafts used to make display spaces at the Al Jasra Handicrafts Center (Source: Author)

	Craft Units	Area (m^2)	Height (m)	WWR (%)
(a)	Boat making	47	3	13.4%
(b)	Gypsum engraving	34	3	13.8%
(c)	Weaving textile	48	3	13.8%
(e)	Palm tree products	47	3	13.4%
(d)	Traditional chests	47	3	13.4%
(f)	Pottery making	35	3	14.2%
	Average	43	3	13.6%

measuring luminous flux per unit of area, as well as the colour temperature, to analyse the lighting intensity and its subtlety in the workplace while maintaining safety. The space was then photographed to capture the overall quality, intensity, and dispersion of light in the exploration area as seen by the human eye. Then, another set of photographs was taken of the handcraft displays to analyse their nature and determine the necessary illumination to make and show such items while ensuring visual comfort. During this phase, the handicrafts were classified according to the level of task detail and difficulty, Figure 3. The crafts were classified based on the level of task detail and the sensitivity of the materials used to light and other environmental factors.

– Difficult visual tasks
  - a) Wood boat craft, usually made of teakwood and known as one of the best boat building materials. Teakwood is highly sensitive to light and may cause colour fading when lighting level is not controlled.
  - b) Gypsum engraving craft, usually made of soft sulphate mineral. Gypsum is not sensitive to light but subjected to high water absorption capacity.

– Moderately difficult visual tasks
  - c) Textile weaving craft, usually made of silk, cotton and wool. Silk is highly sensitive to light and excessive light may result in colour fading and discoloration.
  - d) Palm straw weaving craft, usually made of straw. Lower light levels are necessary for light-sensitive materials.

– Moderately easy visual tasks
  - e) Traditional chests craft, usually made of hardwoods such as oak, maple, and walnut and wenge wood. In addition to that antique brass or copper decorative pins are added. This material is light-sensitive, however more illumination is necessary for engraving intricate traditional decorative elements on wood or brass sheets, which is a challenging process.
  - f) Pottery making craft, typically constructed of clay, is not light-sensitive until coloured with pigments. Excessive illumination can cause colour fading and deterioration. However, because engraving is a challenging visual task, ceramic ornamentation will require more illumination intensity.

Fig. 3: Typical displays made and exhibited in Al Jasra Handicrafts Centre display/making rooms (Source: Author)

Usually, the crafted items are displayed to the public on horizontal, or vertical surfaces, depending on its value and the design of the crafts making/display unit. This paper will focus on the horizontal work plane surfaces because it serves both the crafts making and its display.

Following that, three (3) craft units out of six (6) units were selected for this exploration. The craft units were selected to represent three visual tasks known as difficult, moderately difficult, and moderately easy visual tasks namely, the (1) gypsum engraving, (2) textile weaving, and (3) pottery making craft units. Finally, the plans for the three craft units were redrawn, modeled and exported to the DIALux evo lighting design software, which will evaluate the existing lighting conditions in the spaces under exploration based on room geometry, area, height, Window-Wall-Ratio (WWR), Average Daylight Factor (ADF), and the percentage of daylight effective area under overcast sky conditions, respectively from the climate data of Manama, Bahrain (26.20 °N, 50.60°E), at 12:00 pm, while the artificial light was adopted using no daylight. The internal surface reflectance was adopted from the DIALux evo as 0.86 for the wall and ceiling as the applied finish is white roughcast plastering, and 0.75 for the floor as white ceramic tiles were used. These finishes were observed during the site visit. Also, one luminaire type was employed in all the craft units: LED Recessed Lighting Downlight as observed by the author. Average Daylight Factor (ADF) performance range used in the experiment was between 4-6% as recommended performance criteria for tasks in the art studios and crafts units [2]. While the preferred Uniformity Illuminance for workshops should be as $E_{min}/E_{max} > 0.5$ for acceptable and $E_{min}/E_{max} > 0.7$ preferable as stated in the Indoor Lighting Standard, SFS-EN 12464-1:2011 [35]. The working plane at each craft unit varies as it is 0.9 m in both the gypsum engraving and pottery room, while its 0.5 m at the textile weaving unit. The luminous flux (lumen) for each craft unit was calculated by multiplying the recommended illuminance (lux) by the area (m^2). The results are illustrated in Table 3.

Table 3: Design information of the crafts used to make display spaces at the Al Jasra Handicrafts Center (Source: Author)

Room reference	Recommended illuminance (lux)	Area(m^2)	Required luminous flux(Lumens)
Gypsum engraving	750	34	25.500
Textile weaving	500	48	24.000
Pottery making	300	35	10.500

The above criterion and assumptions will be adopted in when modelling the base case studies in DIALux evo. The results will then be analyzed considering the required luminous flux, next a new lighting design solutions will be proposed considering various lighting techniques, fixtures, and control systems, with the goal of improving visual comfort and energy optimization, thereby contributing in the achievement of Sustainable Development Goals (SDGs). A comparison will be conducted between the existing and proposed scenarios to provide some design recommendations for design in handicrafts units and similar art related space.

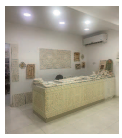
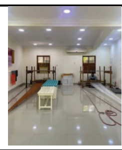
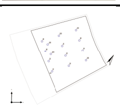
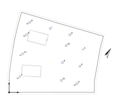
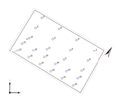
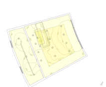
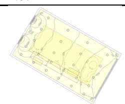
3 Results and Discussion

This section will be divided into two subsections. First, the existing condition of the three craft units will be portrayed and discussed, next the proposed solutions will be explained in comparison to the existing case.

3.1 Existing Scenario

The existing conditions of 3 handicrafts units were simulated using software simulator DIALux evo to determine the average daylight factor (ADF), where daylight was provided under overcast sky conditions, and to determine the impact of the existing artificial lights mounted there on the indoor illuminance with reference to the task difficulty when no daylight was applied. As identified previously the selected handicrafts units are (A) gypsum engraving, (B) textile weaving, and (C) pottery making craft units considering the use of one luminaire in this simulation as observed by the author. The LED Recessed Lighting Downlight with a luminous flux 2200 lumens and colour temperature 4000 Kelvin, as measured by the lux meter (illuminometer). The configured simulation, as shown in Table 4, was carried out with base cases A, B, and C.

Table 4: Design information of the crafts used to make display spaces at the Al Jasra Handicrafts Center (Source: Author)

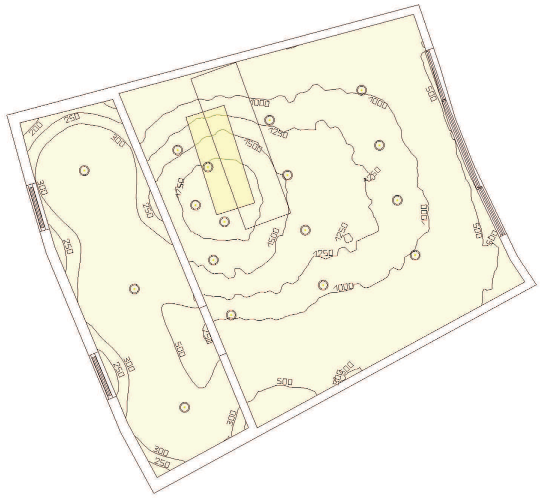
Variable/Case Study	Gypsum Engraving (A)	Textile Weaving(B)	Pottery Making (c)
Room Photo			
Geometry (existing lighting layout)and No. of luminaires			
Area (m^2)	34 m^2	48 m^2	35 m^2
Height (m)	3 m	3 m	3 m
WWR (%)	13.8%	13.8%	14.2%
ADF	2.8%	3.1%	1.8%
Daylight Effective Area (Min/Max)			
	Min 0.0% Max 4.9%	Min 2.53% Max 4.78%	Min 0.76% Max 3.41%

The simulation results confirmed that the average daylight factor (ADF) in base cases 1, 2, and 3 was found to be 2.8%, 3.1%, and 1.8%. The average luminous flux at the three craft units using one luminaire type (2200 lm LED Recessed Downlight) was 896, 726, and 1138 lux. The measured daylight factor at the 3 craft units is less than the required Daylight Factor (DF) in art studios and crafts units, which is 4-6% [2], which means that the 3 craft units lack daylight utilization; therefore, the application of electrical light sources is required throughout the day to perform the required tasks, as claimed by the artisans. On the other hand, the existing artificial luminous flux was found to be above the target lux level in base cases 1, 2, and 3, when the target was 750, 500, and 300 lux, respectively, with reference to the recommended luminous flux based on the type of task and the level of visual detail needed illustrated in Table 1. Although the rooms average illuminance may be appropriate, the assessed uniformity illuminance range found to be below the recommended standard in all the craft units under exploration (Table 5).

Table 5: Illuminance Uniformity in base case(s), adopted from DIALux evo (Source: Author)

No.	Craft room	E_{min}	E_{max}	Illuminance Uniformity (U0)	Result
1	Gypsum engraving	388	1947	0.20	Not acceptable
2	Textile weaving	340	1051	0.32	Not acceptable
3	Pottery making	720	5192	0.14	Not acceptable

Furthermore, excessive brightness can lead to several issues, such as glare, and unnecessary electricity consumption [2][36]. In addition, relying solely on a single type of luminaire can have several disadvantages, such as limiting the ability of artists to control the lighting effects on their crafts-making zone. Starting with the gypsum engraving craft unit, the simulation of the artificial lighting is taken when the natural lighting sources is turned off (Figure **??**). The type of lamp used in the artificial lighting simulation is using 12 units of Recessed downlight Echo 172 with LED, system power equal to19 W, luminous flux of luminaire 2000 lumens, colour rendering index CRI > 90, neutral white, and colour temperature is 4000 K. The result of simulation of the artificial lighting power in the existing condition is 896 lux, which is suitable to the difficult visual tasks≥750 lux, but based on personal experience, the illumination level is not enough for the detailed ornamental patterns engraved on the gypsum. Also, the engraver claimed that sometimes the insufficient lighting levels causes imperfection in the produced work and affects their safety during the process. Furthermore, the craftsman experienced glare directly from the light source, which also limits the visibility, cause eye strain and affect the quality of work. The simulation shows that total luminous flux in the space is 28028 lumens and hits its maximum as 1947 lux on the working plane and concentrated in the middle craft room, which is considered relatively high,



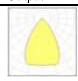
PCS	Image	Light Output	Mounting mode	Specification	System Power(P)	Lamp Flux Φ
14			Recessed downlight LED (Fixed)	Color rendering index CRI > 90, color temperature 4000 K, neutral white	19 W	2000 lm

Fig. 4: Gypsum Engraving craft unit simulation (existing) and lighting fixture type, adapted from DIALux evo (Source: Author)

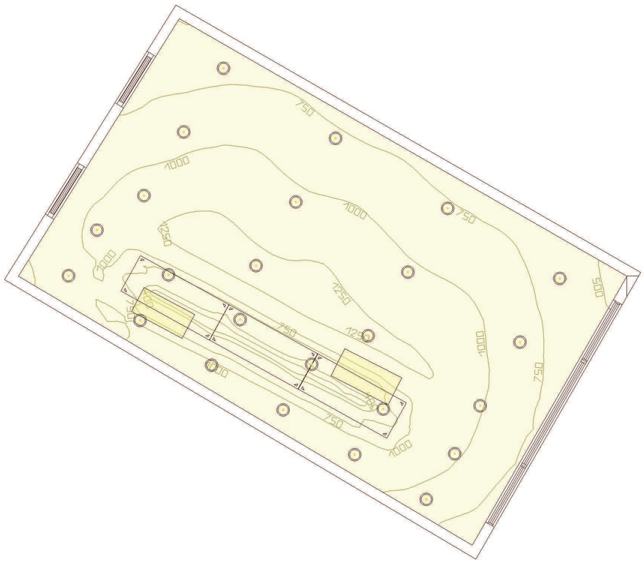
may deter the visual comfort, and high energy consumption due to the wasted light where not needed. Some authors claimed that for visual comfort and energy efficiency, task and ambient lighting should be separated [2][41].

Next, the textile weaving unit the simulation indicated that the average illumination is 726 lux, which is suitable to the moderately difficult visual tasks ≥ 500 lux, but the craft worker stated that overall illumination is enough to some extent but produces casting unwanted shadows which hinders the visual comfort and the quality of the produced work as the it hits almost 950 lux on the work plane (Figure 5).

As seen in (Figure 5), the isolines visualization for luminance indicates unbalanced lighting distribution, where the total illuminance received by the work plane is 24024 lumens, when using 12 LED recessed downlights, (2002 lm / 19 W), and the maximum energy consumption is 1750 kwh/a. while, the Unified Glare Ratio (UGR) at the workstation is 14.1≤19 which is excellent for normal sight, but not enough for the fine visual inspections, as the GI occupations for such fine task has to be 16 at minimum. The author anticipates that the problem here is using a single layer of lighting, which is not practical for any interior space. Hence, this approach will deter users

PCS	Image	Light Output	Mounting mode	Specification	System Power(P)	Lamp Flux Φ
12			Recessed downlight LED (Fixed)	Color rendering index CRI > 90, color temperature 4000 K, neutral white	19 W	2000 lm

Fig. 5: Textile weaving craft unit simulation (existing) and lighting fixture type, adapted from DIALux evo (Source: Author)



PCS	Image	Light Output	Mounting mode	Specification	System Power(P)	Lamp Flux Φ
24			Recessed downlight LED (Fixed)	Color rendering index CRI > 90, color temperature 4000 K, neutral white	19 W	2000 lm

Fig. 6: Pottery-making craft unit simulation (existing) and lighting fixture specification, adapted from DIALux evo (Source: Author)

from adapting the lighting to their specific needs, and with no doubt, it will affect the overall aesthetics of the space. Last, the pottery making existing sitting simulation of the artificial lighting was taken when the natural lighting sources is turned off. The type of lamp used in the artificial lighting simulation is using 24 units of Recessed downlight Echo 172 with LED, system power equal to19 W, luminous flux 2000 lumens, colour rendering index CRI $>$ 90, neutral white, and colour temperature is 4000 K as illustrated in Figure 6.

In the existing setting the average illumination is 1138 lux, which is way more that the illumination recommended for moderately easy visual tasks $\geq$300 lux. In fact, the craftsperson has installed extra luminaires because he experienced less lighting level when working on further details such as engraving on the clay. Consequently, the overall achieved luminous flux is 48048 lumens., where the recommended luminous flux is only 10500 lumens, Table 3 As seen in the three examples, recessed downlights are the only type of lighting fixtures utilized in all craft rooms. This type of lighting fixture has numerous drawbacks the most notable of which is its restricted directionality and inability to adjust the direction or intensity, limiting its applicability to various tasks. Furthermore, choosing only one type of fixture that stands as a ambient lighting layer might result in a monotonous appearance, without the visual appeal that different layers of lighting may bring. Therefore, next section portrays a different lighting systems, arrangements, and levels to enhance the overall craft unit visual environment and allows artisans to adjust the illumination and shadows falling on the actual work plane level.

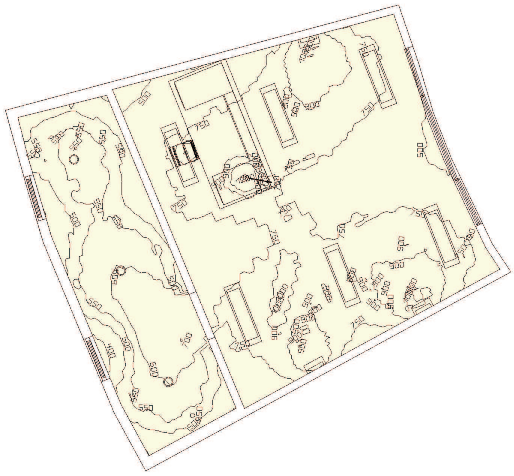
3.2 Proposed Scenario

Starting with the gypsum engraving unit the author proposed a new lighting solution combining 3 light layers namely ambient, task, and decorative. The number and types of lamps used in the artificial lighting simulation is 6 units of Power Balance gen2 with LED luminaires, system power equal to 24.5 W, luminous flux of 3400 lumens, colour rendering index CRI $>$ 90, and colour temperature is 4000 K, as ambient light. Next, 1 warm-white LED luminaire desk lamp, system power equal to 7 W, luminous flux of 284 lumens, colour temperature is 3000 k with on-off control, as task light. Finaly, 3 Surface mounted bulkhead luminaires, system power equal to 6.9 W, luminous flux of luminaire 967 lumens, colour rendering index CRI $>$ 80, and colour temperature is 4000 K, as accent lighting. The last wall mounted lights aim to provide a better rendering for walls displays. The simulation results shown in Figure 7 confirms that the combination of 3 types of luminaires resulted a better illumination distribution, provides more control to the engraved to adjust the intensity of the task light as needed. The result of simulation of the artificial lighting in the proposed scenario is 753 lux, which is suitable to the difficult visual tasks $\geq$750 lux, and its lower comparing to the existing case, which was 896 lux. The total luminous flux received by the entire craft unit has decreased from 24024 to 23585 lumens, and the total electrical power decreased from 266 W to 181.5 W. Regarding the glare, it is calculated as 18.5 $\leq$19, which is seen as excellent to provide the required contrast for the craftsperson when working in highly details ornamentation.

the original lighting arrangement was replaced with 5 LED energy-efficient ceiling lights (5000 lm/36 W) featuring to integrate programming, dimming, colour temperature and remote control. There were installed as a ambient light to provide a discrete and flexible solution for art studio environments,1 wall-mounted luminaires as accent light (967 lm/6.9 W), 4 LED track lights (539 lm/ 5.9 W) featuring adjustable positioning to enhance the visibility and allow artisans greater control over the direction of the light, preventing any undesired casting shadows during work (Figure 8). The result of simulation of the artificial lighting in the proposed scenario is 705 lux, which is suitable to the moderately difficult visual tasks $\geq$ 500 lux, and its lower comparing to the existing case, which was 950 lux. The total luminous flux received by the entire craft unit has increased from 24024 to 28123 lumens, and the total electrical power decreased from 228 W to 210.5 W. Regarding the glare, it is calculated as 15.0 *leq*19. The results confirm that using smart and adjustable luminaires, as well as energy efficient bulbs can contribute in reducing the overall all energy consumption.

Finally, a new lighting design solution is proposed for the pottery making unit in which the original lighting arrangement was replaced with 4 LED energy efficient ceiling lights (3400 lm / 24.5 W) were installed as a ambient light to provide a discreet and flexible solution for art studio environments, and 3 mounting rail track lights luminaires as task lights (400 lm / 9 W) as illustrated in Figure 9.

The result of simulation of the artificial lighting in the proposed scenario is 477 lux, which is suitable to the moderately easy visual tasks $\geq$500 lux, and its lower comparing to the existing case, which was 1138 lux. The total luminous flux received by the entire craft unit has increased from 48048 to 14800 lumens, and the total electrical power increased from 456 W to 125 W. In regard to the Unified Glare Rating (UGR) it found equal to 17.9 $\leq$19 as shown in the simulation results, which is considered as excellent to provide the required contrast for the craftsperson when working in highly detailed clay engraving. The simulation results at the three proposed



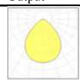
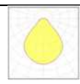
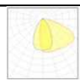
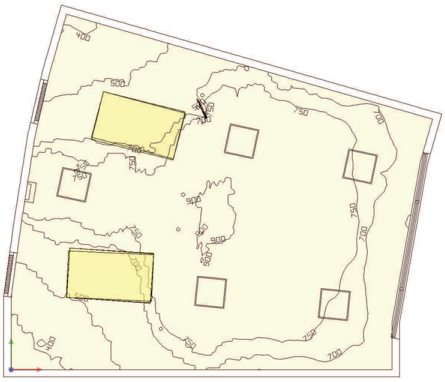
PCS	Image	Light Output	Mounting mode	Specification	System Power(P)	Lamp Flux Φ
5			Ceiling recessed (Fixed)	Color rendering index CRI > 90, color temperature 4000 K, Energy efficient LED	139 W	3400 lm
1			Table luminaire (Adjustable)	Color rendering index CRI > 80, color temperature 3000 K, warm white.Adjustable, rotatable, dimmable, LED	7 W	284 lm
3			Wall mounted (Fixed)	Color rendering index CRI > 80, color temperature 4000 K, Natural White Supplementary emergency lighting	6.9 W	967 lm

Fig. 7: Gypsum Engraving craft unit simulation (proposed) and lighting fixture specification, adapted from DIALux evo (Source: Author)

cases indicates a better Illuminance Uniformity ratio is achieved, which will improve perception, enhance the overall visual comfort, and ensure proper lighting to the space (Table 6).

3.3 *Comparison between the Simulation Results*

This section is intended to compare the simulation results conducted in the existing and proposed scenarios in terms of the total working plane perpendicular illumination and the total power consumption. As seen in Figure 10, there is a reduction in the total illumination recived in the three craft units. Starting with the gypsum engraving craft

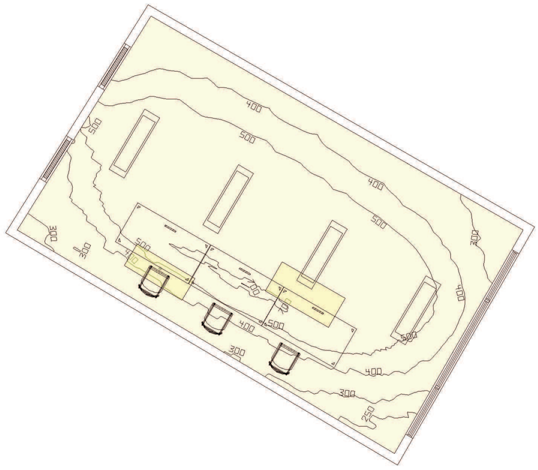


PCS	Image	Light Output	Mounting mode	Specification	System Power(P)	Lamp Flux Φ
5			Ceiling recessed (Fixed)	Color rendering index CRI > 90, color temperature 4000 K, SmartDrive LEDs (ability to integrate programming, dimming, consumption monitoring and remote control). Glare protection: UGR < 19	36 W	5000 lm
4			Table luminaire (Adjustable)	Color rendering index CRI > 83, color temperature 4000 K, natural white. Dimmable, Energy-saving LED	5.9 W	539 lm
1			Wall mounted (Fixed)	Color rendering index CRI > 80, color temperature 4000 K, Natural White Supplementary emergency lighting	6.9 W	967 lm

Fig. 8: Textile waving craft unit simulation (proposed) and lighting fixture specification, adapted from DIALux evo (Source: Author)

room, the total illumination is reduced 15.9%, while in the textile weaving craft unit 25%, and in the pottery making room 58%. This reduction is also reflected in the overall electrical power consumption, as in the gypsum engraving unit it is reduced 19%, while in the textile weaving craft unit 7.6%, and in the pottery making room 72% (Figure 11).

The results indicate that craft units in Bahrain needs a serious attention for improvement to acceptable level of lighting with reference to task difficulty to ensure visual



PCS	Image	Light Output	Mounting mode	Specification	System Power(P)	Lamp Flux Φ
4			Ceiling recessed (Fixed)	Color rendering index CRI > 90, color temperature 4000 K. Energy efficient LED	139 W	3400 lm
3			Table luminaire (Adjustable)	Color rendering index CRI > 90, color temperature 2700 K, warm White.Energy-saving LED.	9 W	400 lm

Fig. 9: TPottery making craft unit simulation (proposed) and lighting fixture specification, adapted from DIALux evo (Source: Author)

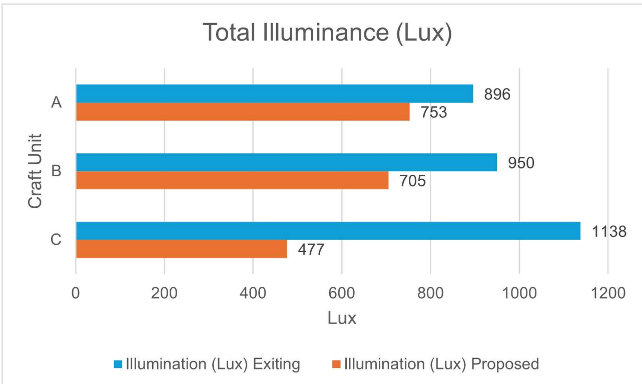


Fig. 10: Comparison of the working plane total perpendicular illumination (Lux). (A) Gypsum Engraving Craft Unit, (B) Textile Weaving Craft Unit, and (C) Pottery Making Craft Unit (Source: Author)

Table 6: Illuminance Uniformity in proposed case(s), adopted from DIALux evo (Source: Author)

No.	Craft room	E min	E max	Illuminance Uniformity (U0)	Result
1	Gypsum engraving	519	1080	0.69	Preferred
2	Textile weaving	539	703	0.77	Preferred
3	Pottery making	676	713	0.95	Preferred

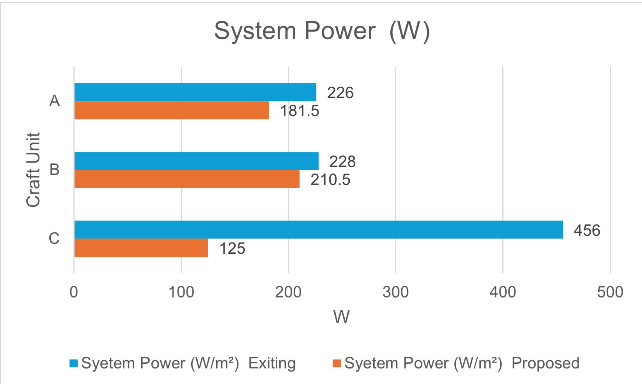


Fig. 11: Comparison of simulation results of the toral electrical power consumption (W). (A) Gypsum Engraving Craft Unit, (B) Textile Weaving Craft Unit, and (C) Pottery Making Craft Unit (Source: Author)

comfort for the artisans, ambient appearance for the visitors as these centres considered as a touristic attraction and last the efficient use of electricity. Therefore, utilizing different layers of lighting in craft designated spaces is essential for both functionality and aesthetics as it supports creativity and comfort. By combining task, ambient, and accent light an inspiring and efficient workspace can be tailored to the crafting needs. Layering allows for flexibility, as the artisan can adjust the lighting based on specific task. On the other hand, incorporating dimmers and smart lighting solutions may help to create the perfect ambiance for any crafting session. Despite the importance of natural lighting, it was not mentioned in this research as spaces under exploration lacks the minimum required lighting and 100% depends on electrical lighting throughout the day as claimed by the artisans and observed by the author. Furthermore, Table 5 and 6confirms that the proposed design enhanced the Illuminance Uniformity in the three spaces under exploration as in the existing scenario it was $\leq$0.4 which is considered as “not acceptable”, hence the proposed scenario enhanced the Illuminance Uniformity to $\geq$0.6 and considered as “preferable”.

3.4 Linking the Research Results to Sustainable Development Goals

Linking lighting design with Sustainable Development goals (SDGs) is essential for promoting sustainability and enhancing quality of our lives on daily basis, particularly those focused on energy, infrastructure, and urban development, which are Goal 7, ”Affordable and Clean Energy”, Goal 9, ”Industry, Innovation, and Infrastructure”, Goal 11, ”Sustainable Cities and Communities”, and Goal 3 “Good Health and Wellbeing”. This study asserts integrating lighting design with SDGs not only enhance energy efficiency but also contributes to healthier, comfortable, and more sustainable communities. For instance, the energy efficient lighting was achieved by integrating LED lighting reduces the energy consumed costs, as aimed by SDG 7. While incorporating smart technology such as zoning switches, dimmer switches, and smart bulbs for customizable brightness and colour temperatures contributes to the achievement of SDG 9. Next, the thoughtful selection of luminaires using eco-friendly materials in lighting design promotes sustainability in manufacturing. Finally, the study contributed to promoting SDG 3, by proposing lighting design that can support the artisans’ optimal visual comfort, and on the other hand a wall-planned lighting can minimize light pollution that benefits both users and the environment. By preauthorizing these goals, designers can archive a better crafts making place that supports innovation and creativity.

4 Conclusion

The research presented three handicraft units in Al Jasra Handicraft Centre namely gypsum engraving, textile weaving, and pottery making craft units, which is only 50% from the overall number of craft units at the centre. It is clearly showed that none of the crafts units undertaken in this exploration were able to achieve the recommended daylight and illuminance acceptable level. This result indicate that artificial light is required throughout the day, which means that a proper lighting design solutions is mandate and a critical attention for the improvement of such spaces to an acceptable level of illumination is required to ensure functionality, aesthetical qualities and efficient energy consumption. It has been proven that the existing scenario at the three craft units exceeded the recommended illuminance flux yet increased the unified glare index (UGI) and total electricity consumption (W), when using one types of luminaires regardless of the type of activity, its level of difficulty and the required resource materials and its sensitivity to light. Although, the last was not considered in this research it is an important factor that affects the selection of luminaires and bulbs. Also, the wall, ceiling, and floor reflectance is another important factor as it plays a crucial role in lighting design and significantly impacts how the light is distributed and perceived within a space. In this study the existing finishes were simulate and kept in the proposed scenarios as it was relatively high as 0.86 for the wall and ceiling and 0.75 for the floor. Furthermore, the study asserted that integration between different types of luminaires, a minimum of 2 layers of lighting enhanced the overall illumination on the working plane, reduced the overall electricity consumption, unified the glare, contrast and shadows, and finally provide the craftsperson a sense of control over the lighting output. Besides that, there are some recommendations that can be applied to the crafts related spaces to better lighting solutions: (1) use layered lighting known as ambient, task and accent, (2) adopt control to brightness option by installing zoning switches, dimmer switches and by the use of smart bulbs for customizable brightness and colour temperatures to promote desired moods, (3) use LED efficient bulbs with no less than 4000K for task lighting, (4) use track lights for flexible positioning and directing of light as needed, (5) avoid dark painted walls and furniture that may disturb the distribution of light, and ask but not least, (6) introduce light shelves to enhance to reflect the external light source to the ceiling would also help to distribute daylight. Finally, improving the overall illuminance uniformity can be made in reference to the surrounding environment of the craft room through proper planning during the design stage.

5 Data Availability

The author confirms that all data generated and analysed during this study are included in this published article using physical data measurements, and computer simulation approach using Dialux Lighting Design Software. One can obtain the relevant materials from the references section. Ethics Declaration The authors have no competing interests to declare that are relevant to the content of this article. The author contributed to the study of conception and design. Material preparation, data collection and analysis were performed by May Al Saffar. The first draft of the manuscript was written by May Al Saffar. In addition, the protocol was approved by the Academic Research and Intellectual Contribution Committee (ARICC) in accordance with the Ahlia University Research Ethics Framework (AUREF), UC/P 377/2019.

6 Funding

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7 Informed Consent

All individual participants involved in the study given their informed consent orally. They are aware that their participation in the informal conversations is on voluntary basis. In addition to that, they are aware that the research findings will be published.

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