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Dedication

It is our pleasure and great privilege to present the fifty-eighth issue of the Academic Journal of Research and Scientific Publishing to all researchers and doctors who published their research in the issue, and we thanks and appreciate to all contributors and supporters of the academic journal and those involved in the production of this scientific knowledge edifice.

Academic Journal of Research and Scientific Publishing

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Sand and Dust Storms Impact on Photovoltaic Panels in Saudi Arabia

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Abstract:

This research aims to assess the spatial potential of solar energy in Saudi Arabia by estimating the total sum and analyzing the spatial variability of solar radiation to determine the best sites for solar energy generation that are least affected by sandstorms in the country. It also explores the effects of sandstorms on solar panels, identifies preventive measures, analyzes their impact on productivity, and recommends best practices for future development. The study utilizes time series analysis to estimate the impact of dust on productivity and identify effective ways to mitigate it. The spatial suitability of solar cell placement in different regions of the country is also analyzed. The study reveals that the Al-Ahsa region is significantly affected by sandstorms, with an average of around 25 sandstorms annually, indicating the region's vulnerability to these environmental phenomena. The western region, specifically the Tabuk station, experiences a lower frequency of about 5.5 sandstorms per year. The Al-Ahsa region shows the highest daily average rate of sandstorms, ranging from 0.4 to 0.7 sandstorms per day, with the highest rates occurring from March to May. In terms of solar energy potential, the northwestern region in Tabuk exhibits the highest average potential of about 6 watts per square meter per day, followed by the southwestern region in Asir with approximately 5.5 watts per square meter per day.

These findings provide valuable insights into understanding sandstorm patterns and identifying optimal locations for solar energy production, contributing to sustainable development efforts and climate change mitigation.

Keywords: Sand, Dust storms, Photovoltaic Panels, Solar panels, Saudi Arabia.

1. Introduction:

In today's rapidly evolving world and society, the imperative for transitioning to renewable energy and sustainable practices has never been more pressing. The global population continues to grow alongside with the demand for energy. It becomes quite evident that the reliance on fossil fuels and unsustainable practices is not only depleting finite resources but also inflicting severe environmental issues. Embracing renewable energy sources, such as solar, wind, hydro, and geothermal power, holds the key to mitigating climate change, securing a greener future, and preserving the delicate balance of our planet for generations to come. The growing interest in transitioning towards sustainable and renewable energy sources is driven by environmental challenges, climate change, and the need to reduce reliance on fossil fuels (IRENA, IEA, 2021). Renewable energy is considered an environmentally friendly and sustainable alternative to traditional energy sources, relying on renewable sources such as solar, wind, water, and biomass (IEA, 2022). Renewable energy technologies generate electricity and meet energy needs in clean and sustainable ways. Reports indicate that renewable energy could account for a significant portion of global electricity production by 2050 (IRENA, 2022). It is important to continue supporting research and development in this field and promoting policies and incentives that encourage the global adoption of renewable energy. The transition towards sustainable and renewable energy sources is necessary to address climate change, reduce pollution, and ensure a more sustainable and clean future (IRENA, 2023).

Solar energy is of utmost importance in the world due to its renewable and clean nature. It is derived from the sun, making it a sustainable and environmentally friendly solution. Solar power generation produces no greenhouse gas emissions or air pollutants, contributing to cleaner air and a healthier environment. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), solar energy plays a crucial role in mitigating climate change by reducing reliance on fossil fuels and lowering carbon dioxide (CO2) emissions. The International Energy Agency (IEA, 2023) highlights the role of solar energy in promoting environmental and economic sustainability.

The International Renewable Energy Agency (IRENA, 2023) provides detailed analyses of the environmental and economic benefits of solar energy. The United Nations, through agencies like the United Nations Environment Programmed (UNEP, 2022), emphasizes the importance of solar energy in addressing climate change challenges and promoting sustainability. Solar energy offers energy independence, job creation, and economic growth opportunities (IPCC, 2021). It provides access to electricity for remote and underserved areas, improving living standards (IEA, 2020). Solar energy systems can be scaled up or down to meet various energy demands, and they offer long-term cost savings (IRENA, 2020). Embracing solar energy leads us towards a greener and more sustainable future. Here are some international studies that have addressed the topic of solar energy and photovoltaic panel cleaning methods, (Pravan et al., 2011) In a study focused on two 1-MW PV systems, the effects of soil type and washing technique on performance losses were examined. The results indicated that the presence of sandy soil contributed to a performance loss of 6.9%, whereas a more compact soil resulted in a lower loss of 1.1%. The study (Jiang et al., 2011) revealed that when a dust deposition layer ranging from 0 to 22 g/cm2 accumulated on the PV panels, there was a linear decrease in PV efficiency by 26%. Interestingly, the study did not find any significant difference in the effects of dust deposition on PV efficiency between different types of solar cells. In addition, the study (Zorrilla-Casanova et al., 2011) During dry seasons, the study observed that energy losses in PV systems exceeded 20% over 3-month periods. The annual average losses in PV output, even with natural cleaning by rain, were measured at 4.4%. To mitigate these losses, the study proposed implementing regular and periodic cleaning schedules for the PV modules. And, the study (Bethea et al., 1983) found that the reflectivity of PV panels is expected to decrease by 2.4% per year due to dust storm conditions. This decrease in reflectivity can significantly impact the overall performance and efficiency of the panels over time. Regular cleaning and maintenance are recommended to minimize the impact of dust storms and maintain optimal reflectivity levels. Furthermore, the study (Bowden et al., 1994) examined the effect of dust on the loss in internal reflectance of the CSP roof units and found that dust only affects the energy conversion to a small degree. The total losses attributed to dust were found to be less than 1.3%. This suggests that while dust can have some impact on the internal reflectance and energy conversion, it does not significantly hinder the overall performance of the CSP roof units. Also, the study (Kattakayam et al., 1996) The accumulation of dust and the increase in temperature of the panel can lead to a significant loss of power. Dust accumulation on the surface of the panel can block sunlight and reduce the amount of energy that can be converted into electricity.

Additionally, increased panel temperature can result in a decrease in the efficiency of the solar cells, leading to a further loss of power generation. Regular cleaning of the panels and implementing cooling measures can help mitigate these losses and maintain optimal power output.). Moreover, the study (Kobayashi et al., 2011) Changing the aspect ratio of the PV cell used for a PV module can result in a degradation of the output by 80% or less, with only 3% of spot dirt on the module area. This suggests that altering the aspect ratio of the PV cell has a significant impact on the module's performance, leading to a substantial decrease in power output. Additionally, the presence of even a small amount of spot dirt on the module area can further contribute to the degradation of output.

Solar energy is considered a crucial factor in reducing carbon emissions in Saudi Arabia. It represents a clean and renewable source of energy, contributing to environmental sustainability. By harnessing solar radiation to generate electricity, reliance on fossil fuels is reduced, thereby decreasing greenhouse gas emissions and environmental pollution. Solar power plants operate in a clean and emission-free manner, improving air quality and the overall environment. Furthermore, the use of solar energy promotes environmental sustainability by preserving natural resources and minimizing pollution. Additionally, solar energy can provide energy savings and cost reduction by installing solar power systems for local electricity generation, reducing dependence on the public grid (United Nations, 2021). This study (Hassan et al., 2005) observed reductions in efficiency of 33.5% after 1 month and 65.8% after 6 months. These reductions in efficiency indicate a significant decline in the performance of the PV system over time. Factors such as dust accumulation, environmental conditions, and aging of the panels can contribute to these efficiency losses. Regular maintenance, including cleaning and inspection, is important to mitigate these reductions and maintain optimal efficiency levels in the long term. Moreover, the study (El-Shobokshy and Hussein, 1993) found that the material, size, and deposition density of dust have a strong effect on the loss of output power in PV systems. Different types of dust, such as fine particles or larger debris, can have varying impacts on the performance of the panels. Additionally, the density of dust deposition, or the amount of dust accumulated on the panel surface, can significantly affect the power output. Therefore, it is crucial to consider the characteristics of dust and implement appropriate cleaning and maintenance practices to minimize the loss of output power in PV systems. Also, the study (Alamoud, 1993) found when exposed to the outside environment, the efficiency of PV modules can decrease by 5.73% to 19.8%, depending on the

type of the module. This reduction in efficiency highlights the impact of external factors such as temperature variations, dust accumulation, shading, and other environmental conditions on the performance of PV modules. It is essential to select modules that are suitable for the specific environmental conditions and implement proper maintenance practices to minimize efficiency losses and maximize power generation. And, this study (El-Nashar, 1994) revealed that the monthly percentage decline in glass transmittance is seasonal, with a 10% decline in the summer and a 6% decline in the winter. This indicates that the transmittance of solar radiation through the glass surfaces of PV modules decreases during these seasons. Furthermore, the study found that leaving the collector without cleaning for one year resulted in a significant reduction of 70% in the collector's performance. This highlights the importance of regular cleaning and maintenance to prevent the accumulation of dirt, dust, and other contaminants on the collector surface, which can hinder the efficiency and overall performance of the system. In addition, the study (Hegazy, 2001) examined the impact of dust accumulation on the solar transmittance of vertical plates with a diameter of 1 mm. The loss in transmittance was found to be typically around 75-80% over a month's exposure. The study compared a calculated "dust factor" or correction factor to the observed reduction in transmittance, providing insights into the accuracy of the model used to estimate the effect of dust on solar transmittance. These findings highlight the significant impact of dust accumulation on the efficiency of solar panels and emphasize the importance of regular cleaning and maintenance to maintain optimal performance. Also, the study (Asl-Soleimani et al., 2001) air pollution, particularly in cities with high pollution levels like Tehran, can significantly reduce the energy output of solar modules by more than 60%. The presence of pollutants, such as particulate matter and smog, in the air can block and scatter sunlight, thus reducing the amount of solar radiation reaching the modules. This reduction in solar irradiance directly impacts the energy conversion capability of the modules, leading to a substantial decrease in energy output. To mitigate the negative effects of air pollution on solar energy generation, regular cleaning of the modules and implementing air pollution control measures are essential. Also, this study (Qasem et al., 2011) the study investigated the impact of dust densities on the performance of solar modules in both vertical and horizontal configurations. It was observed that higher dust densities negatively affected the performance of both configurations. However, the horizontal module configuration was found to have an increased risk of hotspots due to dust deposition. Hotspots are localized areas of increased temperature that can lead to reduced efficiency, decreased power output, and potential damage to the solar cells.

Therefore, regular cleaning and maintenance are crucial, especially for horizontal module configurations, to mitigate the risk of hotspots and maintain optimal performance. These findings emphasize the importance of proper maintenance practices in areas with high dust densities to ensure the long-term efficiency and reliability of solar modules. And, this study (Bajpai and Gupta, 1988) found that poor efficiency in solar systems can be attributed to the scattering of incoming radiation by dust particles. Dust accumulation on the surface of solar panels scatters and diffuses sunlight, reducing the amount of radiation that reaches the solar cells and resulting in decreased energy conversion efficiency. Regular cleaning and maintenance of solar panels are crucial to mitigate the impact of dust scattering and maximize the transmittance of sunlight for optimal energy conversion. Implementing protective measures like panel coatings or anti-soiling technologies can also help minimize the scattering effects of dust particles and improve overall system efficiency.

Dust storms pose a significant challenge to the efficiency and productivity of solar panels worldwide (Alghamdi et al., 2018; Al-Kaff & Alghamdi, 2019). This issue is particularly acute in the Saudi Arabia, where frequent dust storms can cause significant damage to solar panels and lead to decreased energy production (Al-Raddadi et al., 2019). The Saudi Arabia is particularly vulnerable to dust storms, which cause dust and dirt to accumulate on the surface of solar panels, obstructing solar radiation absorption and decreasing solar panel efficiency. Furthermore, dust storms can corrode and damage solar panels, necessitating expensive repair and replacement costs. Therefore, it is crucial to study the impact of dust storms on solar panels in the Saudi Arabia to identify the best methods and solutions to deal with this problem, improve the efficiency of solar panels, and increase electric energy production (Al-Raddadi et al., 2019).

Several studies have been conducted to examine the impact of dust on the performance of solar panels. (Li et al., 2019) discuss the research status and associated challenges in this field. They provide recommendations for enhancing the performance of solar panels in the presence of dust. Building upon this research, (Li et al., 2020) specifically investigate the effects of dust on PV modules. They analyze the optical and thermal impacts of dust on solar panel efficiency and offer an overview of research and strategies employed to mitigate this challenge. Furthermore, (Alghoul et al., 2020) provide a comprehensive view of the influence of dust on photovoltaic systems. Their study explores the electrical and thermal effects of dust on panel performance and offers a review of various techniques and measures used to minimize dust accumulation and its adverse effects on

performance. Additionally, (Zhang et al., 2019) focus on the impact of dust deposition on the performance of photovoltaic panels. They analyze how dust affects light transmission and heat distribution in panels and present an overview of findings and recommendations to address this challenge. And, the study (Adanu, 1994) found that the presence of dust particles in the atmosphere has a detrimental effect on solar irradiance and the energy output of PV arrays. Dust particles scatter and absorb sunlight, reducing the amount of solar irradiance reaching the PV panels. Additionally, the accumulation of dust on the surface of the panels acts as a barrier, further reducing efficiency and energy output. Regular cleaning and maintenance of the PV panels are crucial to mitigate the negative impact of dust particles. By keeping the panels clean and free from dust accumulation, the solar irradiance can be maximized, leading to improved energy generation from the PV array. These practices are essential to maintain optimal efficiency and maximize the energy output of solar systems in areas prone to dust pollution. These studies collectively contribute to the understanding of the impact of dust on the productivity of photovoltaic panels and provide valuable insights into strategies for improving their performance in dusty environments.

The objectives of this study are to analyze the effects of dust storms on the efficiency and performance of solar panels in the Saudi Arabia, identify and evaluate the effectiveness of preventive measures to reduce the impact of dust storms on solar panels, investigate and analyze the effect of dust storms on the productivity of solar panels, and identify best practices for reducing the impact of dust storms on solar panels, as well as recommendations for future system development. Achieving these objectives will help to improve the efficiency of solar panels in the Saudi Arabia, reduce the negative impact of dust storms on the environment, and contribute to the country's strategic goals of providing clean and renewable energy while reducing harmful emissions to the environment. This study is critical for identifying the best methods and solutions to deal with the problem of dust accumulation on solar panels in the Saudi Arabia. Such research can provide valuable insights into the development of novel cleaning techniques and technologies tailored to the local conditions. High-quality research in this area can also inform policy decisions related to the adoption of renewable energy and contribute to the sustainable development of the Saudi Arabia.

2. Material and Methods:

Data:

The study utilized various sources of information, including reports requested from the King Abdullah City for Atomic and Renewable Energy including data about Direct Normal Irradiance (DNI)- kwh/ m^2/ day, Global Horizontal Irradiance (GHI)- kwh/ m^2/ day, Diffuse Horizontal Irradiance (DIH)- kwh/ m^2/ day, and efficiency kwh/ m^2/ day ((Fig. 1) show you the stations locations, and the National Center for Meteorology including data about dust storms events (Day), Horizontal Visibility (HV), pressure (kPa), mean temperature (C), Wind Speed (km/h), and relative humidity (%) (Fig. 2) show you the stations locations.

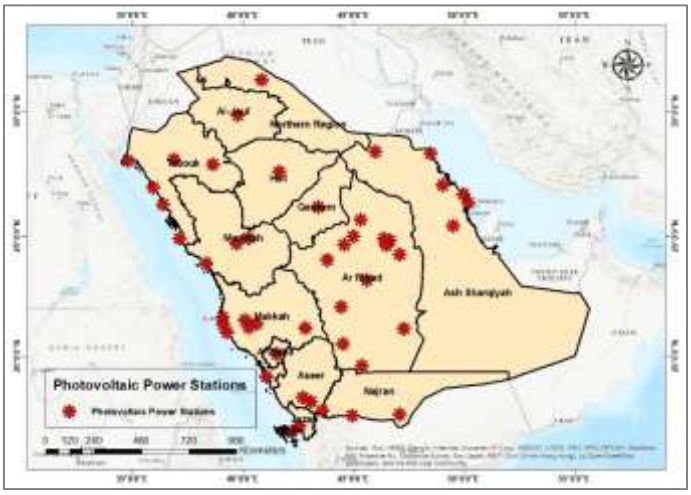

Figure 1. Map showing 49 the locations of solar stations around Saudi Arabia, the map applies to all years considered in this paper (2013-2022).

Figure 2. Map showing 26 the locations of Meteorological stations around Saudi Arabia, the map applies to all years considered in this paper (2013-2022).

Methodology:

The study employed time series to demonstrate the impact of the general trend of dust storms on the amount of photovoltaic panel productivity in the Saudi Arabia from 2013 to 2022. In the Saudi Arabia, estimate the amount of dust deposited on the surface of photovoltaic panels and its impact on productivity. Where the independent time variable (t) (study years 2013-2022) and its corresponding values are the dependent variable (Y) (the amount of electrical energy produced by photovoltaic panels), and each value in time (t) (study years 2013-2022) corresponds to the values of the dependent variable (Y) (the amount of electrical energy produced by photovoltaic panels), y is a function of time t.

In the application of time series, it relied on a number of phenomena affecting the amount of dust storms rising or falling on the productivity of photovoltaic panels, and it included 58 observations of the following phenomena: daily dust storms (DS), total horizontal radiation falling watts / day / hour / m^2 (GHI), direct vertical radiation watts/day/hour/m^2 (DNI), diffuse horizontal radiation watts/day/hour/m^2 (DHI), air temperature (AT), This time series runs from 2013 to 2022.

- The first stage involves testing the time series' stability using the Dickey and Fuller test (unit root test). If the test statistics are (Table-1), and it is discovered that: 0.365 2.36, as well as 0.825 2.36, then the presence of the unit root is accepted. The first differences filter is applied to the time series to make it stable.

Table 1. Summary of Dickey and Fuller test daily dust storms (DS), total horizontal radiation falling watts / day / hour / m^2 (GHI), direct vertical radiation watts/day/hour/m^2 (DNI), diffuse horizontal radiation watts/day/hour/m^2 (DHI), air temperature (AT), This time series runs from 2013 to 2022. The Dickey and Fuller test is a statistical test used to determine the presence of a unit root in a time series, which can indicate non-stationarity and the need for further analysis. The table presents the results of this test for each variable, indicating whether a unit root is present in the time series. This information is important for understanding the statistical properties of the data and for guiding further analysis of the meteorological variables over time.

Test	Module	T value	A= 0.05
D.F.	II	0.365	**2.36**
A.D.F.	II	0.825	**2.36**

- The second stage is to identify the appropriate model that represents the first differences by examining the ACF autocorrelation function for the first difference series, which leads to the MA (1) model being suggested. When the PACF partial autocorrelation function was examined, it suggested the AR model (1). When the two figures are considered, the (3,1,0) ARIMA model can be proposed.
- The third and fourth phases involve estimating the proposed models and confirming their applicability to the time series: Each of the three proposed models went through these two phases. And the models that are found to be valid for representing the time series because of the examination are compared in terms of predictive ability and the best one is chosen.

The amount of solar energy produced in the Saudi Arabia:

- To estimate the amount of solar radiation reaching the Earth's surface, several interconnected quantitative models that rely on measuring or estimating the angles of solar radiation based on the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) model that was used in the analysis of solar radiation measurements have been designed.
- The study's goal is to assess the spatial potential of solar energy in the Saudi Arabia by estimating the total and analyzing the spatial variations of solar radiation to determine which of these sites is the best for generating solar energy and is less affected by dust storms in the Saudi Arabia. In its collection and analysis, the study relied on data from King Abdullah City for Atomic and Renewable Energy and the Global Atlas of Solar Energy, where data from solar energy stations for the period 2013-2022 were entered after unifying the units measured in them, which are (watt / day / hour / m^2) so that the data is consistent. The data was entered into a geographic information system (GIS) to analyze and measure solar radiation. The process involved steps such as converting the data into point format, generalizing the data using interpolation, arranging the results into raster squares, classifying the results into levels, calculating the annual average radiation, and creating a final map of the solar radiation levels.

Development of Spatial Suitability Index for Photovoltaic Projects:

- The methodology used to develop the spatial suitability index for photovoltaic projects involved several steps to assess the energy production potential of different regions. The following paragraphs outline the key components of the methodology:

- Data Collection: Relevant data sources were compiled, including solar radiation data, geographical information, and surface terrain characteristics. Solar radiation data was obtained from meteorological stations, satellite imagery, or other reliable sources.
- Data Preprocessing: The collected data was processed to ensure consistency and compatibility. This involved standardizing units, removing outliers or erroneous data points, and conducting quality checks.
- Conversion to Point Format: The data was converted into a point format, where each data point represented a specific location within the study area. This was necessary to enable spatial analysis and interpolation techniques.
- Interpolation: Interpolation techniques, such as inverse distance weighting or kriging, were applied to generalize the data and estimate solar radiation values at locations where measurements were not available. This helped create a continuous surface of solar radiation distribution across the study area.
- Rasterization: The interpolated results were then arranged into raster squares or grids, where each grid cell represented a specific geographic area. This facilitated further analysis and classification.
- Classification: The rasterized data was classified into suitability categories based on energy production levels. These categories were determined by setting thresholds or ranges of solar radiation values associated with different energy production potentials.
- Suitability Index: A suitability index was developed by assigning numerical scores or weights to each suitability category. The scores were based on the energy production potential of a particular category, with higher scores indicating higher suitability for photovoltaic projects.
- Validation and Refinement: The suitability index was validated using independent data or ground truth measurements to assess its accuracy and reliability. If necessary, the index was refined or adjusted based on the validation results.

3. Results:

3.1. Dust storms affecting photovoltaic panel productivity:

Between 2011 and 2022, the Kingdom of Saudi Arabia experienced various dust storms across different regions, as measured by ground monitoring stations affiliated with the National Center of Meteorology. As shown in Figure 3, The data reveals that the eastern region of the Kingdom,

which includes Al-Ahsa Governorate, is the most affected by dust storms, with an average of approximately 25 dust storms per year. The northern borders region, which includes Rafha and Arar stations, had an average of approximately 11 dust storms per year. The southern region, which includes Wadi Al-Dawasir, Sharurah, and Najran stations, had an average of approximately 9 dust storms per year. The average number of dust storms per year in the western region, which includes Makkah, Al-Madinah, and Tabuk stations, was approximately 5.5 dust storms. The graph provides useful information about the frequency of dust storms at the regional level in the Saudi Arabia, which can help inform decisions related to disaster management and planning.

Al-Ahsa Governorate was the most vulnerable region to dust storms during this period, recording approximately 30 dust storms in 2012, followed by 24 storms in 2015, around 23 storms in 2018, and 13 storms in 2021. The number of storms increased again to about 30 in 2022. The frequency of dust storms varied from year to year and was influenced by factors such as precipitation rate, air fronts, and atmospheric pressure. Approximately 17 dust storms occurred during this period.

The Rafha station recorded approximately 12 storms in 2012 and approximately 9 storms in 2013, with the frequency of storms increasing again in 2015 to approximately 12. The rate of storms decreased to approximately 7 storms in 2018 and approximately 5 storms in 2022. Regarding the Jazan station, the number of dust storms was approximately 8 in 2011, and the rate of storms increased to approximately 17 in 2015. The rate of storms decreased to approximately 14 in 2018, and the decline continued until 2022 with approximately 10 dust storms.

The Wadi Al-Dawasir station recorded about 6 storms in 2011, with the rate decreasing to 4 storms in 2015. The intensity of storms increased to about 13 in 2018, and then decreased to about 11 and 6 straight storms in 2021 and 2022, respectively.

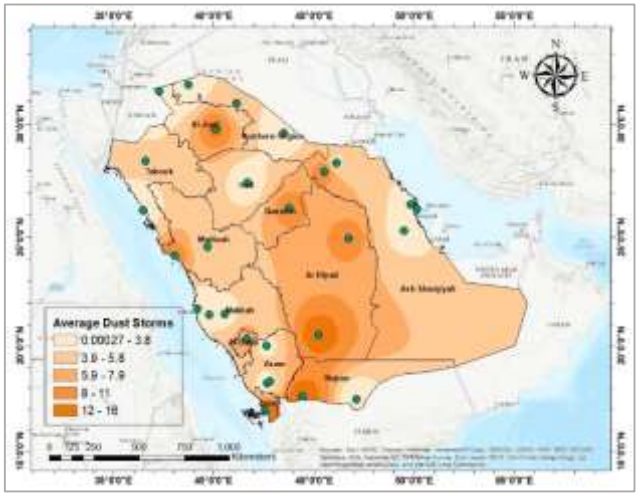

Figure 3. Average dust storms from 2011 to 2022 at the regional level in the Saudi Arabia.

Additionally, the highest monthly occurrence of dust storms in the regions of Saudi Arabia was studied for a period spanning from 2011 to 2022, the data reveals that the eastern region of the Kingdom, which includes Al-Ahsa Governorate, experienced the highest average daily rate of dust storms, ranging from approximately 0.4 to 0.7 dust storms per day, with the highest rates occurring from March to May. The northern borders region, which includes Rafha and Arar stations, had an average daily rate ranging from approximately 0.1 to 0.3 dust storms per day, with the highest rates occurring from March to May. The southern region, which includes Wadi Al-Dawasir, Sharurah, and Najran stations, had an average daily rate ranging from approximately 0.1 to 0.2 dust storms per day, with the highest rates occurring from March to May. The western region, which includes Makkah, Al-Madinah, and Tabuk stations, had an average daily rate ranging from approximately 0.05 to 0.1 dust storms per day, with the highest rates occurring from March to May. The graph provides important information about the average daily rate of dust storms in different regions of the Saudi Arabia, which can help inform decisions related to disaster management and planning. Also, the data reveals that the eastern region of the Kingdom, which includes Al-Ahsa Governorate, experienced the highest percentage of dust storms, ranging from approximately 30% to 50% of monthly days with dust storms, with the highest percentages occurring from March to May. The Northern Borders region, which includes Rafha and Arar stations, had a percentage ranging from approximately 10% to 30% of monthly days with dust storms, with the highest percentages occurring from March to May. The southern region, which includes Wadi Al-Dawasir, Sharurah, and Najran stations, had a percentage ranging from approximately 5% to 20% of monthly days with dust storms, with the highest percentages occurring from March to May. The western region, which includes Makkah, Al-Madinah, and Tabuk stations, had a percentage ranging from approximately 2% to 10% of monthly days with dust storms, with the highest percentages occurring from March to May. The graph provides valuable information about the percentage of monthly days with dust storms in different regions of the Saudi Arabia, which can help inform decisions related to disaster management and planning (Fig. 4, 5). The Al-Ahsa region is the most affected by dust storms, with an average rate ranging from 2.16 to 1.65 days per month from February to June. From February to May, the Hafr Al-Batin station experienced an average of 1.42 to 1.75 stormy days per month. At the Qaisumah station, the number of dust storm days ranged from 1.29 to 1.75 per month from March to May.

The Jazan station's average leading dust storm days ranged from 1.14 to 1.72 days per month from May to September. The Sharurah station experienced dust storms ranging from 1.18 to 0.95 days per month between March and August. The Wadi Al-Dawasir station recorded dust storms ranging from 0.80 to 1.03 days per month from March to May, indicating that the southern region is affected by dust storms after the eastern region. The peak dust storm days at the Arar station ranged from 1.07 to 1.63 days per month from March to May.

The Rafha station recorded an average of 0.53 to 1.43 dust storm days per month from February to May. During February and March, the Al-Jouf station experienced an average of 0.69 to 1.07 dust storms per day. The average number of dust storm days at the Al-Ula station decreased from 0.33 to 1.00 days per month between February and July, while at the Tabuk station, the average number of dust storm days ranged from 0.49 to 0.73 days per month between March and May. Furthermore, between April and August, the rate of dust storms at the Arafat Station in Makkah decreased from 0.14 to 0.86 days per month. During April and May, the rate of dust storm days decreased by about 0.16 to 0.20 days per month at the Al-Madinah Station. This indicates that the western region is less likely to experience dust storms compared to other regions.

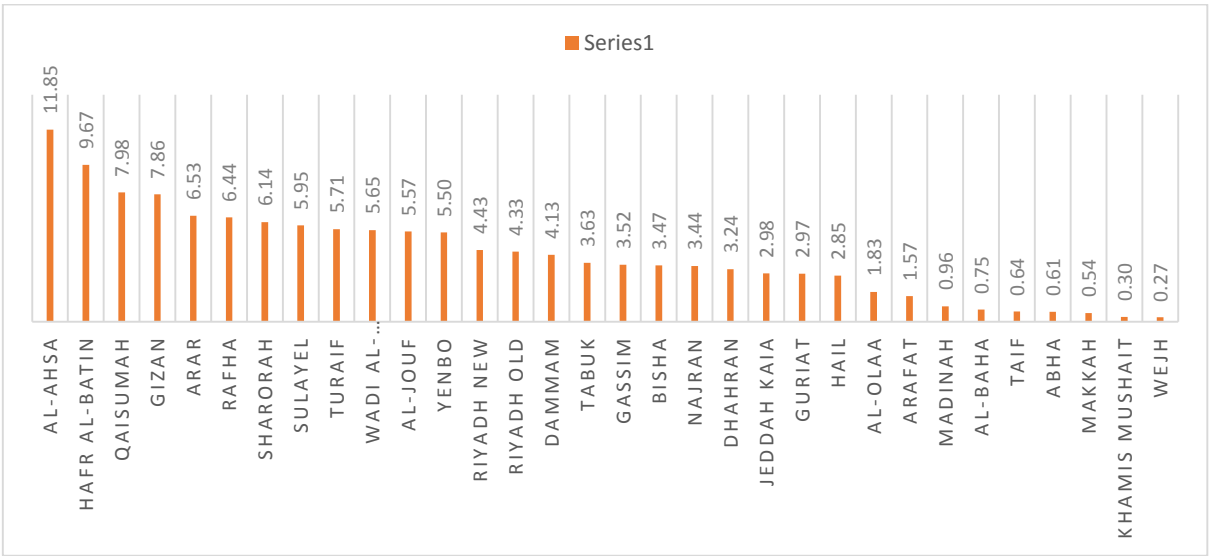

Figure 4. Depicts the average daily rate of dust storms in the Saudi Arabia from 2011 to 2022.

Figure 5. Percentage of average monthly average dust storms from 2011 to 2022 at the regional level in the Saudi Arabia.

3.2. The amount of photovoltaic energy produced and the impact of dust storms:

In an effort to quantify the impact of dust in solar energy production the amount of photovoltaic energy that can be produced in the Saudi Arabia between 2013 and 2022 is investigated (Fig. 6) It shows the amount of photovoltaic energy that can be produced in the Saudi Arabia in watt hours per square meter per day from 2013 to 2022. The data reveals that the northwestern region of Tabuk has the highest potential for photovoltaic energy production, with an average of approximately 6 watts/day/hour/m2. The southwestern region in Asir also has high potential, with an average of approximately 5.5 watts/day/hour/m2. The lowest potential for photovoltaic energy production was recorded in the Jazan region in the west and the eastern region. The graph provides valuable information about the potential for photovoltaic energy production in different regions of the Saudi Arabia, which can help inform decisions related to energy planning and investment. The northwestern region of Tabuk produced approximately 6 watts/day/hour/m^2, while the southwestern region in Asir produced approximately 5.50 watts/day/hour/m^2. The lowest production was recorded in the Jazan region in the western corner and the eastern region. The Kingdom's geographical location and surface topography play a critical role in increasing or decreasing solar radiation and contributing to photovoltaic energy production.

Figure 7 shows the total number of dust storms in the Saudi Arabia from 2011 to 2022. Al-Ahsa station recorded the most total dust storms, with approximately 444 storms, followed by Jazan station with approximately 393 storms and Qaisumah station with 353 storms.

The stations with the fewest dust storms were Al-Ula with approximately 4 storms, Arafat with approximately 11 storms, Al-Wajh with approximately 12 storms, Khamis Mushait and Makkah stations with approximately 15 storms, and Abha station with approximately 27 storms. Additional, the data reveals that the Al-Ahsa station recorded the highest number of dust storms during this period, with approximately 444 storms. Jazan station recorded the second-highest number, with approximately 393 storms, followed by Qaisumah station with 353 storms. The stations with the fewest dust storms were Al-Ula with approximately 4 storms, Arafat with approximately 11 storms, Al-Wajh with approximately 12 storms, Khamis Mushait and Makkah stations with approximately 15 storms, and Abha station with approximately 27 storms. The graph provides important information about the frequency of dust storms in different regions of Saudi Arabia, which can help inform decisions related to disaster management and planning. It also highlights the regions that are most vulnerable to dust storms, which can be used to prioritize the implementation of dust storm mitigation measures in these areas.

Based on this analysis, the eastern, southern, and northern regions are the areas most vulnerable to dust storms, which explains the impact on the productivity of photovoltaic panels in these regions.

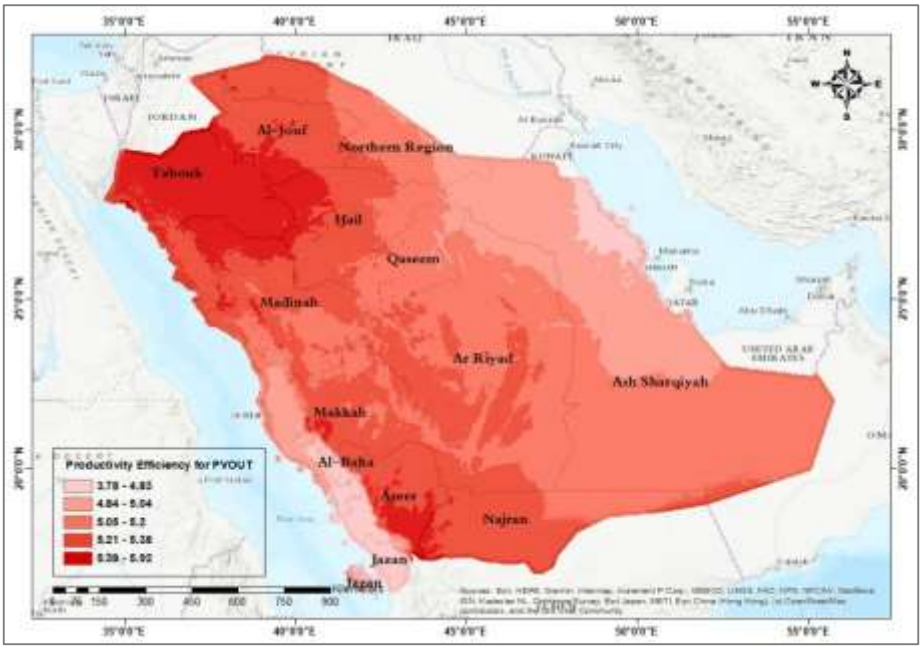

Figure 6. The amount of photovoltaic energy that can be produced in Saudi Arabia (watt hours / m^2 / day).

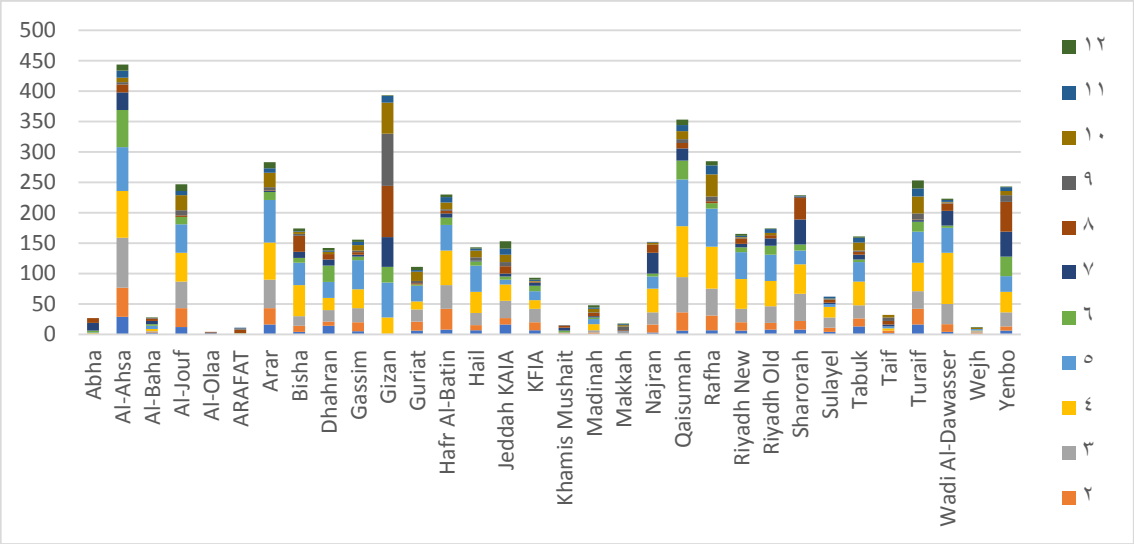

Figure 7. It shows the total number of dust storms that occurred at the regional level in Saudi Arabia from 2011 to 2022.

4. Discussion:

Figure 8, and table 2 depicts the spatial suitability categories were determined by calculating the average solar radiation for each region of Saudi Arabia at the monthly level from January to December for the period 2013-2020. The figure shows a classification of spatial suitability ranges for the construction of photovoltaic energy projects. The suitability ranges are divided into five categories, ranging from very high suitability to very low suitability. The classification is based on factors such as land use, land cover, slope, and distance from infrastructure. The purpose of this classification is to provide guidance for decision-makers in identifying areas that are suitable for the construction of photovoltaic energy projects, while minimizing the potential environmental impact and maximizing energy production. The table presents the land areas for each of the spatial suitability categories for the establishment of photovoltaic energy projects. The five categories are very high suitability, high suitability, moderate suitability, low suitability, and very low suitability. The table shows the total land area in square kilometers and the percentage of the total study area for each suitability category.

The results indicate that the majority of the study area falls within the moderate suitability category, with a total land area of 42,510 square kilometers, or 41.5% of the total study area. The very high suitability and high suitability categories have a combined land area of 8,702 square kilometers, or 8.5% of the total study area. The low suitability and very low suitability categories have a combined land area of 72,791 square kilometers, or 71% of the total study area.

These results provide valuable information for decision-makers in identifying areas that are suitable for the establishment of photovoltaic energy projects and can help to optimize energy production while minimizing potential environmental impacts. Analysis of this data identified the region's most suitable for placement of photovoltaic panels during specific months of the year, based on the solar radiation received, and the analysis of the data was conducted on an annual basis to identify the most suitable regions for permanent installation of solar panels. The northern corner of the Kingdom, including regions like Tabuk, Al-Jouf, Hail, the northern border, and Medina, was found to be highly favorable for photovoltaic energy production throughout the year. These areas receive consistently high levels of solar radiation due to their geographical location and surface terrain, making them ideal for permanent solar panel installations. The northern corner of the Kingdom, including regions such as Tabuk, Al-Jouf, Hail, the northern border, and Medina, was found to be most suitable for photovoltaic energy production from March to September. This is due to the high solar radiation these regions receive during this period, characterized by geographical location and surface terrain that allows relatively large amounts of solar radiation.

On the other hand, the analysis was conducted on an annual basis to determine the most suitable regions for the permanent installation of solar panels. The southern regions like south of the Eastern Province, south of Riyadh, Najran, Asir, east of Al-Baha, and south of Makkah were found to be most suitable for photovoltaic energy from October to December. This is because they receive higher solar radiation during this period compared to other months. Additionally, the northwestern corner, including Tabuk, Hail, Al-Jawf, and Al-Madinah, can generate moderate photovoltaic energy owing to the moderate solar radiation received. The northeastern Arabian Gulf coast and northern borders, as well as southwestern Red Sea coast regions like Jazan, Asir, Al-Baha, and Makkah receive relatively less solar radiation due to location and terrain. As a result, they are less suitable for photovoltaic energy compared to other regions.

The spatial suitability categories for photovoltaic projects are divided into four categories based on energy production. Category 4, covering 9% of the Kingdom's area in the northwest and southwest corners, represents the highest suitability. Category 3 indicates moderate suitability, covering approximately 65% of the Kingdom's area. This includes the central region, south of the Eastern Province, Najran, Makkah, Al-Madinah, and the Northern Region. Category 2 denotes unsuitability for photovoltaic energy production, covering around 20% of the area. This category is in the eastern parts of the Eastern and Central regions, as well as the northern borders.

Category 1 represents areas unsuitable for photovoltaic energy production, covering approximately 6% of the Kingdom's area. This category encompasses the eastern and western outskirts of the Arabian Gulf coast and the Red Sea coast in Jizan, Asir, and Al-Baha.

In summary, the analysis divided Saudi Arabia into four spatial suitability categories for photovoltaic projects based on solar radiation data. The highest suitability areas in Categories 3 and 4 comprise the northern, central and southern regions. The lowest suitability coastal areas are designated as Categories 1 and 2. The classifications provide guidance for optimal locations to implement photovoltaic projects while minimizing environmental impact.

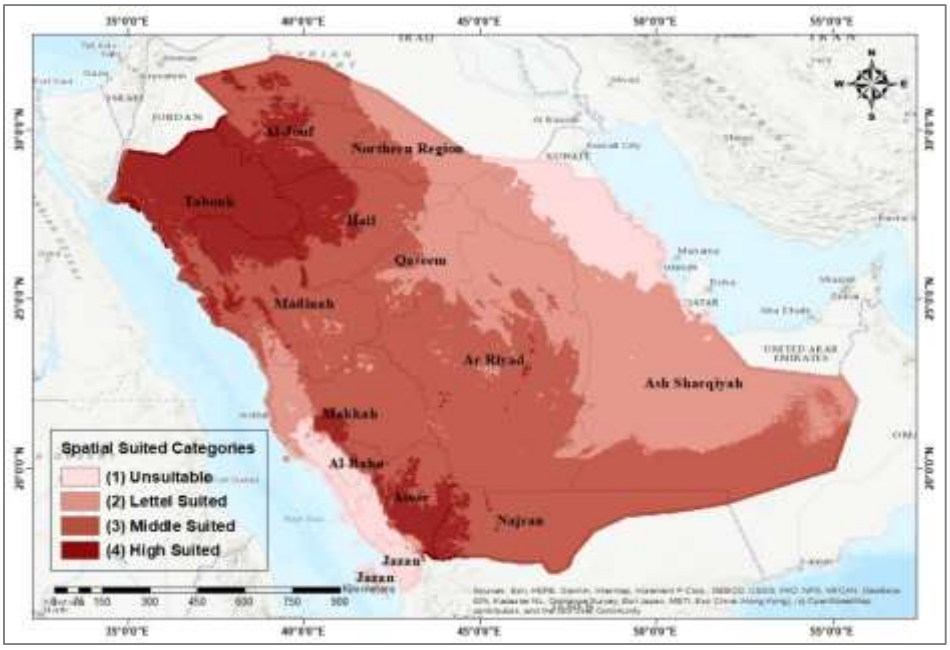

Figure 8. Suitability index for the construction of photovoltaic energy projects.

Table 2. Land areas for each of the spatial suitability categories for the establishment of photovoltaic energy projects.

Category	Appropriate category	Convenience limits	Area (Km2)	Relative Area (%)
1	Unsuitable	Excluded (0)	584723	**20**
2	Little suited	50-40	198425	**6**
3	Middle suited	80-50	575652	**65**
4	High suited	100- 80	851297	**9**

Based on the analysis of Figure 9 and Table 3, Total dust storms in the Saudi Arabia from 2011 to 2022. The figure illustrates the spatial distribution of dust storms across different regions of the Kingdom and highlights the variation in their frequency over time. The figure indicates that some regions, such as the northern corner of the Kingdom, experience relatively low incidence of dust storms, while other regions, such as the northeastern parts of the Arabian Gulf coast and the southwest Red Sea coast, are more prone to dust storms. The figure also shows that the frequency of dust storms varies seasonally, with lower incidence during the months from March to September and higher incidence during the months from November to February. Overall, the figure provides important information for assessing the suitability of different regions for photovoltaic energy production and identifying appropriate mitigation measures to minimize the impact of dust storms on the efficiency and maintenance of photovoltaic panels. And, the table shows the low frequency of dust storms, land areas for spatial suitability categories for the establishment of photovoltaic energy projects are limited. It provides information on the land areas that fall under different spatial suitability categories for photovoltaic energy projects based on the frequency of dust storms in different regions of the Saudi Arabia.

The table indicates that the land areas categorized as very high suitability (Category 6) and ideal locations with low frequency of dust storms (Category 5) account for a relatively small proportion of the Kingdom's total land area, at approximately 5% and 15%, respectively. In contrast, the land areas categorized as medium suitability (Category 4), low suitability (Category 3), and unsuitable (Categories 1 and 2) account for a much larger proportion of the Kingdom's total land area, at approximately 30%, 40%, and 4-6%, respectively. This suggests that due to the high frequency of dust storms in many parts of the Kingdom, the land areas that are suitable for photovoltaic energy projects are limited, which highlights the importance of identifying appropriate mitigation measures to minimize the impact of dust storms on the efficiency and maintenance of photovoltaic panels. Specifically, the northern corner of the Kingdom, including regions such as Tabuk, Al-Ula, and Abha, are suitable during the months from March to September.

Regions that are unsuitable for photovoltaic panel installation or have high frequency of dust storms are located in the northeastern parts of the Arabian Gulf coast in the eastern region and the southwest on the Red Sea coast, represented by Jazan, Asir, Al-Baha, and Makkah. This is due to the recurrence of dust storms caused by wind speed and direction, as well as their influence on air masses, resulting from their geographical location and surface shapes.

In contrast, some areas experience lower frequency of dust storms due to their geographical location and surface shapes that affect winds and air masses differently.

Category 6, representing very high suitability for photovoltaic energy projects due to the absence of dust storms, covers an area of approximately 22,031 km^2, or approximately 5% of the Kingdom's area, and is in the northwestern corner in Tabuk and Al-Ula, as well as the southwestern corner in Makkah, Al-Baha, Asir, and parts of Najran.

Category 5, representing ideal locations with low frequency of dust storms for photovoltaic energy projects, covers approximately 432,873 km^2, accounting for 15% of the Kingdom's total land area. It is present in the central region, the southern part of the eastern region, Najran, Makkah, Madinah, and the northern region.

Category 4 indicates medium suitability for photovoltaic energy production and is subject to frequent dust storms. It covers an area of approximately 63,762 km^2, accounting for 30% of the Kingdom's total area, and is in the southeastern and southern regions. Category 3 represents areas with low suitability for photovoltaic energy production due to the high frequency of dust storms. It covers approximately 76,325 km^2, accounting for 40% of the Kingdom's total land area. It is found in both the central and eastern parts of the western regions, as well as the southern parts of the northern region.

Categories 1 and 2 denote areas that are weak and unsuitable for generating photovoltaic energy due to the high frequency of dust storms. They occupy an area of about 18,567 km^2 and 37,452 km2, respectively, which accounts for 4-6% of the Kingdom's total area. They are found in Jizan, Asir, and Al-Baha in the western Red Sea coast as well as in the eastern region along the Arabian Gulf coast.

One important factor that contributes to the different levels of suitability for photovoltaic energy production across Saudi Arabia is the variation in wind patterns and surface characteristics. The regions with higher incidence of dust storms tend to have higher wind speeds and more rugged terrain, which can create more dust and sand particles and thus reduce the efficiency of photovoltaic panels. In contrast, regions with lower incidence of dust storms tend to have more stable wind patterns and smoother terrain, which can enhance the efficiency of photovoltaic panels.

Another important factor is the seasonal variation in dust storms, which can affect the suitability of different regions for photovoltaic energy production.

The months from March to September are generally associated with lower incidence of dust storms in the northern corner of the Kingdom, which makes this region more suitable for installing photovoltaic panels during this period. In contrast, the months from November to February are associated with higher incidence of dust storms in many parts of the Kingdom, which can reduce the efficiency of photovoltaic panels during this period.

To address the challenges posed by dust storms, various mitigation measures can be implemented to minimize their impact on the efficiency and maintenance of photovoltaic panels. For instance, regular cleaning of the panels can remove accumulated dust and sand particles and enhance their performance. The installation of protective barriers, such as fences or walls, can also reduce the amount of dust and sand particles that reach the panels. Additionally, the use of advanced monitoring systems can enable real-time detection and response to dust storms, such as by tilting the panels to minimize the accumulation of dust or shutting down the system temporarily during severe dust storms.

Overall, the spatial assessment of dust storms in Saudi Arabia provides valuable insights into the suitability of different regions for photovoltaic energy production, as well as the challenges and opportunities associated with harnessing the country's abundant solar energy resources. By leveraging these insights and implementing appropriate mitigation measures, the Kingdom can accelerate its transition to a low-carbon economy and contribute to global efforts to mitigate the impacts of climate change.

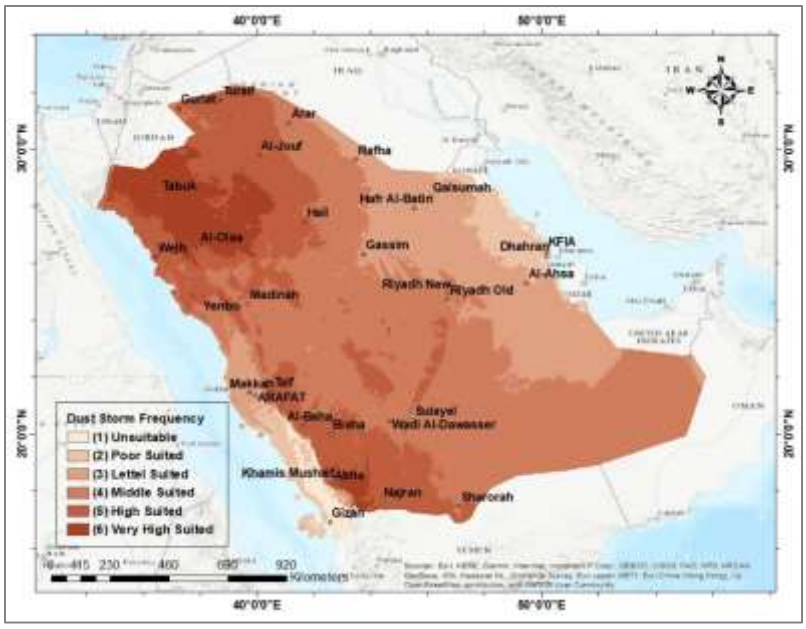

Figure 9. Suitability index for solar energy installations based on dust storms frequency.

Table 3. Converge of land areas for each of the dust- frequency related, suitability categories for solar energy applications.

Category	Appropriate category	Convenience limits	Area (Km2)	Relative Area (%)
1	Unsuitable	Excluded (0)	18567	**4**
2	Poor suited	20-30	37452	**6**
3	Little suited	40-50	76325	**40**
4	Middle suited	50- 60	63762	**30**
5	High suited	70-80	432873	**15**
6	Very high suited	90- 100	22031	**5**

5. Conclusions

The spatial assessment conducted on Saudi Arabia highlights the most appropriate locations for photovoltaic energy projects. By analyzing the monthly averages of solar radiation and the total number of dust storms, we found a strong correlation between these two factors, it was discovered that the northern corner of the Kingdom, covering regions such as Tabuk, Al-Jouf, Hail, the north border, and Medina, is the best place for photovoltaic energy production during the months from March to September. On the other hand, the southern parts of the Kingdom, including regions such as the south of the Eastern Province, the south of Riyadh, Najran, Asir, the east of Al-Baha, and the south of Makkah, are most suitable for photovoltaic energy production during the months of October to December.

The spatial assessment also identified areas that are not suitable for photovoltaic energy production due to the frequency of dust storms. These areas are found in the northeastern parts of the Arabian Gulf coast in the eastern region, as well as the southwestern parts of the Red Sea coast, and are represented by Jazan, Asir, Al-Baha, and Makkah.

Overall, the spatial assessment has categorized the Kingdom's land into six categories of suitability for photovoltaic energy production, ranging from very high to unsuitable. The results of this analysis can serve as a guide for decision-makers and stakeholders in the energy sector to identify the most appropriate locations for photovoltaic energy projects, thereby increasing the efficiency and effectiveness of the Kingdom's energy infrastructure.

In summary, the spatial assessment can serve as a valuable tool for decision-makers and stakeholders in the energy sector to identify the most appropriate locations for photovoltaic energy projects and to maximize the efficiency and effectiveness of the Kingdom's energy infrastructure.

Based on this analysis, it is recommended that decision-makers and stakeholders in the energy sector focus their efforts on developing photovoltaic energy projects in the most suitable locations identified by the spatial assessment. These locations include the northern corner of the Kingdom during the months from March to September and the southern parts of the Kingdom during the months of October to December.

Furthermore, it is important to consider the frequency of dust storms in the selected locations to ensure that the photovoltaic panels are not affected by the dust and to maximize their efficiency. The spatial assessment has identified areas that are not suitable for photovoltaic energy production due to the high frequency of dust storms, and it is recommended that these areas be avoided when planning and implementing photovoltaic energy projects.

It is also recommended that further research be conducted to explore the potential for photovoltaic energy production in the medium and low suitability categories, as these areas still have the potential to contribute to the Kingdom's energy infrastructure. However, the frequency of dust storms in these areas should be taken into consideration.

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Delivery of a Solar-Powered Forward Osmosis Seawater Desalination Plant: Trevi's 500 m3/day Zero-Carbon FO Seawater Desalination Plant at NELHA

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Abstract:

This paper presents an account of Trevi's delivery of a 500 m3/day solar powered forward osmosis (FO) seawater desalination plant at the Ocean Science and Technology Park of the Natural Energy Laboratory of Hawaii Authority (NELHA). The project aimed to demonstrate the viability of solar thermal-powered desalination for agricultural applications through the integration of a 2MW micro-dish solar thermal array with a state-of-the-art FO system. Highlighted in the paper are the three distinct project phases; Planning and Design, System Construction, Installation & Testing followed finally by System Operation and Optimization. Results and decisions which led to the final plant design will be shared, highlighting how Trevi Systems succeeded in producing a zero-carbon FO seawater desalination plant with a projected Levelized Cost of Water (LCOW) estimate competitive with existing carbon-intensive RO technologies (based on some assumptions and the cost of heat which is required for FO). Trevi's design and implementation of a solar-powered FO seawater desalination plant at NELHA demonstrated groundbreaking advancements in sustainable desalination. The careful planning, strategic design selection, and innovative technological developments resulted in a zero-carbon, competitive LCOW desalination solution.

Keywords: Forward Osmosis, Solar-Powered Desalination, Seawater Reverse Osmosis, Renewable Energy, Environmental Sustainability

1. Introduction

The pressing global water crisis, exacerbated by population growth, climate change-induced disruptions, and the decline in freshwater reserves, underscores the urgent need for sustainable and innovative solutions in water resource management. This crisis has propelled the quest for advanced desalination technologies capable of mitigating freshwater scarcity and ensuring a reliable supply of potable water. Consequently, the imperative to develop efficient, energy-effective, and eco-friendly desalination technologies has never been more critical.[1]

Conventional desalination methods, primarily seawater reverse osmosis (SWRO), have been instrumental in augmenting freshwater supply. However, the widespread adoption of SWRO has been constrained by its carbon-intensive operation, reliant on non-renewable electrical energy resources. These approach, while technically effective, imposes a substantial environmental footprint and escalating cost as fossil fuels decline, rendering them less sustainable and economically viable in the long term.[2]

In response to these challenges, Trevi Systems Inc designed and produced a 500 m3/day solar-powered Forward Osmosis (FO) seawater desalination plant, made possible by a $4 million grant from the US Department of Energy and awarded to NELHA in 2019. The project's aim was to introduce a renewable-energy driven desalination system, leveraging the inherent advantages of FO technology to address the water crisis sustainably.

FO technology, predicated on utilizing the natural process of osmosis, osmotic concentration differentials, and low-pressure operation, offers a promising alternative to the energy-intensive nature of traditional reverse osmosis desalination method. By harnessing solar thermal energy and integrating FO instead of RO, Trevi sought to demonstrate an approach that alleviates the carbon burden associated with reverse osmosis.

Ultimately, the transformative potential of renewable FO technology heralds a promising era in zero-carbon water resource management, steering us towards a more resilient and sustainable water-dependent ecosystem.

2. Materials and Methods

The project was structured into three distinct phases, each delineating specific stages and decision-making criteria.

2.1. Project Phase 1: Planning and Design

This phase focused on establishing the groundwork for the renewable forward osmosis (FO) plant, encompassing environmental and logistical assessments and selection of critical components for the solar FO system. Key activities included:

2.1.1. Draw Solution Toxicity Assessment: Protocols were devised and implemented to evaluate the toxicity of the draw solution concerning a downstream algae farm user. In case of toxicity, mitigation strategies were identified and employed.

2.1.2. CSP Array Design Modifications & Recommissioning: A process was undertaken to re-power an idle Concentrated Solar Power (CSP) array, which had been inactive for nearly 8 years after it failed to meet electrical energy delivery targets.

2.1.3. Component Selection for the FO System: Evaluation and testing were conducted for crucial elements like membranes, draw solution cost, heat exchangers, and system instrumentation. Innovations in draw solution design, polymeric heat exchanger development, and FO membranes were explored to improve efficiency while reducing capital expenditure.

2.2. Project Phase 2: System Construction, Installation & Testing

During this second phase, the various key cost components of the solar FO systems were tested, followed by the construction and integration into the solar CSP plant at the NELHA site. This was undertaken despite challenges posed by the Covid outbreak and associated quarantine measures. Key activities involved:

2.2.1. Testing CSP Array: Testing was performed on the CSP array, accompanied by the replacement of outdated computer architectures, and configuring the array to operate with hot water storage of less than 130^{o}C.

2.2.2. FO plant metric performance identification: Three significant metrics were identified:

a. Verification of overall system operation during low water production (turndown range).
b. Ensuring the FO system did not release polymer into the environment through reverse diffusion through the FO membrane.
c. Utilizing the reconditioned CSP array to reliably provide and regulate heat to the FO plant.

2.3. Project Phase 3: System Operation and Optimization

This phase focused on multiple operational cycles, with water production, water quality testing and optimization procedures to enhance the plant performance. Key elements included:

2.3.1. Identifying and Measuring Performance Metrics:

2.3.1.1. Ensuring the reconditioned CSP system met thermal production metrics.

2.3.1.2. Validating the correct functioning of the thermal energy storage system.

2.3.1.3. Determining water production rates from the FO system.

2.3.2. Cost Projection and Analysis: Calculations based on capital and operating costs of the pilot plant were utilized to project costs for a 20X scaled plant. These projections, informed by pilot plant data, aided in setting thermal energy cost targets for future CSP arrays to meet Levelized Cost of Water (LCOW) objectives. These estimates were compared to traditional seawater reverse osmosis (SWRO) estimates for a similar sized plant.

3. Results: Final FO Design Selection & Operation

This comprehensive three-phase structure led to results that informed the final selection and operational blueprint and guided the project toward a refined, sustainable, and renewably powered FO plant, marked by its technological advancements, sustainability, and alignment with cost-efficient water production.

3.1. Results from Project Phase 1: Planning and Design

3.1.1. Draw Solution Toxicity Assessment

This sub-phase of the project included conducting end-user testing of Trevi's forward osmosis (FO) draw solution polymer, evaluating its impact on the growth rate and productivity of commercially produced freshwater microalgae. The subcontractor Cyanotech carried out controlled laboratory tests on three key species of microalgae, assessing the effects of varying concentrations of the FO polymer on algae growth as shown by the two figures below.

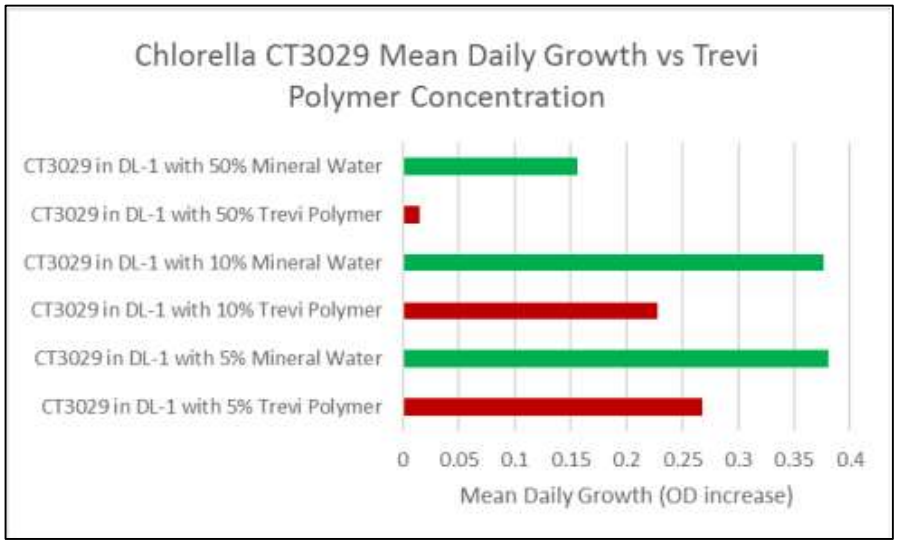

Fig 1: Chlorella growth vs. Polymer concentration

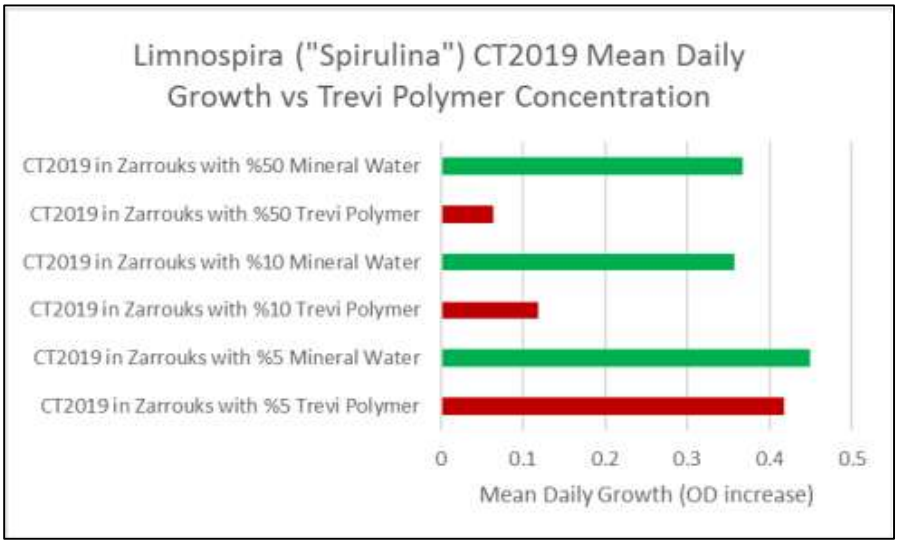

Fig 2: Limnospira Groth vs Polymer concentration.

The findings indicated that concentrations below 500 ppm had no discernible adverse effects on algal growth or appearance. However, concentrations exceeding 500 ppm led to growth suppression and eventual culture death. Daily additions up to 5 ppm did not impact growth. Additionally, FO polymer did not affect the microbiome of production cultures below 500 ppm. These results suggest that Trevi's FO system can deliver water that meets Cyanotech' s requirements for growing algae, provided the system implements fail-safe measures to prevent polymer concentrations from exceeding 10 ppm in the delivered water, alerting users in case of system failure. The study's findings offer valuable insights into ensuring the compatibility of FO systems with algal cultivation needs.

3.1.2. Design Modifications & Recommissioning of the CSP Array

There were 2 major undertakings in this sub-task. The existing CSP array had to be modeled to determine the operating range of its application as a thermal energy source and the necessary modifications were determined and designed for coupling with the FO system. The existing thermal energy storage system capacity was evaluated, and a supplemental storage system was also sized and specified for procurement and installation in a subsequent phase of the project.

3.1.2.1. Estimate of CSP System capacity

The CSP system, covering 8180 m^2 with 980 mirrors, yielded an annual production of around 17.4GWh/year with an average GHI of 5.6kWh/m2. Using NELHA's solar data, daily energy calculations and two thermal energy models for Trevi's FO plant (38kWh/m^3 design and a stretch target of 32kWh/m^3), monthly water production was estimated, shown in Figure 3 below.

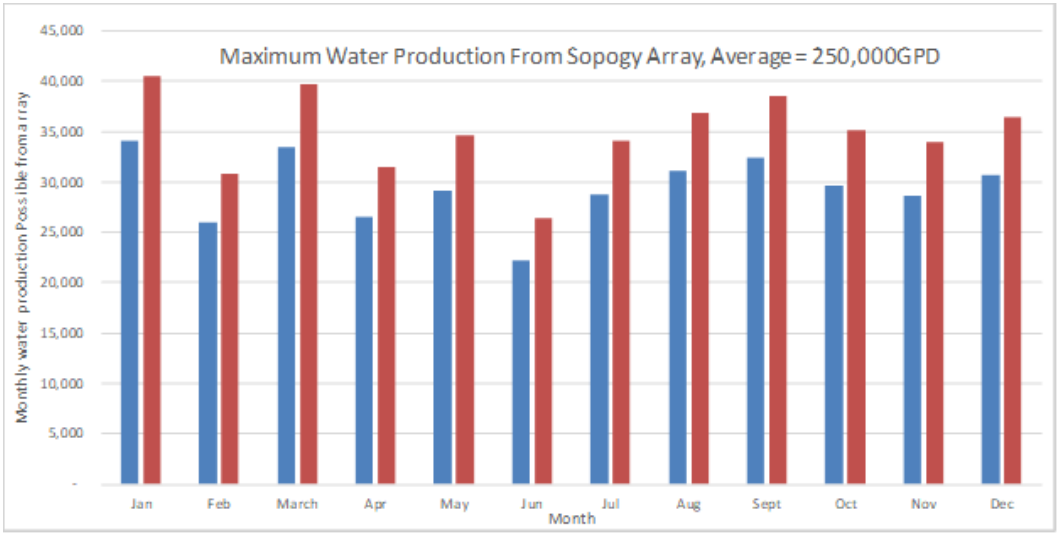

Figure 3 - Modelled Monthly Production Capacity of FO System Powered by the NELHA CSP Array

Figure 3 illustrates the monthly production capacity of the FO system powered by the NELHA CSP Array. Blue bars indicate existing (higher) thermal energy consumption (resulting in lower water production) from Trevi's current FO system, while red bars show increased water production if energy improvement targets are met. In June, the lowest solar output (worst-case blue bar) forecasted a production of 22,000m^3/month or 733m3/day (193,000gpd) assuming a 100% roundtrip thermal storage efficiency.

3.1.2.2. Supplemental Thermal Storage for CSP

This section evaluated adding additional thermal storage options for powering Trevi's 500m^3/day FO system. It projected storage sizing at 38 kWh (126 MJ) and for the stretch goal of 30kWh/m^3 production rate, factoring in 12% extra for heat loss, or approximating 40 kWh/m^3 in thermal energy. For daily operation, the system requires 20,000 kWh (72,000 MJ), needing 833 kW or 3,000 MJ per hour. Analysis suggests that during sunlight hours, the CSP array could sustain full capacity, but stored thermal energy is essential at night or when sunlight is unavailable. The existing NELHA CSP storage system comprises two tanks with 4500 gallons each of hot water storage. This provides approximately 2 hours of storage time under full production, so additional storage would be essential to meet capacity contracts. An investigation into numerous storage options was undertaken and Phase Change Energy Solutions' BioPCM showed increased storage capacity but at significantly higher costs compared to hot water, making hot water the most cost-effective choice. The following table presents a performance and cost comparison of their newest BioPCM storage system vs. hot water.

Operating Range	PhaseStor 180-170C	Water 180-170C	PhaseStor 180-80C	Water 180-80C
Volume and Mass	4.3m^3/4500lbs	4.8m^3/5300lbs	4.3m^3/4500lbs	4.8m^3/5300lbs
Latent kWh	175	0	175	0
Sensible kWh	12	27	125	272
Total Energy	187	27	300	272
Cost			$260,000	$17,740
Advantages	90% stored at high temp		90% stored at high temp	
Disadvantages				Stored over wide range (2 tank solution).

Table 1 - Thermal Storage Comparison of PhaseStor and Water

3.1.3. Component Selection for FO System

3.1.3.1. Draw Solution Optimization

Trevi opted for a liquid/liquid extraction methodology in the development of its fourth-generation FO system at NELHA. This approach hinges on utilizing a salt draw solution interfacing with the FO membrane, followed by a thermo-lytic polymer extraction stage. During the initial phase, three polymer and salt combinations were earmarked for testing. Suppliers were engaged to provide volume quotations for the required chemicals. However, environmental concerns arose regarding the selected ionic salts due to their potential promotion of organic growth in the environment, like the phosphates used in agricultural fertilizers. Subsequently, several amino acid salts, as well as organic salts such as Potassium Citrate, Potassium Tartrate, Choline Taurate, and Potassium Taurate, were scrutinized. Notably, some of these compounds also boast CO_2 carbon capturing capabilities, highlighting the potential of a draw solution that can both sequester CO_2 and leverage low-grade heat for regeneration, albeit beyond the scope of this grant.

Exploration of carbon capture abilities was undertaken using a CO_2 bubble column under pressure. Potassium Taurate, an alternative CO_2 sequestering salt, exhibited promising carbon uptake potential, suggesting its viability for both flue gas water purification using FO and carbon sequestration. For ease of sourcing, safety, low environmental impact, and for mitigating reverse diffusion concerns through the FO membrane, magnesium sulphate (Epsom salts) was chosen as the primary draw agent.

Regarding polymer optimization, Trevi's current TL1150-1 polymer exhibited commendable performance except for reduced osmotic pressure at higher temperatures. Despite Hawaii's cooler waters not posing a problem, further optimization of similar compounds was undertaken to

enhance overall performance in future plants where the warmer Gulf seawaters would be a factor. Collaboration with Nippon Shokubai, a large Petro-chemical manufacturer yielded the EO-BO variety of polymers, with reduced thermal dependence as shown in Figure 4 below:

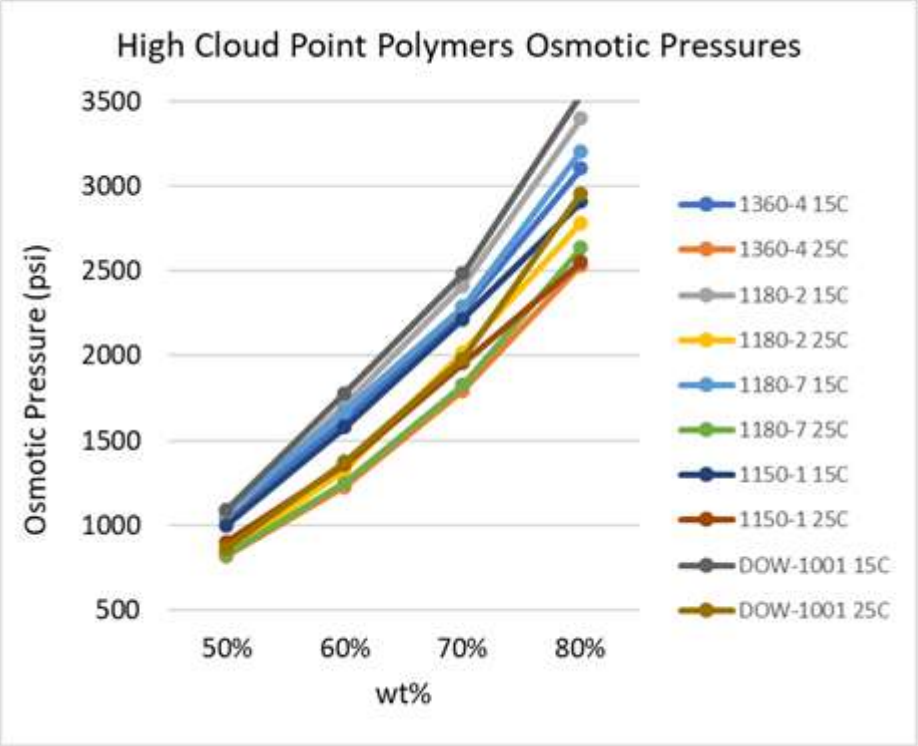

Figure 4 – Draw Solution Osmotic Pressure vs Concentration.

Adjustments were made to increase the osmotic pressure of the draw solution from a cloud point temperature of 65C to 75C, leveraging the solar thermal array's capacity to generate higher temperatures, as osmotic pressure is linearly correlated with cloud point for the thermolytic polymers under consideration.

Analysis of polymer osmotic pressure between 15C and 25C indicated osmotic pressures exceeding 3000psi, suggesting potential seawater recovery rates of over 80% (scaling neglected for the moment) in Hawaii. This higher recovery rate showcased the FO plant's potential to outperform RO systems, typically operating at around 45% recovery. This higher recovery in FO systems reduces the need for high pre-conditioning chemicals in the pre-treatment stages, subsequently curtailing both capital and operating costs proportionately.

Further qualification of additional vendors through testing was conducted based on a pre-defined specification from Trevi. Notably, polymers such as 55GI-1602, 70GI-2703, 55GI-2001, 55GI-2101, 55PI-1501, 55TG-36, GL-2015-BC, GL-2108, GL-2109, GL-2110, 70BI-2601, 70BI-1501, and 70GI-1803 showcased favorable properties. Conversely, approximately 5 polymers did not pass the rapid screening test, culminating in the selection of an EO-BO polymer from Nippon Shokubai for its advantageous phase separation characteristics, robust osmotic strength, and low toxicity.

3.1.3.2. FO Membrane Selection

Trevi had to evaluate available FO membrane suppliers through small-scale water production vs. cost analysis and identify the preferred membrane types and suppliers for integration into the FO system. The selection process considered both capital and operating costs designed for the nominal 500 m3/day configuration.

Assessments were carried out on three distinct membrane configurations:

a) 180 micron/1.3m long hollow fiber membranes,
b) 230 micron/1.3m long hollow fiber membranes, and
c) 180 micron/2m long hollow fiber membranes.

Experiments entailed feeding concentrated polymer draw agent on the shell side of the membrane and synthetic seawater in the bore. Comparisons revealed that directing the strong draw from the outer circumference towards the center yielded nearly identical water production to the configuration with the draw was fed from the center towards the outer circumference as shown by Table 2 below.

Membrane Type	Strong Draw	Seawater Feed	Surface Area (m^2)	Strong Draw Flow (m^3/Day)	Feed Flow (m^3/Day)	Strong Draw Pressure (PSI)	Seawater Feed Pressure (PSI)	Water Produced (m^3/Day)	Flux (LMH)	Seawater Recovery Rate (%)
1.3m, 180 Micron	Shell In->Out	Bore	375	64.32	54.78	14.5	40	32.19	3.58	54.0%
1.3m, 180 Micron	Shell Out->In	Bore	375	68.68	53.42	16	40	31.34	3.48	53.1%
1.3m, 180 Micron - Modified	Shell In->Out	Bore	375	69.23	53.42	18.5	40	30.03	3.34	52.0%
1.3m, 230 Micron	Shell In->Out	Bore	332	63.23	87.21	14	40	32.16	4.04	34.4%
1.3m, 230 Micron	Bore	Shell In->Out	332	51.78	48.51	42	6	27.15	3.41	41.7%
2m, 180 Micron	Shell In->Out	Bore	705	61.05	55.06	10	42	33.41	1.97	60.7%
2m, 180 Micron	Shell Out->In	Bore	705	67.59	58.33	13	41	34.34	2.03	58.9%

Table 2 - FO Membrane Test Results

All three membranes surpassed the benchmark target of 0.6 LMH, displaying mean flux rates (± 95% CI) of 3.05±0.70, 3.74±0.89, and 1.84±0.46, respectively. Consequently, the tested membranes produced approximately 30 m^3/day of fresh water at a 50-55% recovery rate (refer to Table-3).

	A: 1.3 m, 180 micron, 375m2		B: 1.3 m, 230 micron, 332m2		C: 2 m, 180 micron, 705m2	
	Recovery (%)	Flux (LMH)	Recovery (%)	Flux (LMH)	Recovery (%)	Flux (LMH)
	51.1%	3.06	49.1%	3.29	58.9%	2.03
	47.6%	2.73	34.4%	3.75	57.7%	1.92
	50.9%	2.31	30.6%	4.18	53.6%	1.59
	54.0%	3.24				
	54.0%	3.20				
	55.5%	3.32				
	57.2%	3.60				
	52.0%	2.96				
	53.0%	3.05				
	53.1%	3.04				
One Sample t-Test:						
Compare to target value of 0.6 LMH						
Mean Flux (LMH)	3.05		3.74		1.84	
Observations	10		3		3	
Variance	0.12		0.20		0.05	
95% CI	0.70		0.89		0.46	
t Stat	22.21		12.23		9.42	
P(T<=t) one-tail	1.8E-09	*	0.0033	*	0.0055	
** indicates significant at P<=0.05*						

Table 3 - Comparison of FO Membrane Performance Results to Benchmark Metric

This enhanced performance compared to previous state-of-the-art solutions significantly reduces the expected membrane count and overall form-factor to one-third of the initially projected figures for the plant.

Pricing for the specified membranes were acquired from three commercial vendors. The lowest quotation for the 500m3/day demonstration system stands at $150,000, constituting a third of the original project budget for this aspect. Scaling up to a full commercial 10,000m3/day system sees the quoted unit pricing halve from this initial amount.

3.1.3.3. Heat Exchanger Development & Testing

This task focused on heat exchanger development and testing, aiming to compare new Trevi designs to commercially available options, optimize costs, sizes, and performance for integration into the FO system. The primary objective was to find cost-efficient alternatives to the conventional plate-and-frame heat exchangers, known for their poor performance when the substantial viscosity changes experienced in Trevi's FO polymer are taken into consideration.

To address this challenge, a two-pronged approach was employed: internally designing and fabricating a low-cost polymeric heat exchanger and outsourcing the development of a custom-built metal unit.

Polymeric Heat Exchangers - Pilot Scale:

A prototype of Trevi's inline "twisted tube in shell" polymeric heat exchanger was designed, built and bench tested. The heat exchanger consisted of PEEK tubes twisted around each other and bundled into an annular tubular space. Initial tests demonstrated promising heat transfer coefficients, but further optimizations were necessary for practical implementation.

Polymeric Heat Exchangers - Modelling Scale-up:

Numerical models were developed to assess tube diameter and length requirements for the novel heat exchanger design, factoring in fluid properties, tubing geometry, and performance metrics. These models allowed for comprehensive visualization of trade-offs and led to the selection of polypropylene as the low cost material of choice for cost-effective tubing.

Makai Thin Foil Heat Exchangers:

In a paid study Makai Engineering designed and tested Thin Foil Heat Exchangers (THFXTM), which show potential for weight and size reductions compared to traditional plate-and-frame units. Prototype testing of THFXTM revealed unforeseen behaviors due to low fluid velocities and the specific properties of the FO polymer, necessitating adjustments in the design.

Despite initial progress in developing proprietary polymeric heat exchangers and exploring Makai's THFXTM, unforeseen challenges arose, impacting their immediate integration into the FO system. To expedite the FO plant build and mitigate program risks, Trevi decided to procure standard commercial plate-and-frame heat exchangers. While innovative heat exchanger designs showed promise, unforeseen complexities prompted Trevi to opt for conventional units to meet immediate project timelines and minimize risks.

3.1.3.4. Nano-filtration Membrane Selection

This activity focused on developing and testing high-temperature nano-filters for potential integration into the FO system as a draw solution polishing step. The aim was to leverage these filters to modify the system design, reducing thermal energy consumption, heat exchanger sizes, and potentially cutting final nano-filtration costs.

A critical aspect of various applications, including forward osmosis desalination, is the acquisition of nano-filters that maintain useful permeate flux and effective rejection rates at high temperatures.

Initial testing of a commercially sourced ceramic Al_2O_3-based tubular ceramic membrane had promising results. This membrane achieved impressive rejection rates of the bulk draw solution at high fluxes and temperatures under moderate pressure (less than 80psi).

The project initially focused on internally fabricated elements utilizing nano-coated ceramic elements. These elements were manufactured by coating existing UF ceramic membranes with a thin layer of polymerized film. Although preliminary tests showed some success in terms of rejection rates and flux at high temperatures, the performance degraded over time, which is an ongoing area of research to resolve. Subsequently, the project shifted focus to electrochemically depositing metallic coatings on cost-effective substrates, but these results were also unsatisfactory due to poor rejection stability.

Eventually, the team identified, tested, and selected a commercially available ceramic nano-filtration membrane during the developmental phase, marking a shift toward procuring these ready-made units for the FO system.

3.1.3.5. FO System Design

We developed a completed FO system design and from this, a Process & Instrumentation Diagram was generated (see Figure 5 below). From the P&ID, a process flow diagram was generated (PFD) to determine the flow rates in the various parts of the system, aiding in pipe and pump sizing, as well as heat exchanger sizing. Thereafter, detailed 3D CAD spool drawings were done of all the various piping components to allow outside fabrication estimates of the assemblies.

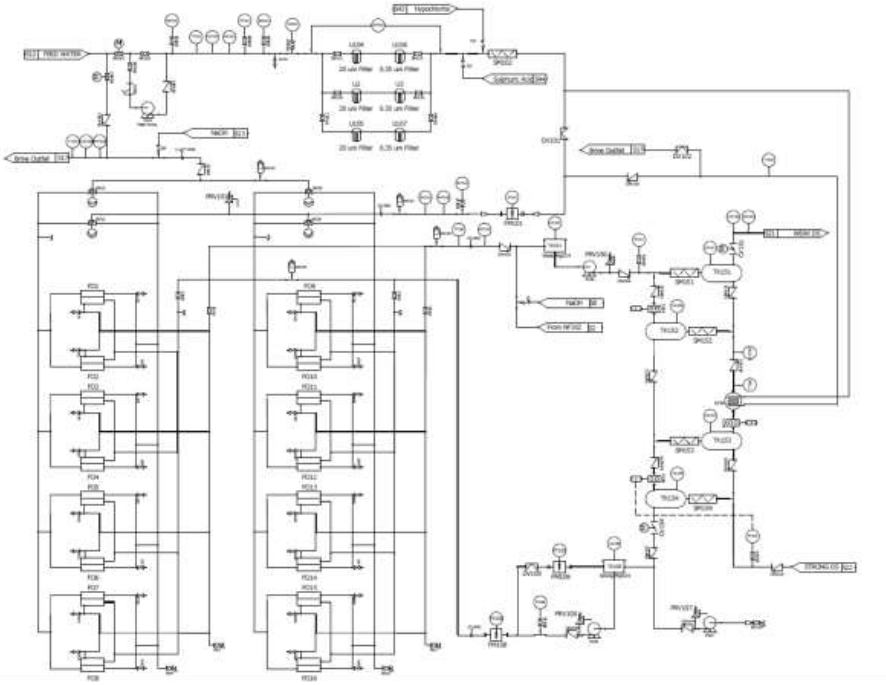

Figure 5 – P&ID 500m3/day FI System (1 of 4)

3.1.3.6. Project Costs

An extensive cost analysis of the project was done at this point to evaluate if it would be cost competitive to a commercially fabricated RO plant. A summary of the findings are as follows:

Heat Exchanger Cost Analysis:

The cost analysis outlined the expenses associated with the three types of heat exchangers for the 500m³/day FO system. Although the innovative Trevi Inline Twisted Tube in Shell Polymeric heat exchangers using 10" FRP housings offered potentially lower costs, this version was still in development and remained untested at full scale. The final FO system design incorporated commercial Plate and Frame heat exchangers.

Assembly Labor Cost Analysis:

An estimate of assembly manpower requirements was undertaken to compare against RO methods and materials of construction. RO plants require labor intensive stainless steel high pressure plumbing as well as costs associated with high voltage switchgear. Trevi sought to validate the budget allocation for a third-party EPC vendor, obtaining quotes from Hawaii-based contractors for fabricating the plastic piping and plumbing spools. Considering the complexity of the project and the challenges in finding skilled labor during the pandemic, Trevi opted to use in-house labor, with a budget allocation for specialized work by outside contractors.

Bill of Materials:

The material costs for the SunShot 500 m³/day FO system was detailed, indicating firm vendor-supported costs and those pending quotes. The total estimated costs were within the original budget estimate of $1.1 million.

Final Cost Analysis Review:

Several key items dominate the entire CAPEX bid package, these being the Forward Osmosis membranes and the Heat exchangers (making up 52% of the total system CAPEX). A price quote for 16 FO membrane units (sufficient for the 500m3/day) and for 320 FO membrane elements for the 10,000m3/day was received from the membrane vendor to project the 10,000m3/day system pricing more accurately. In addition, for the 500m3/day system, both the Trevi polymeric heat exchangers and the Makai metal heat exchangers were included in the costing of the 500m3/day system, with cost projections for both types received. In the 10,000m3/day system, only the polymeric heat exchanger option was selected.

The pie charts below (Figure 6) show the percentage cost contribution of the FO membranes and Heat exchangers for the 500m3/day system, and (using the volume pricing for these items received) and the projected CAPEX for the 10,000m3/day system:

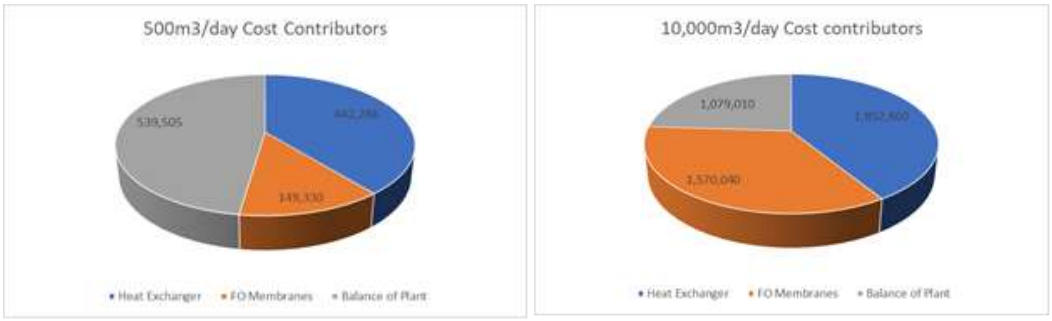

Figure 6 CAPEX Costs

The balance of plant scale-up is driven only by increased pipe, tank and pump sizes which scale in cost based on pipe diameter, therefore modestly. All instrumentation, controls and auxiliary equipment remains the same between a 500 and 10,000m3/day plant. Forward osmosis membranes point to an effort needed into cost reducing these, as the only remaining viable path to reducing CAPEX further for large plants. The projected 10,000m^3 day plant, based on these scaled up projections, indicates a CAPEX of around $4.5million is achievable (as originally projected), based on cost reductions for these two dominant pricing elements, heat exchangers and FO membranes.

3.2. Results from Project Phase 2: System Construction, Installation & Testing

In this stage, all the various components of the entire solar FO plant were received and verified. This was followed by the installation of the CSP and the construction of the FO system respectively. These were then integrated, commissioned, and verified. Initial data was used to verify energy consumption. The system was operated, occasionally shutting down to make modifications to install alternative components for testing.

3.2.1. Connecting the Utilities and Solar Array to the FO system

The FO system involved five crucial connections: an electrical feed, monitored by NELHA staff to determine the electrical power consumption (480v 3 phase) of both the solar array and the FO plant separately; a thermal measurement (flow and temperature difference) instrumented by Trevi on the primary water feed loop from NELHA and a secondary loop on the polymer flow within the system; connections for seawater feed, brine discharge, and permeate water. While the thermal measurements and flows for seawater, brine, and permeate are logged in Trevi's PLC system,

the integration of electrical consumption data wasn't configured during the tests, necessitating manual recording.

3.2.2. Preparation for System Commissioning

The commissioning plan was structured into three significant components:

Hydrostatic Integrity Testing: As the system was too large for water-based leak detection, air pressurization at 30psi and 60psi levels was conducted, followed by a water fill. All pumps and associated components were exercised to ensure they met design flow rates. This phase confirmed no leaks and verified the functionality of the system's pumps and associated equipment.

Instrumentation Verification: A validation plan ensured that all sensors were visible on the system PLC, calibrated within required accuracy levels, and screened values aligned with expected ranges. This encompassed calibrating 40+ sensors (pressure, temperature, flow) and verifying their readings on the PLC system. It also involved testing alarm tables, data trending, PID tuning, and enabling remote operations via screens installed at NELHA and Trevi's headquarters in California.

Consumables Loading: This step involved installing and validating three types of membranes (FO, Hot NF, and Cold NF) and filling them with the required preservation solutions to ensure membrane integrity. Chemical pre-treatment loading and validation, included sulfuric acid (sea water pH adjustment), sodium meta-bisulfate (de-oxygenation), sodium hydroxide (pH re-adjustment), sodium hypochlorite (disinfection), and activated carbon (taste improvement), with pump dosing levels were verified to maintain correct chemical concentrations.

3.2.3. System Warm-up, Operation and Ongoing Refinement

During the commissioning phase, three checkpoints were set to evaluate system readiness, each offering significant insights amidst the construction challenges encountered. The Forward Osmosis (FO) system underwent bi-weekly operation, generating daily permeate water volumes ranging between 80 to 150m^3. However, outputs lower than 80m^3 were unattainable due to heat exchanger inefficiencies, resulting in a system turndown ratio of 16%. Performance logs were compared against anticipated benchmarks to refine the system. Automation was implemented for inline refractive index sensors which facilitated precise draw solution osmotic pressure measurement. Software enhancements enabled membrane flux calculation and heat exchanger balance. An innovative PLC algorithm enabled autonomous system operation with minimal manual intervention. Initial water production revealed multiple challenges.

Early operations unveiled various issues:

- Discrepancies in pump performance contradicted expected flow rates, requiring technical support and correctional measures.
- Vibration issues in motors prompted structural enhancements for stabilization.
- Inadequate seawater flow necessitated the replacement of an undersized seawater feed pump motor.
- Draw solution miscalculation demanded additional draw solution shipment to the site for adjustment.
- Extractor imbalance led to unexpected mixing, investigated via borescope, requiring design modifications.
- Extractor tank simulations determined that external mixing improved system performance over internal mixing.
- Elevated temperatures in nano-filtration (NF) impacted extraction efficiency, prompting the pursuit of suitable NF membranes and system modifications.
- TDS (Total Dissolved Solids) in permeate water exceeded target levels due to over mixing in the extractor.
- Polymer detection was below detection levels in the brine, but TDS was higher than desired in the permeate.
- Validation tests showed permeate exceeding the target Total Organic Carbon (ToC) limit of 5ppm due to mixer refinement needs and NF membrane mismatch.

The successful generation of water from seawater in early July marked a significant milestone. However, early water quality assessments revealed challenges related to Total Dissolved Solids (TDS) levels due to extractor imbalance, impacting the system's cost-effectiveness. Efforts persist to achieve the targeted TDS of 250ppm, which will be achieved once the extractor issue is resolved.

3.2.4. Operating Results

As mentioned above, at low speeds extractor imbalance is minimized and TDS can meet the 500ppm threshold, but with increasing production, TDS rises to 500-700ppm.

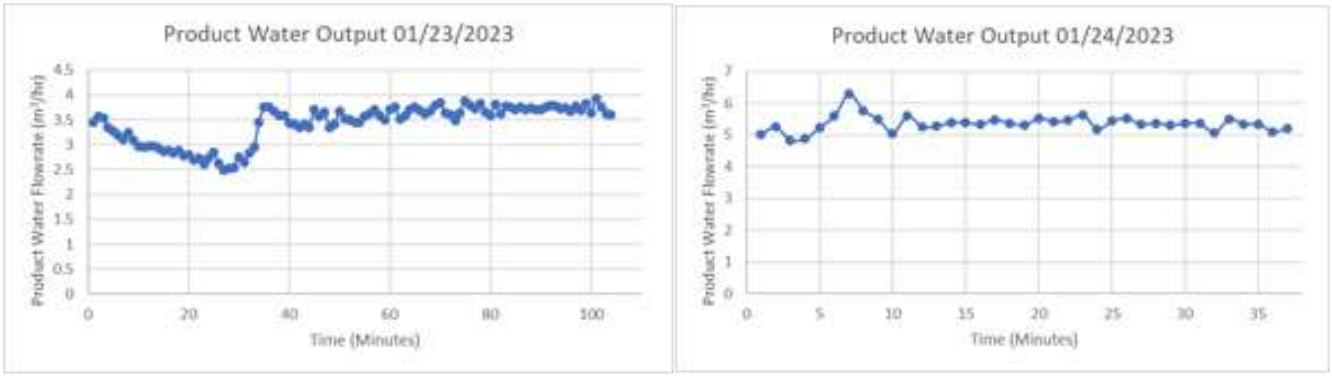

Figure 7 Permeate Production

A number of test-runs similar to the above two were performed with data summarized below in the T-test analysis showing the water production target was met, but not the TDS target:

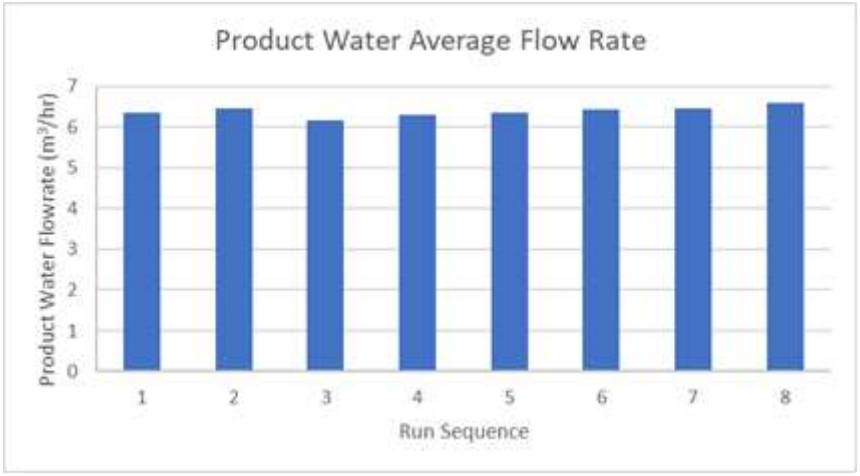

Figure 8: 5m3/day test runs

The recovery rate (permeate production to sea water feed) was also calculated for these runs and shown below:

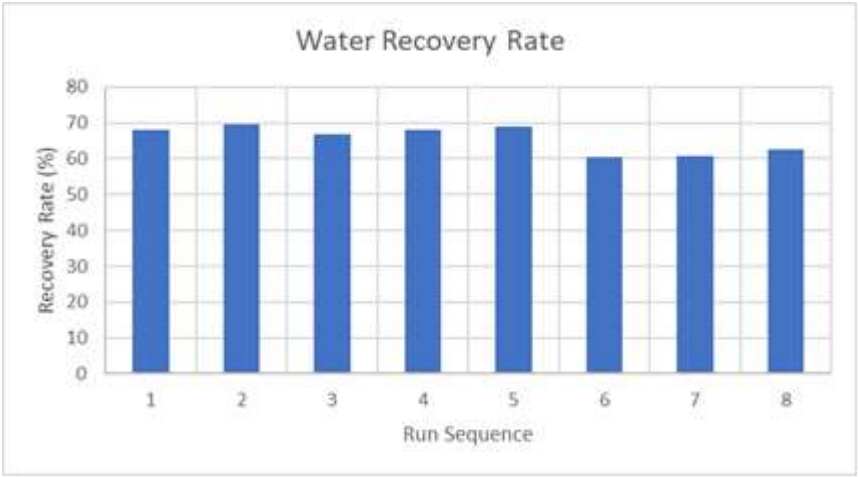

Figure 9: Recovery rate for 8 runs

The system has met the requirement for manual water production. Recovery rates at times approached 70%, higher than Ultra High-Pressure RO, which can only achieve a recovery of 65%. The FO result obtained is extremely encouraging for Zero Liquid discharge applications.

The investigation of the permeate water's Total Dissolved Solids (TDS) across 18 test-runs revealed levels typically doubling the 500ppm target ceiling as shown below:

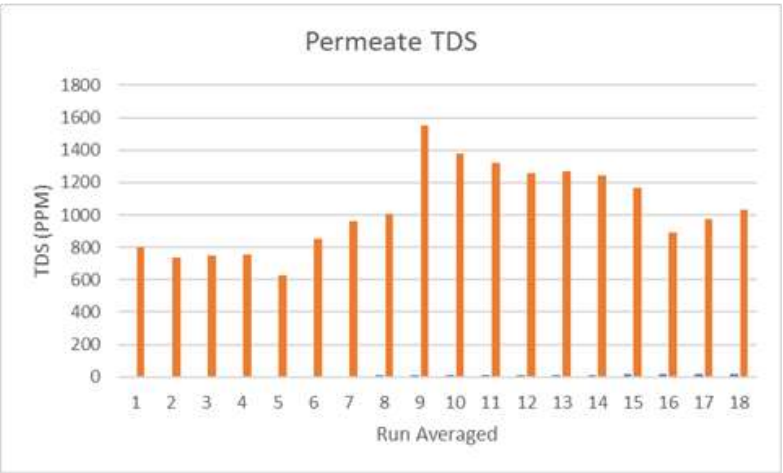

Figure 10 Permeate TDS over 18 runs

This increase in salt concentration mirrors the excessive polymer concentrations (ToC) in the permeate surpassing the 5ppm limit. Two primary causes for this overabundance of salts have been identified: excessive mixing in the extraction stage and the use of underperforming nano-filtration membranes.

While overmixing in the extractors contributes to the problem, the root issue stems from the substitution of nano-filter units rated at 99.5% rejection instead of the required 99.8% for divalent ions. Rectifying this discrepancy by replacing the current membranes with the appropriate rating is expected to reduce TDS levels by 62%, aligning with the design specifications and improving polymer rejection.

Additionally, the elevated operating temperature (45°-50°C) of the Nano filtration membranes has significantly reduced their rejection rates. To address this, proposed changes involve up-sizing the heat input control valve from the Concentrated Solar Power (CSP) array and installing a heat exchanger to cool the process stream before nano-filtration. These modifications aimed to lower system temperatures, enhancing rejection rates.

During the evaluation of permeate water quality, the analysis necessitated shipping samples to California on ice to prevent Total Organic Carbon (ToC) degradation in transit due to bacteria.

Unfortunately, obtaining local ToC measurements proved challenging, as only the University of Hawaii possessed equipment capable of measuring below 5ppm. Three samples were collected on different dates and sent to Trevi for analysis:

Date	Cold Nano Permeate TOC Measurement from Preliminary Runs Before Tuning Process
1/23/2023	41 ppm
1/24/2023	78.4 ppm
1/25/2023	55.6 ppm

Table 4 Water ToC

Tests on brine samples thus far have shown undetectable levels of polymer, using a highly sensitive analytical method with a lower detection limit of 1ppm. This indicates a low environmental impact of the draw solution to marine life.

Despite the extractor and NF challenges, the system achieved high water production performance and displayed promising recovery rates, exceeding those of Ultra High-Pressure Reverse Osmosis systems. However, ongoing optimization is crucial to meet water quality targets and reduce undesirable salt carry-over. Efforts to rectify NF membrane discrepancies and improve temperature control are underway, thereby enhancing system performance for consistent water quality output.

3.3. Results from Project Phase 3: Project CAPEX & Thermal Power consumption.

3.3.1. System Operation and Main Findings

This project phase focused on long duration system operation and data collection which was used to calculate energy consumption of the FO system. The three main findings were as follows:

Firstly, the capability of the Concentrated Solar Power (CSP) system to generate over 17,500kWh/day of thermal heat was successfully met. Secondly, the system's thermal storage capacity reached the required threshold of 1,100kWh/day. Finally, numerous test runs conducted over several months, surpassing more than 100-hours cumulative interval, yield an average permeate production close to 8m^3/day.

Although the system consistently operated for prolonged durations at 30gpm (163m^3/day), the operational time was constrained to 4 to 6 hours daily due to CSP array heat availability limitations. The bottleneck resulting in this lower than expected flow wasn't primarily due to CSP heat availability but rather stemmed from extractor imbalance issues causing water quality degradation at higher permeate production rates.

3.3.2. Project Estimates – CAPEX and Thermal Load

3.3.2.1. CAPEX

During one of the final stages of this project, Trevi revisited the plant's financial estimates, refining the CAPEX figures based on updates from June 2022 and March 2023. The pandemic posed challenges in procuring certain items, especially those requiring custom fabrication like coalescer tanks, extractors, and pump assemblies. These hurdles inflated earlier price estimates and were still not fully resolved in 2023.

Throughout the operational phase, modifications in the system's configuration were implemented, reducing the number and types of pumps needed. The original plan, calling for six expensive lobe pumps at around $26,000 each, was streamlined to only requiring three pumps, with the addition of more economical centrifugal types. Additionally, electrically operated valves were replaced with air-operated ones, accompanied by the incorporation of a central air compressor, significantly reducing costs compared to the initial design.

Further cost efficiencies were realized through the insulation of crucial components like coalescers and hot loop elements. Insulation significantly curtailed overnight temperature losses in the coalescer, minimizing startup time from roughly an hour to less than 5 minutes, thereby decreasing thermal operational expenses. Additional insulation efforts aimed at heat exchangers and pipes are anticipated to diminish overall thermal losses.

Key findings from the re-evaluation exercise encompassed several noteworthy points:

- A global surge in stainless steel costs by approximately 25-30%, affected components like heat exchangers, coalescers, and mixers.
- An inflation-adjusted increase of about 7% in costs related to small parts, piping, and valves within the CAPEX model.
- Introduction of plastic heat exchangers, a Trevi-manufactured solution, effectively mitigated the elevated costs linked with stainless steel components.
- Reducing the use of expensive lobe pumps.

- Transitioning non-critical elements of the PLC functionality to a cloud-based approach.
- Rationalizing the necessity and functionality of sensors, simplifying the design which was previously overly equipped for data collection purposes.
- Substantial reduction in FO membrane costs due to competitive pressure from a new Chinese vendor, dramatically affecting pricing.
- Direct procurement of components instead of relying on stocking distribution channels, a necessity during the pandemic.
- A significant drop in the cost of hot nanofiltration elements from $1300/element to $100/element, marking a considerable reduction in overall costs for the larger 10,000m3/day system.

Overall, the revised CAPEX estimate at $1,101/m3 (see breakdown of major components below) showcases competitive pricing compared to RO systems, and notably lower than UPRO systems at approximately $1,650/$m^3$, a trend likely to continue as prices evolve over time.

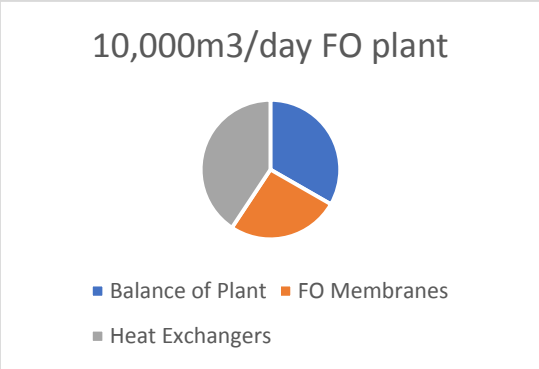

Figure 11 July 2023 Estimate $1,101/m3

3.3.2.2. Thermal Energy Demand

The FO system was benchmarked over 11 operating periods, where the thermal energy consumption was monitored both on the primary (water feed from NELHA) and secondary side (Polymer flow inside Trevi's FO system). Those results are shown below, with the hot water flow showing a slightly larger demand than the polymer flow. This discrepancy is probably due to the difficulty in estimating the heat capacity of the polymer flow. Trevi used the water flow heat load in its LCOH calculation of 24kWh/m3. This dramatic reduction from previous generations of Trevi's FO plants is primarily due to the 15% energy savings from the Hot nano retentate return, as well as the larger system size (previous generations of plants were 10x smaller, so radiative heat

losses played a larger role in the overall consumption. The incoming temperature from the CSP array is also shown below, over a 91-85C range, showing only a modest correlation between increased temperature and increased thermal demand.

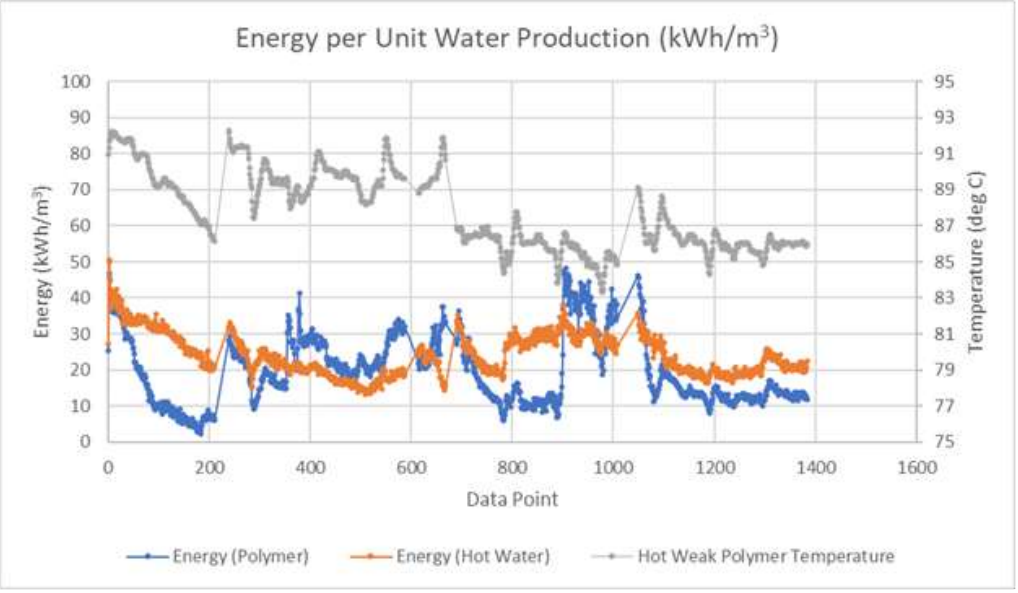

Figure 12 Thermal Energy Consumption

4. Discussion

4.1. Final FO Design Parameters with LCOH & LCOW Estimates

Trevi's planning during the initial phase led to the selection of crucial components for the FO system. Innovations in draw solution design and the development of polymeric heat exchangers aimed to advance the technology while simultaneously minimizing capital expenditure. Trevi's approach emphasized the importance of ensuring the safety of the ecosystem while advancing desalination technology.

1.1. LCOH and LCOW

The above estimates in section 3.2.2 were used in the projected levelized cost of heat (LCOH) and the levelized cost of water (LCOW) calculations at the 10,000m3/day size for a solar powered FO seawater desalination plant. The calculation of LCOW follows the formula:

$$\text{Levelized Cost of Water} = \frac{(\text{capital cost} \times \text{CRF}) + \text{annual O\&M costs} + \text{R\&R costs}}{\text{average annual yield in acre-feet}},$$

$$\text{where CRF} = \frac{r(1+r)^n}{[(1+r)^n]-1};\ \text{n = useful life (in years); r = discount rate}$$

The levelized cost of water (LCOW), assuming a 25-year lifespan and a 5% interest rate, is assessed for both a representative Reverse Osmosis (RO) system and the Forward Osmosis (FO) plant delineated in this report, factoring in Hawaii's prevailing electricity rate of 32 cents/kWh during the study period. Notably, recent studies advocating the use of exclusively renewable energy affect the approach for both systems. For an RO system, this necessitates considering the capacity factor of a photovoltaic (PV) system operating at 20% efficiency, along with a Battery Energy Storage System (BESS). Conversely, an FO system requires reducing the PV array size and integrating a thermal energy storage system. However, the exclusive renewable energy calculation is omitted here, suggesting an alternative approach of expanding the plant's capacity to store excess water rather than surplus energy.

In comparing the pricing of RO and FO systems, RO equipment costs exhibit pricing maturity and costs predominantly fluctuate based on localized conditions such as pipeline expenses, zoning regulations, and land costs. For this analysis, both the FO and RO systems are assumed to bear a capital cost of $4,500,000 for a 10,000m3/day system. Operating and Maintenance (O&M) cost estimations are drawn from the GWI database, utilizing a Specific Energy Consumption (SEC) of 3.5 kWh/m3 for the RO plant (UPRO is more than 2x this number).

Regarding Replacement and Renewal (R&R) costs, these expenses account for annual equipment replacements, constituting a percentage of the plant's capital cost. For RO systems, the R&R costs typically cover membrane replacements and high-pressure pump maintenance, while FO systems, devoid of high-pressure pumps, chiefly require low-pressure FO membrane replacements during their lifespan.

O&M expenses for RO plants encompass the cost of chemicals utilized for pre- and post-treatment, in addition to the SEC. In contrast, O&M costing for FO plants is rooted in the actual chemical consumption data from the NELHA plant. Notably, while RO systems typically employ an anti-scalant at 2-3 mg/l, the Trevi NELHA FO system necessitates draw solution replacement at approximately 10 mg/l. Cost assessments indicate anti-scalants at $35/kg and draw solutions at $15/kg. Moreover, both FO and RO systems employ sulfuric acid for pH adjustment and caustic soda for brine re-neutralization and permeate pH adjustment, with similar dosage levels, rendering chemical consumption estimates relatively independent of the membrane technology choice.

For both RO and FO plants, a production factor of 96% is assumed in annual water output.

The figure below shows the LCOW for a range of LCOH values for the thermal heat generated by the NELHA plant. These water costs are before operator profits, so they are to be considered the floor value for water production costs. In areas of high electricity cost such as in HI, the cost of thermal heat can approach 3c/kWh and still be competitive with an RO system located there. In areas where power is less expensive, an assumed price of electricity of 20c/kWh produces an equivalent LCOH of around 1.7c/kWh of thermal power.

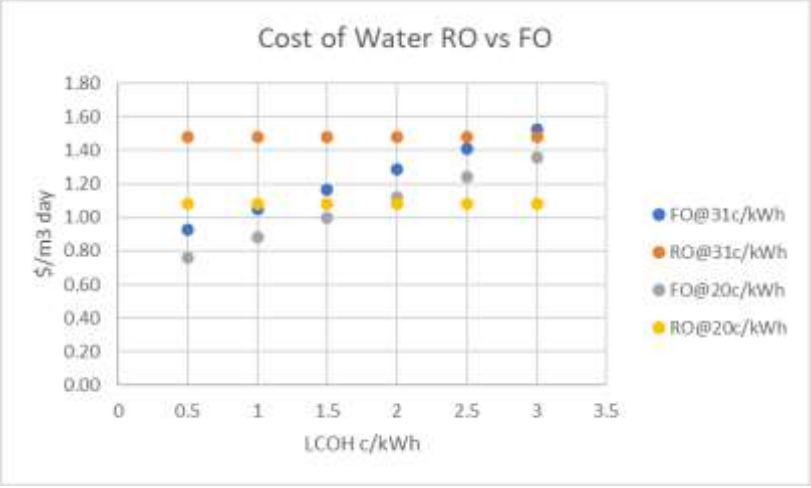

Figure 13 Cost of Water RO vs FO

5. Project Challenges and Accomplishments

Throughout this initiative, Trevi embarked on a dual path of innovation, targeting both individual components and the overall system architecture approach to reduce cost. At the component level, the efforts involved pioneering designs for forward osmosis (FO) membranes, the creation of novel draw solutions, and the manufacturing of polymeric heat exchangers and high-temperature nano-filtration membranes.

On the system front, Trevi introduced a new, 4th generation FO system. However, the complexity of a well-established chemical process—liquid/liquid extraction—proved more intricate at the operational scale within the stringent time constraints of the program. This challenge surfaced when the limitations of this mature process were encountered at Trevi's operational scale.

Amidst an aggressive technology development plan, the project contended with delays caused by the Covid pandemic's supply chain disruptions and multiple volcanic eruptions on the Big Island, presenting multiple challenges. However, despite these hurdles, the selection of the 4th generation FO system uncovered three remarkable breakthroughs in FO performance, paving the way for advancements in solar thermal technology for desalination:

- Demonstrated high recovery rates exceeding 70% on seawater, surpassing the recovery capabilities of the next generation of RO technology (UPRO) while consuming significantly less electrical power (1.7kWh/m^3 vs. 7kWh/m^3). This technology holds immediate promise for zero liquid discharge applications in high salinity brines across industrial and agricultural domains.
- Reduced thermal energy consumption to below 30kWh/m^3, a notable improvement compared to the current industry leader MED-TVC, achieving 65kWh/m^3 at similar operating temperature.
- Utilizing new ceramic nano-filtration membranes to enhance the FO process's efficiency.
- Development of an innovative twisted tube polymeric heat exchanger for megawatt-scale waste heat recovery.
- Creation of new draw solutions tailored for extremely high feed water Total Dissolved Solids (TDS) desalination.

While the 4th generation (dual salt/polymer) loop offers a technological edge for high TDS waters, such as in Oil and Gas produced waters, its complexity may limit its deployment in less sophisticated settings. Consequently, a simpler 5th generation FO system, stemming from this program, was developed to navigate liquid/liquid extraction intricacies, offering a more robust start-up and stop protocol.

The low thermal consumption of the FO process positions it as a competitive alternative to RO, especially in scenarios requiring renewable energy or encountering high TDS waters.

6. Conclusion

Trevi's Forward Osmosis (FO) technology has undergone significant evolution, advancing to its present version 4, and is now poised for a transformative leap to version 5. The new iteration introduces an improveddraw solution, eliminating complex extraction stages while maintaining high system flux. This new draw solution, marked by higher osmotic strength and lower viscosity, permits direct application of the polymer draw solution to the FO membrane, reducing system complexity and capital expenditure (CAPEX).

Furthermore, the development of polymeric heat exchangers, now ready for commercial implementation, presents an opportunity to integrate these advancements into the existing NELHA design or future models, driving down CAPEX costs. Moreover, substantial cost reductions in hot nano-filtration modules bolster savings within the system.

Ongoing work at the site to upgrade and complete the program awaits further funding from supportive agencies. Additional funding will facilitate the integration of the innovative draw solution and polymeric heat exchangers, enhancing efficiency and reducing operational costs. In tandem, as Trevi aims for larger-scale applications handling 10,000m3/day, research into improved thermal storage mechanisms like phase change materials, including salt hydrates, becomes imperative. These materials can significantly elevate storage efficiency and reduce costs at larger scales, pivotal for the success of expanded FO systems. Challenges in hot water storage beyond 3000m3/day necessitate cost-effective solutions, considering the escalating expense of water tanks.

The transition to version 5 signifies a critical milestone, positioning Trevi to meet the escalating demands for sustainable and efficient water treatment solutions. Despite the challenges faced during the program, Trevi's design and implementation of a solar-powered FO seawater desalination plant at NELHA demonstrated groundbreaking advancements in sustainable desalination. The careful planning, strategic design selection, and innovative technological developments resulted in a zero-carbon, competitive LCOW desalination solution. These achievements mark a significant leap forward towards a low-carbon future in desalination, emphasizing the importance of renewable energy integration, environmental sustainability, and technological innovation in zero carbon water treatment.

7. Acknowledgements:

This work in this paper was supported by the US Department of Energy as well as the Natural Energy Laboratory of Hawaii Authority (NELHA).

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The Influence of Employee Monetary Rewards on the Company Performance in Saudi Arabia's Manufacturing Sector

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Abstract

This study aimed to analyze the impact of Monetary Rewards on the Company Performance in the Saudi Manufacturing Sector. This sector population consists of organizations working in oilfield services, industrial services, energy, and manufacturing. In particular, the researcher intended to help the practitioners in the Saudi Manufacturing Sector to develop their strategy to enhance organizational efficiency. To do that, the researcher observed the impact of monetary rewards on employees' performance and how it contributes to the growth of companies. In this context, quantitative and qualitative analyses approaches were used to address the research objectives. The researcher used an explanatory sequential mixed research design which was constructed from web-based survey and semi-structured face-to-face interviews. Accordingly, 578 employees working in different organizations in Saudi Manufacturing Sector participated in the survey questionnaires. On the other hand, for the qualitative part, 30 employees working in panel boards manufacturing factory were purposely selected to participate in face-to-face interviews. Significant relationships were observed from the quantitative analysis then verified using qualitative analysis. Results showed that majority of the participants believed that monetary rewards are significantly motivate their performance which can positively contribute to Company effectiveness and growth.

Keywords: Monetary Rewards, Employee's Performance, Company's Performance, Growth

1. Introduction

An organization's human resources management develop programs that enhance the employees' performance and reduce its risks on the company performance. These programs evaluate the employee's motivation, organizational factors, work engagement factors and employee's satisfaction factors that have direct impact on their performance (Alshahrani, Alqahtani, and Al-shahrani 2015). However, intrinsic motivation enhances the need of self-developed goals and extrinsic motivation improves the employees' performance as per the reward system (Kuvaas et al. 2017) . Thus, types of rewards affect the employees' performance differently. This impact needs to be evaluated in the Saudi Manufacturing Sector to specify the type of reward that motivate the employees' performance. The researcher argued that Employees' Monetary Rewards played a role in Company's Performance. In consequence, the independent variable in this research is monetary rewards as employees' motivational factor. On the other side, the dependent variable is companies' performance.

1.1 Research Objective

To identify the relationship between Monetary Rewards as motivation factor and Companies' performance in Saudi Arabia Manufacturing Sector.

1.2 Research Question

Do monetary rewards have significant impact on the Companies' performance in Saudi Arabia Manufacturing Sector?

2. Literature Review

Organizations concentrate extensively on adopting effective strategies to influence the employees understanding of motivational theories. Hence, the primary focus of top management is to enhance the motivation level of the employees to increase their commitment and to provide significant benefits to the firms (Berg 2015). Consequently, obtaining such employees requires motivation strategy that encourages them to show high potential for accepting the targets and working on them extensively. Thus, employee's acceptance of motivational strategies encourages them to perform better. Therefore, individual performance can be improved with intrinsic as well as extrinsic motivation remarkably (Mangi, Kanasro, and Burdi 2015). Accordingly, Mangi et al. (2015) was able to justify the positive relationship between the employees acceptance of the company motivational strategies and their perceptible outputs (Mangi et al. 2015).

Furthermore, concentrating on other motivational theory, Herzberg's Two-factor theory shows different inspiring approach that focuses on the motivators and hygiene factors to boost individual's performance. In the subsequent theory of motivation, motivators are satisfying worker's need whereas the hygiene factors are responsible for worker dissatisfaction (Alshmemri, Shahwan-Akl, and Maude 2017). Moreover, motivational theories are continually emphasizing on personal values of the employees to inspire them and boost their self-interest (Pinder 2014).

As defined in the literature, monetary rewards are defined as the money-based incentives that are given when an employee meets or exceeds management expectations (Presslee, Vance, and Webb 2013). However, the reward system plays significant role in developing employees' tasks and push them to take efficient action in execution. Presslee, Vance and Webb (2013) study indicated that cash rewards lead to better performance even when difficult tasks are assigned to the employees. Accordingly, financial incentives like salaries had the major impact on employees' performance in private schools in Saudi Arabia (Al Doghan and Albar 2015). Thus, management concentrates on the incentives that encourage people but with systematic process. That concerns about the formation of business objectives then evaluate whether the assigned employee exceeded the requirement or no.

Furthermore, monetary rewards and impetus framework give inspiration to the employees for being more committed to organizational objectives with noticeable improvement in their performance (Lee, Wormington, Linnenbrink-Garcia, & Roseth, 2017). In addition, healthy work environment increases employees' level of productivity. Factors like fast incentives and recognition plans are helpful in developing such environment and have positive impact on employees' performance (Awan and Tahir 2015). Similarly, the rewards enable better employee engagement in Saudi banks (Al Shehri et al. 2017). Also, monetary rewards was one of the six important factors that identified as strong influencer of employee performance in the Steel Factory in Saudi Arabia (Hijry and Haleem 2017). Moreover, reward does matter in the job satisfaction among physiotherapists in Saudi Arabia (Alkassabi et al. 2018). Therefore, as indicated by Saeed et al. (2013), financial rewards are significantly associated with employees' performance improvement because they contribute noticeably in solving employees' personal problems. Generally, previous researchers were able to prove the relationship between employees' performance and some critical factors like motivation, satisfaction, and monetary rewards.

The gap analysis of the previous studies showed that none of them were evaluating the Monetary Rewards' impact on Organizational Performance in the Saudi Arabia Manufacturing Sector.

2.1 Conceptual Model

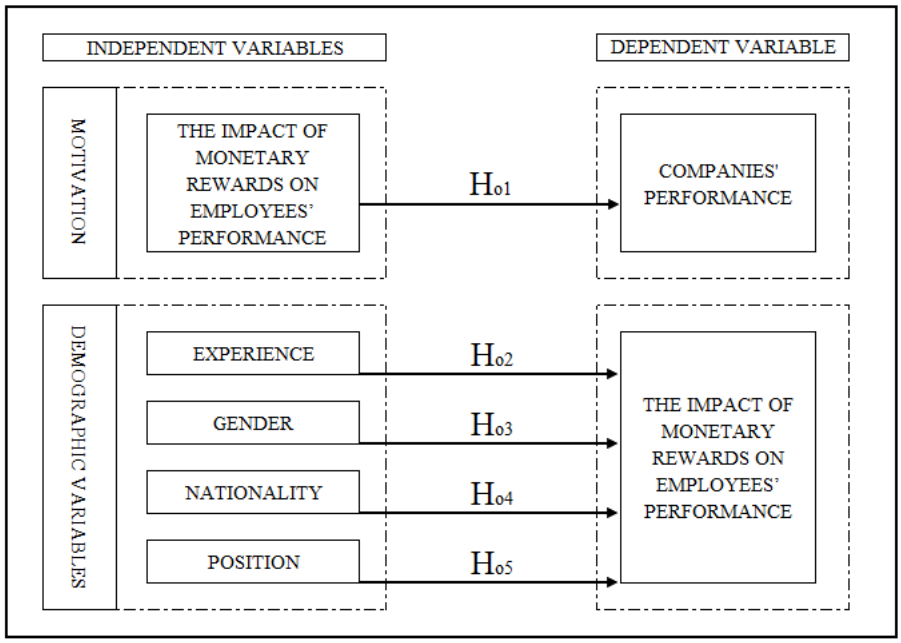

Figure 1: Conceptual diagram

2.2 Hypothesis Statement

- Hypothesis 1

  Null Hypothesis (H_{o1}): The impact of Monetary rewards on employees' performance has no significant relation with Companies' performance in Saudi Arabian Manufacturing Sector.

  Alternative Hypothesis (H_{a1}): The impact of Monetary rewards on employees' performance has significant relation with Companies' performance in Saudi Arabian Manufacturing Sector.

- Hypothesis 2

  Null Hypothesis (H_{o2}): Employees' experience is not significantly related to the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector.

  Alternative Hypothesis (H_{a2}): Employees' experience is significantly related to the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector.

- Hypothesis 3

  Null Hypothesis (H_{o3}): Employees' gender has no significant correlation with the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector.

  Alternative Hypothesis (H_{a3}): Employees' gender has significant correlation with the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector.

- Hypothesis 4

  Null Hypothesis (H_{o4}): Employees' nationality is not significantly related to the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector.

  Alternative Hypothesis (H_{a4}): Employees' nationality is significantly related to the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector.

- Hypothesis 5

  Null Hypothesis (H_{o5}): Employees' position has no significant correlation with the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector.

  Alternative Hypothesis (H_{a5}): Employees' position has significant correlation with the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector.

3. Methodology

Quantitative and qualitative designs are the two traditional research approaches that are commonly used in the social studies. In this study, both research approaches were used. Accordingly, in this mixed research methods approach, data was sequentially collected starting with the qualitative data collection from the survey questionnaire then the qualitative data collection from face-to-face interviews. The rationale for using both quantitative and qualitative data is to sufficiently evaluate the impact the of monetary rewards on employees' performance and subsequently on the company performance.

Based on literature, two research philosophies are normally used in social studies: positivism and interpretivism. An interpretivist approach is usually qualitative using unstructured interviews. While, positivism approach considers quantitative data (Mytty, Pedak, and Sun 2016). Particularly, in positivism studies, trustworthy knowledge in business and social study is gained through observation. Thus, in positivism philosophy, the researcher is limited to data collection and interpretation.

In this study, the researcher independently observed and randomly collected primary data to test the hypotheses statistically using deductive research approach. Moreover, the positivism philosophy followed in this study requires the researcher to be independent in all research process and concentrate on facts.

Research strategy approach was based on data collection and hypotheses development. Using positivist research approach, structured methodology was followed to test the proposed hypotheses. The primary data collection method was applied using survey questionnaire. Survey questionnaire was conducted to evaluate the population of all employees working in the Manufacturing Sector in Saudi Arabia. Furthermore, quantifiable observations were obtained from the collected data using quantitative Five (5)-point Likert scale questionnaire survey which was statistically analyzed. Precisely, the survey design was cross-sectional. The quantitative survey responses report was extracted from Surveymonky.com at the end of April 2019. While the face-to-face interviews were conducted at the end of May 2019.

Additionally, the research strategy consists of eight steps. The first step is reviewing the literature about the factors that affect the employees' performance. That presents the gap related to the factors that was not analyzed in the Saudi Manufacturing Sector. The researcher identified the factors that can be analyzed as independent variable at the end of this stage including conceptual diagram and hypotheses. The second step is preparing the quantitative questionnaire which is validated in the third step through pilot study. After the validation of the survey questionnaire, the quantitative data collection process starts. Social media was used to distribute the survey questionnaire. The collected data were analyzed using appropriate statistical analysis. In step six, the findings of the quantitative analysis were verified through a case study conducted at one of the panel boards manufacturing companies in Dammam Second Industrial City as a validation of the findings. For the qualitative data, face-to-face interviews was conducted using randomly selected employees from the same Company. Content analysis was used to analyze the data. The process is illustrated below:

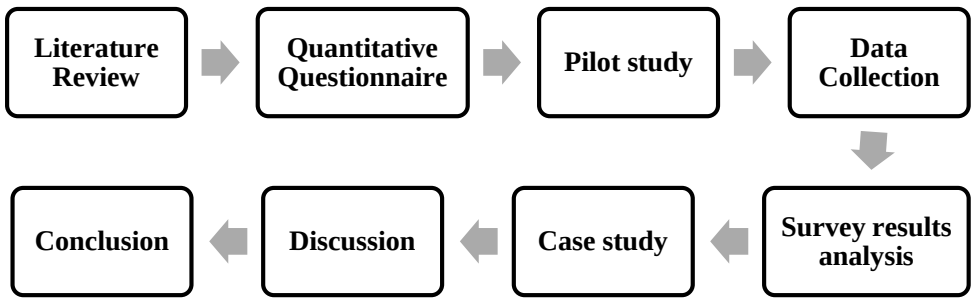

Figure 2: Research strategy

3.1 Population and sample

Table 1: Saudi Arabian Manufacturing Sector Labour Force Summary

GOSI-Table (3-8)	Nationality		
Manufacturing	Saudi	Non-Saudi	Total
Male	210,562	851,315	1,061,877
Female	113,778	8,896	122,674
Total	324,340	860,211	1,184,551

GOSI- Table (3-9)	Manufacturing			
Administrative Region	Riyadh	Makkah	Madinah	Qassim
	475,340	237,428	45,758	53,473
Easte. Prov.	Asir	Tabuk	Hail	North Bord
266,336	36,576	12,717	11,460	4,959
Jazan	Najran	AL - Baha	AL - Jouf	Total
18,343	10,768	4,573	6,820	1,184,551

Source: (GOSI 2023)

According to Saudi General Authority of Statistics (2023), there are 1,184,551 employees working in the manufacturing sector in Saudi Arabia as shown in Table (1). Moreover, this sector consists of diverse types of industries and multinational employees. The industrial establishments in this sector covered different economic activities like manufacturing of food products, manufacturing of clothes, manufacturing of fabricated metal products, transformative industries, etc. Moreover, there are 13 administrative regions in Saudi Arabia. For instance, the largest region is Riyadh which has 475,340 employees while the smallest region is Al-Baha with 4,573 employees. In total, there are 266,336 employees working in the Manufacturing Sector in Eastern region (GOSI 2023).

Table 2: Collected Primary Data Summary

Total number of responders	Category		Frequency	Percentage
566	**Gender**	Female	36	6.36%
		Male	530	93.64%
574	**Nationality**	Saudi	476	82.93%
		Non-Saudi	98	17.07%
569	**Age**	Below 25 years	19	3.34%
		25-40 years	303	53.25%
		41-50 years	189	33.22%
		51-65 years	58	10.19%
563	**Education**	Secondary School or less	155	27.53%
		Bachelor's Degree	335	59.5%
		Master's Degree	68	12.08%
		PhD	5	0.89%
564	**Position**	Production and Site Technicians	179	31.74%
		Administrations and Engineering	235	41.67%
		Middle Management	114	20.21%
		Top Management	36	6.38%
566	**Experience**	5 years or less	95	16.78%
		6 to 12 years	148	26.15%
		13 to 19 years	156	27.56%
		20 years or more	167	29.51%
Total number of participants			**578**	**100%**

Source: Primary Data

The population for the quantitative phase is all employees who are working in Saudi Arabian Manufacturing Sector. Since population size is known, by using simple random sampling method, the sample size required for this study was estimated under confidence level of 95% and 5% margin of error as 384 participants as indicated in the sample size table issued by (The Research

Advisors Web 2006). As sown in table (2), the total participants in the shared questionnaire were 578 employees.

Additionally, for the qualitative phase, the selected Factory population is 200 employees. Specifically, purposive sampling technique was used to select the required employees for the face-to-face interviews. The researcher selected this sampling method due to the respondents knowledgeable and experience in make to order manufacturing industry. This sampling technique was followed to ensure that all population categories had equal chance to provide their feedback. Moreover, as indicated by Fridlund and Hildingh (2000), one to thirty interviewees were common sample size in qualitative studies (Bengtsson 2016). Thus, 30 employees were selected to participate in this research face-to-face interviews.

The researcher used simple and clear English to design the interview questions. This made it possible for the respondents to provide their feedback comfortably. Furthermore, the researcher clarified the questions to the respondents for easy comprehension. The researcher also controlled the data collection through flexible dialogue and discussion sessions. Specifically, structured interview guide was provided by the researcher to enhance the discussion about the employee's performance and organization growth.

The following questions were used to determine the factors that impact the employees' performance and to evaluate the relationship between the employees' performance and the monthly revenue plan accuracy in that particular factory.

a) What kind of monetary reward makes you satisfied the most?
b) What is the relationship between the impact of monetary rewards on employees' performance and the company performance?

3.2 Analysis Techniques

For the quantitative part, Data was analyzed statistically using the Microsoft Excel 2016. Precisely, the collected primary data was analyzed using descriptive analysis for demographic variables. Moreover, research questions and findings were assessed statistically through Regression test, Chi-Square Test, Spearman's r, Independent Sample t-test and Tukey-Kramer Multiple Comparisons. While for the qualitative part, content analysis approach was used by the researcher to analyze the gathered data.

4. Analysis and Discussion

4.1 Hypothesis 1: Monetary Rewards and Company Performance

The objective of this study was to identify the relationship between Monetary Rewards as motivation factor and Companies' performance in Saudi Arabia Manufacturing Sector. That was tested in the first hypothesis. The null Hypothesis (H_{01}) was "The impact of Monetary rewards on employees' performance has no significant relation with Companies' performance in Saudi Arabian Manufacturing Sector". Accordingly, the employees were requested to provide their opinions for five statements regarding the impact of monetary rewards on their performance which might affect the Company growth.

Table 3: Showing the results of monetary rewards items

Items (7 to 11) in the questionnaire		F	P
7- Monetary rewards are one of the best motivators to increase employee's performance. M= 4.28 Mo= 5 Md= 4	TR	546	(94.46%)
	SD	17	(3.11%)
	D	17	(3.11%)
	N	27	(4.95%)
	A	218	(39.93%)
	SA	267	(48.9%)
8- Rewards and compensations are directly linked to Company's performance. M= 3.90 Mo= 4 Md= 4	TR	549	(94.98%)
	SD	21	(3.83%)
	D	47	(8.56%)
	N	52	(9.47%)
	A	274	(49.91%)
	SA	155	(28.23%)
9- Financial Incentives improves employee's commitment towards organizational goals. M= 4.29	TR	548	(94.81%)
	SD	9	(1.64%)
	D	20	(3.65%)
	N	33	(6.02%)

Mo= 5		A	227	(41.42%)
	Md= 4	SA	259	(47.26%)
10- Company growth ensures the yearly bonus for noticeable employees' performance.		TR	548	(94.81%)
		SD	22	(4.01%)
		D	32	(5.84%)
M= 3.99		N	81	(14.78%)
Mo= 5		A	206	(37.59%)
	Md= 4	SA	207	(37.77%)
11- Recognition and reward shall be based on compliance with the procedures, job quality and job consistency, not only on outcome.		TR	548	(94.81%)
		SD	7	(1.28%)
		D	20	(3.65%)
M= 4.16		N	56	(10.22%)
Mo= 4		A	263	(47.99%)
	Md= 4	SA	202	(36.86%)

NOTE: M=Mean, Mo=Mode, Md=Median, TR=Total number of responders per item, SD=Strongly Disagreed, D=Disagreed, N=Neutral, A=Agreed, SA=Strongly Agreed, F=Frequency and P=Percentage)

Source: Primary Data

The study findings in table (3) showed that the respondents noted the monetary rewards factor as one of the best motivators that increase their performance (mean = 4.28). They also agreed on the existence of the relationship between compensations and company performance (mean = 3.9). However, they showed positive intention to use factors like compliance with the procedures, job quality and job consistency when recognize and reward the employees (mean = 4.16). In addition, they believed that financial incentives improve employee's commitment towards organizational goals (mean = 4.29). Moreover, they expected yearly bonus when company growth achieved (mean = 3.99).

Consequently, the monetary rewards were positively linked with the employees' performance as analyzed in item 7 and item 9 (cumulative mean = 4.285). A comparison on these items showed that the percentage of employees who opposed were 5.755 percent. While the percentage of those who were neutral was 5.485 percent. Moreover, the percentage of those who concurred was 88.755 percent.

Furthermore, the monetary rewards were positively linked with the companies' performance as analyzed in item 8 and item 10 (cumulative mean = 3.945). A comparison on these items showed that the percentage of employees who opposed were 11.12 percent. While the percentage of those who were neutral was 12.125 percent. Moreover, the percentage of those who concurred was 76.75 percent. Hence, the range of percentages of the opposed employees' group and the undecided employees' group were lower compared to the concurred employees' group. Thus, monetary rewards had positive impact on the employees' performance and can lead to Company growth.

Table 4: Showing the results of monetary rewards t-test

	Item 7	**Item 9**
Mean	4.2839	4.2894
Standard deviation	0.92963	0.8634
Variance	0.86422	0.74546
Sample	546	546
Probability P-Value		0.91942
t Stat		6.451
t Critical two-tail		1.9621
(t[1090]=6.4512,p>0.05)		

	Item 8	**Item 10**
Mean	3.9011	3.9927
Standard deviation	1.02864	1.05945
Variance	1.05809	1.12243
Sample	546	548
Probability P-Value		0.14713
t Stat		2.625
t Critical two-tail		1.9621
(t[1092]=2.6248,p>0.05)		

Moreover, researcher tested the respondents' feedback with the null hypothesis (H0) assuming that there is no significant difference between the groups being compared. Accordingly, several t-test were conducted to evaluate if there was significant difference between the means of the responses about the effect of monetary rewards on the employees' performance and company performance. As shown in table (4), after comparing the responses between Item 7 and Item 9

about the monetary rewards impact on employees' performance, the P-Value from t-test was (0.91942) greater than 0.05 and t-stat value was (6.451) greater than t-Critical (1.9621); (t[1090]=6.4512,p>0.05). Hence, there was not enough evidence to reject the null hypothesis and no significant difference between the mean of the collected data in Item 7 and Item 9 was found. Therefore, it was most likely reflected the real intrinsic differences in the population, and they were not by chance.

Similarly, after comparing the responses between Item 8 and Item 10 about the relationship of monetary rewards and company performance, the P-Value from t-test was (0.14713) greater than 0.05 and t-stat value was (2.625) greater than t-Critical (1.9621); (t[1092]=2.6248,p>0.05). Hence, there was not enough evidence to reject the null hypothesis and no significant difference between the mean of the collected data in Item 8 and Item 10 was found. Therefore, it was most likely reflected the real intrinsic differences in the population, and they were not by chance as well.

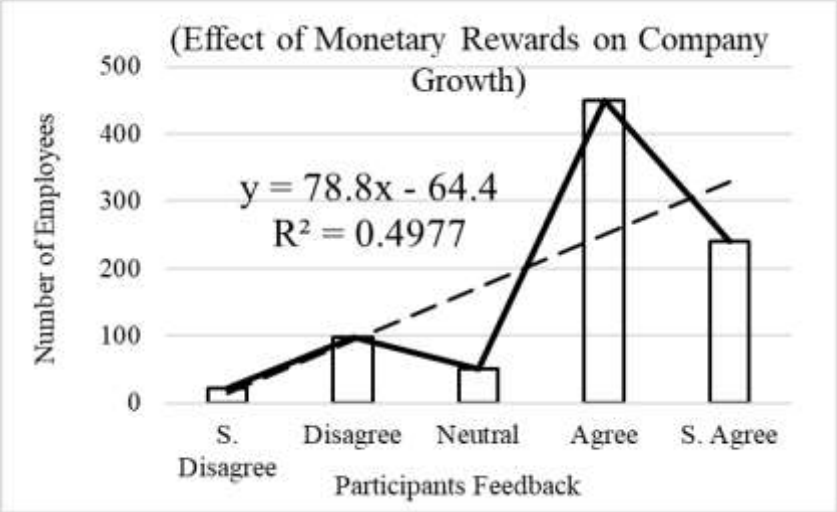

Figure 3: Responses analysis between monetary rewards and company growth

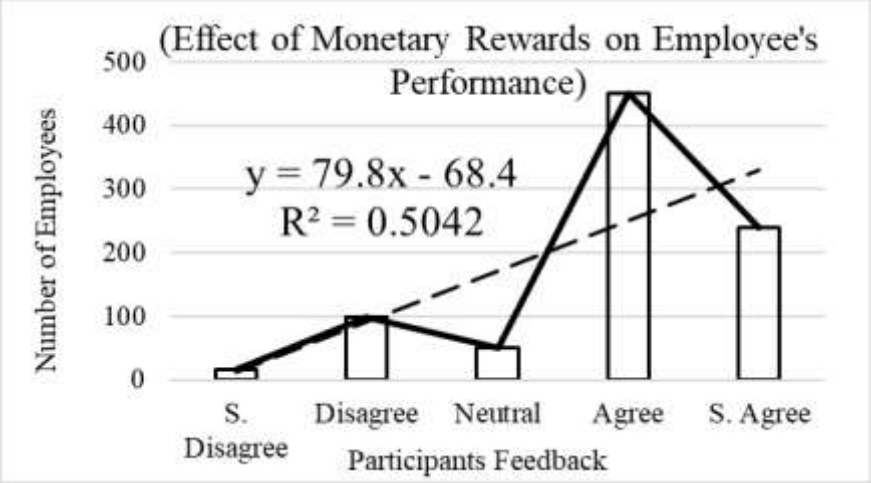

Figure 4: Responses analysis between monetary rewards and employees' performance

Additionally, in order to determine the influence of monetary rewards on employee's performance and company growth, the regression analysis was conducted. The first test was compering the relationship between the respondents' feedback and number of respondents. Clear trend was observed as shown in Figure (3) and figure (4). Specifically, when respondents' feedback changed from strongly disagree toward strongly agreed, number of employees who are considering the monetary rewards as important factor that impact employees' performance as well as company growth were increased.

Secondly, the relationship between (1) Monetary Rewards impact on employees' performance (Item 7 and 9) and (2) Employees performance impact on Company performance (Item 8 and 10) was tested using regression test. The results are summarized in table (5).

Table 5: Regression test Monetary Rewards and Company Performance

Regression Test Between (1) Monetary Rewards impact on employees' performance (Item 7 and 9) (2) Employees performance impact on Company performance (Item 8 and 10)				
Multiple R	0.9366		t-Stat	4.6308
R Square	0.8773		F-Value	21.4438
P-value	0.019		Lower 95%	0.2284
Observations	2195		Upper 95%	1.2324
Linear Equation		Y = 0.7304 X + 59.5899		
(r=0.9366, F[1, 3]=21.4438,p<0.05)				

Regression test was conducted to verify the correlation between monetary rewards and company performance. According to the results summarized in table (5), researcher found that there is significant relationship between the monetary rewards impact on employees' performance and the employees performance impact on Company performance. The P-value was (0.019) less than 0.05 which indicates significant association between participants who were motivated with monetary rewards and the company performance. Namely, when observing the scale of evaluation from strongly disagree to strongly agree for the items about monetary rewards, number of employees who improve their performance was increased. Moreover, the correlation coefficient R was (0.9366) closed to one which indicates strong linear relationship. Therefore, the factor of monetary rewards impact on employee's performance was good predictor of employee's performance impact on company' performance. Hence, the model was significant ($r=0.9366$, $F[1, 3]=21.4438$, $p<0.05$). The coefficient of determination, which is a square of the correlation coefficient ($R^2 = 0.8773$), explains the variance in the impact of employee's performance on company performance due to the impact of monetary rewards on employee's performance. Therefore, the monetary rewards impact on employee's performance held to be 87.78 percent variance in employees' performance impact on company performance.

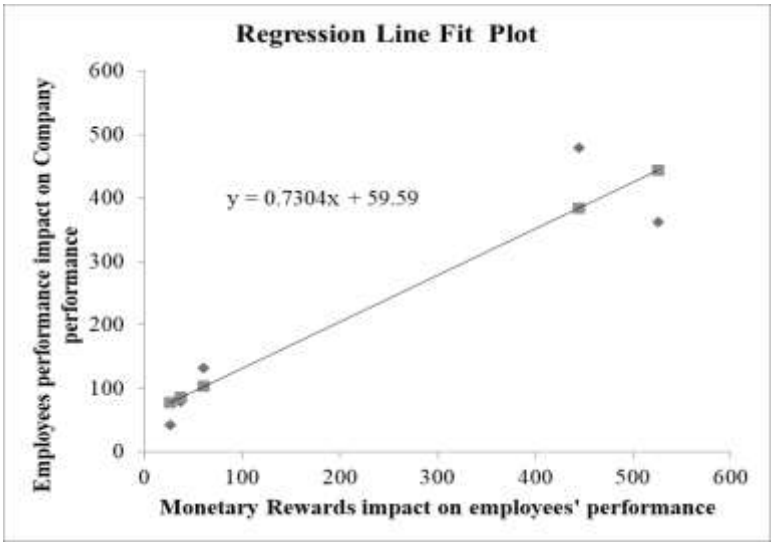

Figure 5: Regression analysis between monetary rewards and company performance

Accordingly, the relationship plot is shown in figure (5) which indicates linear relationship between the monetary rewards impact on employee's performance and the employee's performance impact on company performance.

4.1.1 Findings

Researcher found that there was no significant difference between the mean of the collected data in Item 7 and Item 9 which presented the participants feedback about the impact of monetary rewards on employees' performance. Also, between Item 8 and Item 10 which were participants feedback about the impact of monetary rewards on company performance. Therefore, the data collected was most likely reflected the real intrinsic differences in the population, and they were not by chance.

In addition, collected data showed that there was significant relationship between monetary rewards and employee's performance and between monetary rewards and company performance. Moreover, regression test indicated strong leaner relationship between the monetary rewards impact on employee's performance and employees' performance impact on company performance. Therefore, the null hypothesis (H_{01}) should be rejected due to the presence of significance relationship between the impact of monetary rewards on employees' performance and Companies' performance in Saudi Arabian Manufacturing Sector.

4.2 Demographic Variables Analysis

Furthermore, Chi Square tests were conducted to test if employee's experience, gender, nationality, and position were significantly moderate the relationship between the impact of Monetary rewards on employees' performance and Companies' performance in Saudi Arabian Manufacturing Sector.

4.2.1 Hypothesis 2: The Employees' experience and Monetary rewards

Table 6: Observation data to test experience as moderator of monetary rewards

Experience	Opposed Employees	Undecided Employees	Concurred Employees	SUM
5 years or less	29	49	272	*350*
6 to 12 years	58	56	418	*532*
13 to 19 years	64	78	419	*561*
20 years or more	57	64	442	*563*
SUM	208	247	1551	2006

Using the observed data in Table (6), the calculated Chi Square (X^2) value was (6.6976) less than the critical value (12.592); (X^2= [6, N=2006] =6.6976, $p<0.05$). That indicates the observed distribution was most likely due to chance. Hence, employee's experience was not significantly

moderating the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector. Therefore, the null hypothesis (H_{02}) was NOT rejected.

4.2.2 Hypothesis 3: The Employees' gender and Monetary rewards

Table 7: Observation data to test gender as moderator of monetary rewards

Gender	Opposed Employees	Undecided Employees	Concurred Employees	SUM
Female	12	18	94	*124*
Male	198	227	1461	*1886*
SUM	*210*	*245*	*1555*	*2010*

Using the observed data in Table (7), the calculated Chi Square (X^2) value was (0.7036) less than the critical value (5.991); (X^2=[2,N=2010]=0.7036,p<0.05). That indicates the observed distribution was most likely due to chance. Hence, employee's gender was not significantly moderating the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector. Therefore, the null hypothesis (H_{03}) was NOT rejected.

4.2.3 Hypothesis 4: The Employees' nationality and Monetary rewards

Table 8: Observation data to test nationality as moderator of monetary rewards

Nationality	Opposed Employees	Undecided Employees	Concurred Employees	SUM
Saudi	156	181	1346	1683
Non-Saudi	56	67	219	342
SUM	212	248	1565	2025

Using the observed data in Table (8), the calculated Chi Square (X^2) value was (41.173) greater than the critical value (5.991); (X^2=[2,N=2025]=41.173,p<0.05). That indicates the observed distribution was most likely NOT due to chance. Hence, employee's nationality was significantly moderating the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector. Therefore, the null hypothesis (H_{03}) was rejected.

4.2.4 Hypothesis 5: The Employees' position and Monetary rewards

Table 9: Observation data to test employee's position as moderator of monetary rewards

Position	Opposed Employees	Undecided Employees	Concurred Employees	SUM
Production and Site Technicians	75	77	496	648
Administrations and Engineering	66	95	681	842
Middle Management	45	51	297	393
Top Management	22	20	82	124
SUM	208	243	1556	2007

Using the observed data in Table (9), the calculated Chi Square (X^2) value was (19.0325) less than the critical value (12.592); ($X^2=[6,N=2007]=19.0325, p<0.05$). That indicates the observed distribution was most likely NOT due to chance. Hence, employee's position was significantly moderating the impact of Monetary rewards on employees' performance in Saudi Arabian Manufacturing Sector. Therefore, the null hypothesis (H_{02}) was rejected.

4.2.5 Findings:

The impact of monetary rewards on employees' performance in the Saudi Arabian Manufacturing Sector was not significantly moderated by employee experience and gender. However, employee nationality and position did show moderating effects.

4.3 Case Study and Implications

The case study was conducted in one of the panel board manufacturing factories in Dammam second industrial city. The factory population was 200 multinational employees, and the selected sample was 30 employees from deferent career level. The researcher analyzed the face-to-face interviews data using content analysis and regression test.

4.3.1 What kind of monetary reward makes you satisfied the most?

After analyzing the participants' feedback about types of rewards that had significant impact on their performance, codes and categories were grouped as shown in the conceptual map in figure (6). Respondents stated that the cash monetary rewards satisfied them the most, like annual bonus or incentive. Moreover, respondents emphasized that the competitive salary with either monthly or annually increment enhance their performance. In addition, respondents believed that nun cash rewards influence their performance as well. Gifts, recognition, appreciation from managers or paid leave are non-cash examples that interviewees mentioned.

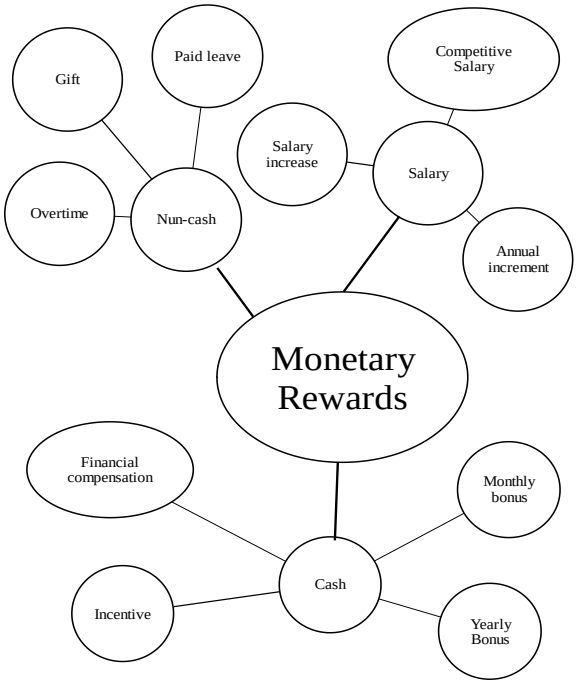

Figure 6: Code and categories conceptual map from interviewees' feedback about type of rewards that effect their performance

their performance

	Category	Frequency	Percentage	Themes
1	Cash	17	55%	Bonus
2	Salary	10	32%	Salary increment
3	Nun-cash	4	13%	Paid leave

In addition, the results shown in table (10) indicate that the considerable theme from interviewee's feedback was bonus. Specifically, 55 percent of the participants believed that employee's performance influenced by cash monetary rewards. Other 32 percent expected direct proportional relationship between their performance and salary increment. Moreover, 13 percent motivated with nun cash reward like paid leave.

4.3.2 What is the relationship between the impact of monetary rewards on employees' performance and the company growth?

This section presents the quantitative analysis for the collected interviews data. To analyze the relationship between monetary rewards and company growth, the researcher requested the interviewees to rate the relationship between monetary rewards and their performance and rate the

impact of their performance on the factory revenue in scale of zero to ten where ten presented the maximum effect.

Table 1 The percentage impact of Monetary rewards on employees' performance

Mean	7.8	Skewness	-0.62
Standard Error	0.42	Range	8
Median	8	Minimum	2
Mode	10	Maximum	10
Standard Deviation	2.3	Sum	234
Sample Variance	5.27	Count	30
Kurtosis	-0.54	Confidence Level (95.0%)	0.86

The study findings in table (11) show that monetary rewards were positively linked with the employees' performance at the factory with cumulative mean of 7.8 out of ten.

Table 12: The impact of employees' performance on Factory's performance

Mean	7.67	Skewness	-1.05
Standard Error	0.54	Range	9
Median	9	Minimum	1
Mode	10	Maximum	10
Standard Deviation	2.96	Sum	230
Sample Variance	8.78	Count	30
Kurtosis	-0.28	Confidence Level (95.0%)	1.11

In addition, the interviewees were asked about the relationship between their performance and the Factory revenue. Accordingly, the study findings in table (12) show that employees' performance had significant relationship with the Factory growth (cumulative mean was 7.67 out of ten).

Table 132: Regression test for (1) the monetary rewards impact on employees' performance and (2) the employees 'performance impact on Factory's Performance

Multiple R	0.92
R Square	0.84

Adjusted R Square	0.81
Standard Error	3.31
Observations	30
F (ANOVA)	155
Significance F	6.00E-13
Lower 95.0%	0.78
Upper 95.0%	1.08

According to the results summarized in table (13), researcher found that the monetary rewards had significant effects on factory's performance. Regression tests were conducted to verify the correlation between the impact of monetary rewards on employees' performance and the impact of employees' performance on factory revenue. The P-values were less than 0.05 which indicates significant association between them. Moreover, the correlation coefficient R values were (around 0.8) closed to one which indicates strong linear relationship. Consequently, the impact of monetary rewards on employees' performance was good predictor of the Factory's performance. The coefficient of determination (R^2 = 0.84) explains the variance in factory's performance due to the monetary rewards factor.

4.3.3 Case study findings:

Firstly, Cash monetary rewards satisfied the factory employees the most, like annual bonus or incentive. Secondly, there was significant relationship between the monetary rewards and the employee's performance as well as between the employees' performance and the factory revenue. Thirdly, strong leaner correlation was found between the impact of monetary rewards on employees' performance and the Factory's performance.

5. Conclusion

The significance association between the monetary rewards and the employees' performance had significant association with Company growth. Namely, cash monetary reward satisfied the employees greatly. Expressly, when their achievement induced with bonus. This finding confirms preceding study postulation which predicted significant impact of monetary rewards on employee's engagement (Al Shehri et al. 2017). Hence, cash bonus and competitive salary with either monthly or annually increment policy enhance the employees' performance and contribute positively to company performance in Saudi manufacturing sector.

The real and direct contribution in company growth is caused by competitive employees, teamwork, and sincere employees. The satisfaction level of these motivated employees must be maintained and monitored continually by management. Their high commitment level can be acquired if management support the employees' personal needs by monetary rewards. Organizations are recommended to invest in improving their HR policy to favor the employees. Such investment can be paid back by the increase of their employees' satisfaction which reflects positively in their performance and ultimately causes company growth.

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Contaminated Money Investigation into the Hygiene Status of some Hospitals as Obtained from Food Outlet

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Abstract

This study aims to determine the presence of bacterial contamination associated with currency as obtained from hospital's food outlet. Samples were randomly collected from cafeteria's of Benghazi Medical Center Hospital, Benghazi Children's Hospital, and Al Jalaa Hospital. Bacteria isolates belonged to gram negative and gram positive were used to perform antibiotic sensitivity testing. Total count of bacteria from currency found 10 type of bacteria, the highest type of bacteria, *Lactobacillus* 50%, followed by *Acinetobacter* 20.3%, *Klebsiella* 7.4%, *Staphylococcus aureus* and *Escherichia coli* 3.7%, while the lowest *Staphylococcus epidermas, Pseudomonas stutzeri, Rhizobium radiobacter* were 1.8% and no growth 22.8%, the sensitivity of the isolated bacteria showed the *Acinetobacter baumanni* highest resistant to Augmantine (78%) and lowest to both Ceftazidimde and Aztronam with (11%), the *Klebsiella pneumonia* shows (100%) resistant to Erythromycin and Oxcilin. While the two sample of *Escherichia coli* were resistant to Augmantine and Ceftazidime. In addition, the two samples of *Staphylococcus aureus* were resistant to Erythromycin and Oxcilin (100%), two samples of *Staphylococcu epidermidis* were resistant to Erythromycin and Oxcilin (100%), while the one sample *Pseudomonas spp* was resistant to *Colastin (100%),* the *Pantoea spp* sample was resistant to both Ceftriaxone and Colastin (100%), while the only sample of *Staphylococcus Haemolyticus* was resistant (100%) to Erythromycin. Confirming that the contaminated currency spread in the hospital cafeteria was contaminated with disease-causing bacteria.

Keywords: Currency, Coin, Contaminated, Bacteria, Pathogenic, Antibiotics, Resistance, Infection.

1. Introduction

Healthcare-associated infections are one of the most extreme affected problems in healthcare these days, pathogens are capable of living on surfaces that can act as assets of pathogen transmission if no disinfection is completed (Sikora A. & Zahra F., 2021). Fomites have been described to be the one of the most source of nosocomial infections. The pathogens can continue to exist or persist on surfaces for months and can thereby be a non-forestall supply of transmission (Abdulmoneim M., et al., 2001), (Awodi et al., 2001). Therefore the possibility that money can also act as environmental fomite for the transmission of disease. In each day exchange, coins are treated thru individuals could be handled under non hygienic requirements and possibly contaminated with different microbes (Ramsden, 2004), (Prasai T, et al., 2010). Microorganisms on the skin can be transferred from cashiers, salespeople and most people to currency that manipulates material switch of cloth from arms, surfaces, and the surroundings can contaminate the currency therefore, contamination of pathogenic microorganisms is of public health importance as infected materials may be feasible resources of transmission of such pathogens according to (El-Dars F. & Hassan, 2005), (Xu J. et al., 2005), (Kuria J. et al., 2009). Human pathogens can be transferred immediately through physical contact, or in a roundabout way through many other environmental substances which consist of: air, water, food or other inanimate objects, that may bring about significant infection and illness in human beings . the tainted money get in flow and therefore unfold contaminated microbes to others hand and therefore‹ transmitting the pathogens by means of this procedure. consequently, this look at targets to decide the extent of the presence of bacterial contamination associated with Libyan foreign exchange coins that could play a massive position in an effort to discover the opportunities of transmission of infectious marketers in circulate round medical services in Benghazi, amassed from exquisite categories of people . The aim this study is to determine the presence of bacterial contamination associated with currency notes (coins) as obtained from hospital's food outlet.

1.1. Aim of this study:

To determine the presence of bacterial contamination associated with currency as obtained from hospital's food outlet.

Specific Objectives:

1. To isolate bacteria from currency of collected samples.

2. To find the frequency of type of bacteria growth (Gram+ Gram -).
3. To find type of bacterial isolated sample from different places of collection.
4. To find the percentage of resistance of isolated bacteria to antibodies.

2. Methodology:

2.1. Study area

Collection of the 70 samples, will collect randomly from different food outlet, of Benghazi Medical Center, Children's Hospital, and Al Jalaa Trauma Hospital, also from 6 samples from bank as a control.

2.2. Collection of sample

A total of 77 coins, 22 coins were collected from cafeteria Al Jalaa Trauma Hospital, 22 coins from cafeteria Children's Hospital, and 27 coins from cafeteria Benghazi medical center, and 6 samples as control from the bank.

2.3. Culture media

MacConkey agar, Muller-Hinton agar and blood agar base manufactured by Oxoid Ltd., were used to culture samples collected in this study. The media were prepared by following manufacture instructions and autoclave at 121°C for 15-20 minutes. After sterilization of media, MacConkey agar and Muller Hinton agar were cooled to 50°C and poured into petri dishes and set o dry. Blood agar base media was converted to blood agar by adding 10 cc of human blood at 60 °C, then, the media poured into petri dishes and set to dry.

2.4. Antibiotic sensitivity test (AST)

MHA was used to perform antibiotic sensitivity testing the antibiotics used in this study were: Ceftazidime (CAZ) Ciprofloxacin (CIP) gentamicin (CN) imipenem (IPM) Augmentin (AMC) Aztronam (ATM) Clindamcin (DA) Erythromycin (E) cefoxitin (FOX) Oxcilin (OX) vancomycin (VA).

2.5. Method of testing bacterial isolated to antimicrobial:

The sensitivity of bacterial isolates to antimicrobial was tasted as follows:

The concentration of each isolate was determined by preparing bacterial suspension and adjusted to 0.5 MCFarland standard. A sterile cotton swab was impregnated into the bacterial suspension and rotated inside the tube to remove excess moisture, and then the bacteria was streaked on MHA in three direction.

Antibiotics were added to the culture media and incubated at 37°c for 18 - 24 hrs. The zone on inhibition around each disc were measured by a ruler, by using Clinical and laboratory standard. Institute (CLSI) guideline, the sensitivity of each bacterium was measured as sensitive resistant according to standard.

3. Results:

In Table 1 results show that the highest bacterial growth was shown from samples collected from cafeteria Benghazi Medical Center (33.8 %), also the highest Gram negative bacteria was from the samples from Benghazi Medical Center with frequency of (65.3%), while the highest frequency of Gram positive Bacteria were from the samples collected from Al Jalaa Trauma Hospital with frequency of (85.7%).

Table 1: Frequency of type of Bacterial growth (Gram +, Gram -).

place	growth		no growth
	Gram positive	Gram negative	
Benghazi Medical Center	9	14	1
Benghazi Children‘s Hospital	8	7	7
Al Jalla Trauma Hospital	12	2	8
new currency from bank	1	0	5

All 77 samples that were collected randomly from different users from food outlet of Benghazi Medical Center, Children's Hospital, and Al Jalla Trauma Hospital, also from one bank as a control, have shown bacterial contamination on currency. Total count of bacteria from currency coin found 10 type of bacteria as shown in (Table 2), the highest type of bacteria, *Lactobacillus* 50%, followed by *Acinetobacter* 20.3%, *klebsiella* 7.4%, *S. Aureus* and *E. Coli* 3.7%, while the lowest *S. epidermas, Pseudomonas stutzeri, Rhizobium radiobacter* were 1.8% and no growth 22.8% (Figure 1).

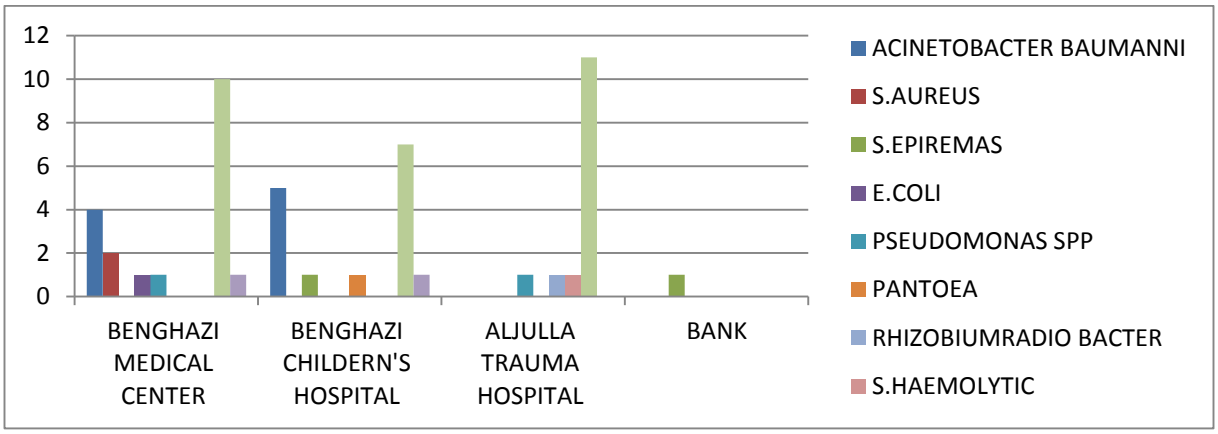

Figure 1: Type of Bacterial contamination found in sample from different places of collection**.**

Table 2: bacteria isolated from currency notes and coins.

Bacteria	Benghazi Medical Center	Benghazi Children's Hospital	Aljulla Trauma Hospital	Bank
Acintobacter baumannii	8	5	0	0
S.aureus	2	0	0	0
S.epidermas	0	1	0	1
Escherichia coli	2	0	0	0
Klebsiella pneumoniae	4	1	0	0
Pseudomonas ssp	1	0	1	0
Pantoea spp	0	1	0	0
Rhizobium bacter	0	0	1	0
S.haemolytic	0	0	1	0
Lactobacillus	9	7	11	0
TOTAL	26	15	14	1

The results of the sensitivity of the isolated bacteria from the collected samples in (Table 3) Showed the *Acinetobacter baumanni* highest resistant to Augmantine (78%) and lowest to both Ceftazidimde and Aztronam with (11%), the *Klebsiella pneumonia* shows (100%)resistant to Erythromycin and Oxcilin, While the two sample of *Escherichia coli* were resistant to Augmantine and Ceftazidime. In addition, the two samples of *Staphylococcus aureus* were resistant to Erythromycin and Oxcilin (100%), also the two samples of *Staphylococcu epidermidis* were resistant to Erythromycin and Oxcilin (100%),

while the one sample *Pseudomonas spp was resistant to Colastin (100%),* the *Pantoea spp* sample was resistant to both Ceftriaxone and Colastin (100%), while the only sample of *Staphylococcus Haemolyticus* was resistant (100%) to Erythromycin.

Table 3: Percentage of Resistance of Isolated Bacteria to Antibodies

Antibiotic	*Acinetobacter baumanni* N=9(R%)	*Klebsiella pneumonia* N=2 (R%)	*Escherichia coli* N=2 (R%)	*Staphylococcus aureus* N=2(R%)	*Staphylococcus epidermidis* N=2(R%)	*Pseudomonas SPP* N=1(R%)	*Pantoea SPP* N=1(R%)	*Staphylococcus Haemolyticus* N=1(R%)
Augmenting	78%	0%	100%	0%	0%	0%	100%	0%
Ceftazidimde	11%	0%	100%	0%	0%	0%	0%	0%
Aztronam	11%	0%	0%	0%	0%	0%	0%	0%
Oxcilin	0%	100%	0%	100%	100%	0%	0%	0%
Erythromycin	0%	100%	0%	100%	100%	0%	0%	100%
Colastin	0%	0%	0%	0%	0%	100%	100%	0%
Ceftriaxone	0%	0%	0%	0%	0%	0%	100%	0%

4. Discussion:

Paper currency and coins may be a public health risk when associated with the simultaneous handling of food and could lead to the spread of nosocomial infections. Results from this study showed that the currency collected from food outlet (cafeteria) Benghazi Medical center, Children's Hospital, and Al Jalaa Hospital are contaminated with 10 type of bacteria which, were isolated; *Acintobacter baumannii, S.aureus, S.epidermas, Escherichia coli, Klebsiella pneumonia, Pseudomonas ssp Pantoea spp, Rhizobium bacter, S.haemolytic,*and *Lactobacillus.* These results were compatible with previous researchers from other countries, which elucidated that currency banknotes are usually contaminated by pathogenic microorganisms (Nasser & Alwakeel, 2012), (Gedik H. et al., 2013), (Sharma & Sumbali, 2014).

The amount of bacterial contamination on currency varies widely between countries. As a result, 88% of the paper notes tested in Jeddah, Saudi Arabia were contaminated with a variety of microorganisms (Al-Ghamdi et al., 2001), and 94% of US$1 bills had bacterial contamination (Pope TW. et al., 2002). Also a study on Ghanaian currency note were contaminated with both gram positive and gram negative bacteria (Feglo P. & N kansah M., 2010). As in our study bacteria isolates were of both gram positive and gram negative with higher frequency from gram negative bacteria (73.6%). An Egyptian study implied that gram-negative bacteria can remain as long as eleven days on coins (El-Dars & Hassan, 2005). A different study showed Gram-positive bacilli and staphylococci predominate among bacteria found on the surface of copper coins (Santo et al., 2010). In a previous review reported that many Gram-positive bacteria, such as *Enterococcus* spp., *S. aureus* and *Streptococcus pyogenes*, and Gram-negative bacteria,

such as *Acinetobacter* spp., *Escherichia coli*, *Klebsiella* spp., *Pseudomonas aeruginosa*, *Serratia marcescens* and *Shigella* spp., can survive for months on surfaces (Kramer et al., 2006).

The types of bacteria isolates in this study has been also seen in different studies and have been isolated from money worldwide, including developed countries, microbes, such as *S. aureus*, *E. coli*, *Klebsiella* spp. and *Enterobacter* spp., have been identified as common contaminants. Moreover, bacterial isolates from banknotes from different countries, found that *E. coli* was most commonly isolated on banknotes from the USA and China, and a *Salmonella* sp. was isolated only from samples in the USA, China and Ireland, while the presence of *S. aureus* varied (Vriesekoop et al., 2010). While the absence of streptococci isolates from coins probably suggests a high sensitivity of these bacteria to metallic Currency (Espirito et al., 2010).

As Known of organisms, bear the potentials for survival on dry fomites like currency. They have evolved complicated separate physiologic resting stages that give them the advantage for surviving due to low water activity. Transmission of microorganisms is possible from any place where they are attached. Hand to hand transfer of money plays important role in spread of diseases. The number of transferring organisms from coins or paper notes can be depended on a series of factors such as the number of organisms present and their ability to survive in dry environment. However, evidence for the presence of pathogenic bacteria on currency reinforces the need for strict adherence to hygienic practices among money handlers who also handle food (Prasai T. et al., 2008). For example, the bacteria that as isolated from this study as the *Escherichia coli*, are usually nonpathogenic but some strains can cause serious food poisoning in humans and urinary tract infections. Also, the *Klebsiella pneumoniae* is a virulent organism that can cause pneumonia typically along with urinary tract and wound infections, particularly in immuno-compromised individuals (Lamichhane J. et al., 2009). In addition, *Acinetobacter* spp., have emerged as infectious agents of nosocomial infections, including bacteremia and urinary tract infection (Towner, 1997).

Furthermore, *S. aureus.* Which is a major pathogen for humans, for it can cross contaminate foods and cause food poisoning. It has been recognized for cross implication in various types of infections; pneumonia, skin infection, impetigo, endocarditis, septic arthritis, gastroenteritis localized collection of pus, known as an abscess (Neel, 2012), (Winn Washington et al., 2006). Therefore, as pathogens on currency notes survive, they may multiply (Sharma & Sumbali, 2014).

Also, they may cause food borne illnesses and that represents an often overlooked enteric disease reservoir (Barry, 2002), (Gedik et al., 2013). This is of concern, due to the fact that currency notes could serve as a vehicle for transmission of diseases.

On the other hand results from of the sensitivity of the isolated bacteria from the collected samples show resistance to the antibiotics used (Table 3) the *Acinetobacter baumanni* highest resistant to Augmantine (78%) and lowest to both Ceftazidimde and Aztronam with (11%), the *Klebsiella pneumonia* shows (100%) resistant to Erythromycin and Oxcilin, While the two sample of *Escherichia coli* were resistant to Augmantine and Ceftazidime. In addition, the two samples of *Staphylococcus aureus* were resistant to Erythromycin and Oxcilin (100%), also the two samples of *Staphylococcu epidermidis* were resistant to Erythromycin and Oxcilin (100%), while the one sample *Pseudomonas spp was resistant to Colastin (*100%), the *Pantoea spp* sample was resistant to both Ceftriaxone and Colastin (100%), while the only sample of *Staphylococcus Haemolyticus* was resistant (100%) to Erythromycin. The results agree with the findings of others who also reported that *Staphylococcus aureus* was found resistant to many antibiotics; as resistant to Augmentin, Nitrofurantoin and amoxicillin (Tagoe et al., 2011), (Ayandele & Adeniyi, 2011). Also *Escherichia coli* was found in a different study resistances to Clindamycin, Linezolid, Erythromycin (Kabir et al., 2013). Another study on Ghanaian currency notes that, *Klebsiella pneumonia* whcih resistances (100%) to Ampicillin, Cloxacillin, Penicillin and Cefuroxime (Walsh et al., 1996). The bacteria resist to antibiotics, represent a risk to the public health in the community. Antimicrobial resistance is a global phenomenon that has resulted in high morbidity and mortality as a result of treatment failures and increased health care costs (Sharma & Dhanashree, 2011). Research has shown that contaminated fomites or surfaces play a key role in the spread of bacterial infections with antimicrobial resistance.

In many food outlets, workers handle money and prepare food at the same time. In addition, pathogens of the nose, throat, feces or skin can be transmitted by hands, highlighting the need for hand hygiene (Todd EC et al., 2009). Money collected from food sellers is highly contaminated, and the presence of infectious agents on currency is indicative of poor hygiene in the person who recently handled the currency. Moreover, the manner in which the paper currency or coins were kept in food outlets can influence the presence of these infectious agents on the currency. Keeping money in dirty places and as a habit, wetting fingers with saliva while counting currency notes suggests that humans are the major source of microorganisms on currency.

Additionally, unwashed fingers, including indiscriminate coughing, sneezing and defecation with indecent handling of currency notes were the most common sources of contamination (WHO, 2009), (Gedik et al., 2013), (Neel, 2012). Furthermore, the materials of which the currency was manufactured are probably a factor that affects the survival of microorganisms on the banknotes (Gedik et al., 2013).

The study showed that the contaminated coin, spread in the hospital cafeteria was contaminated with disease-causing bacteria, including resistant bacteria, and may play an important role in the transmission of bacterial infection.

5. Conclusion:

Currency can be pathogenic and have dangerous bacteria that is resistance to antibiotic. Contaminated currency are a public health risk when associated with the simultaneous handling of food, and currency may spread nosocomial infections in hospitals. The currency circulating in different hospitals could serve as a vehicle for transmission of pathogenic bacteria.

6. Recommendations:

Ready-to-eat food vendors should receive education to prevent cross-contamination between currency notes and the food they sell. Using methods of preventing cross contamination include use of a separate staff member to handle money, using separate materials and changing disposable gloves before touching cooked or ready to eat foods. Visa card and banking services should be made easier to use. Hand washing with soap after using currency notes is one way to reduce hand contamination and therefore reduce currency pollution. It is also recommended that future studies could be done to determine other microorganisms.

7. Ethical Consideration:

The authors acknowledge that this research did not include experiments on humans or animals.

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Building Blocks Properties and Temperature Transfer between Block Walls

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Abstract

The construction field in the Arabic gulf area is supported on the blocks martials as a primary cladding source for exterior elevations and interior walls. There are two types of blocks that are mainly used in the region. First, the solid cement black blocks which is constructed of cement, fine aggregate, fine aggregate and Portland cement. Second is the white block which Consists of Portland cement, cement ash, fine sand, aluminium powder, lime and silica. Cement black blocks act as load bearing walls, because of its high pressure and shear resistance. Add to that, the cement blocks are considered a cheap material. However, the cement black blocks considered a heavy material and overload to its holding structure. In addition, the cement black blocks are weak temperature and sound isolators, to fill the cement black blocks missing properties, the white blocks are used. The white blocks are light weigh, good temperature and sound insulators and easy to cut and build. On the other hand, the white blocks weak points are its low bearing load resistance, in which it is not possible to clad the white blocks with marble or stones. In this research paper, the gypsy blocks are introduced and studied as alternative material that have both the black and white blocks benefit and compensate for both materials' weak points.

Keywords: Building Blocks, Properties, Temperature Transfer, Block Walls

1. Introduction

The gypsy blocks are manufactured by mixing dry gypsum with glass fibres and water in a hollow block oven. The gypsy blocks are used in residential and commercial buildings and malls. In addition, it can be used in hospitals and factories due to the gypsy blocks anti-bacterial surface. The gypsum board is light weighted, in which make it a economical aid in designed the buildings concrete structure and is more safe to build as extension to existing aged structure. Moreover, the gypsy blocks have a high water and moisture resistance characteristics which make it a great choice for wet area walls such as toilets and swimming pools. Additionally, due to the gypsy blocks special chemical combination and hollow interior, the blocks services as temperature isolator which add to its economic value in energy saving because this will reduce the premises air conditional units load to maintain the desired temperature. For the same hollow interior body structure characteristics, the gypsy blocks are great sound isolators. Moreover, the gypsy blocks have a smooth surface that provide the privilege of applying the painting process directly after the blocks fixing stage without the need of doing the plastering works, which in return add a big economic value in saving the cost, time and materials of the plastering process the gypsy blocks are fixed through been placed in aligned rows and are supported by gypsum powder adherence that are mixed with water and applied between each horizontal and vertical blocks. Windows and doors opening can be made in the gypsy blocks walls by adding a galvanized 3mm sheet above the wall opening.

1.1. The study problem

The following study discuss the disadvantages in using the traditional black and white blocks that are used as the prime buildings cladding in the Arabic gulf areas since the past century, such disadvantages start from the blocks heavy weight that tools additional cost on the building through requiring additional reinforcement in the concrete structure. Furthermore, the black cement blocks do not serve as good sound and temperature isolators which in respond requires additional costs for adding insolation materials and additional energy loads through air condition units to maintain the premises temperature, such downsides can be solved through replacing the black cement block with the white lime blocks which is characterized by being light weighted materials and good sound and temperature isolators. However, the white blocks problems are that it is not a good choice to be fixed in wet areas such as toilets and swimming pools and like the black cement blocks, the blocks need to be applied with the plastering process before proceeding with the

painting and finishing stage. For both the black cement and white lime stones displayed problems, the gypsy blocks act as the solution for both materials disadvantages in addition to other benefits.

1.2. The Study Aims:

The study main goal is to Point out the flows of the classic black cement blocks and white lame blocks. In addition, to display the how the gypsy blocks solve the classic blocks downsides. Furthermore, identify the advantages and usage of the gypsy blocks.

1.3. The Study Methodology

The study methodology depends on the scientific study of the gypsy blocks chemical compound and physical characteristics that made the gypsy block a construction material choice for varies applications in a tested field of study and usage.

2. The Study Framework

The study farmwork will demonstrate the function and aids of using the gypsy blocks as an alternative material to the black cement and white lime blocks supported by lab tests and practical filed experiments

The study farmwork can be summarized in the following bullet points:

1- The definition and description of the physical characteristic of the gypsy blocks.
2- The gypsy block plastering free ready to paint surface.
3- The gypsy block weigh
4- The gypsy blocks Thermal insulation properties
5- The gypsy block water and moister isolation properties
6- The gypsy block sound insolation properties.
7- The gypsy blocks fire resistance properties.

2.1. The definition and description of the physical characteristic of the gypsy blocks.

The gypsy block is the commercial name of the gypsum buildings block, are lightweight building blocks made from gypsum, a naturally occurring mineral found in sedimentary rock formations. Which are composed mainly of gypsum, along with water, plaster, and sometimes additives like fibres for enhanced strength. The gypsy blocks are hollow rectangle blocks that are produced in sizes of 50x50x15cm and 50x65x10 cm as the common sizes used in the Arabic gulf area.

2.2. The gypsy block plastering free ready to paint surface.

The gypsy blocks have a smooth surface that's ready to paint or wallpaper, eliminating the need for additional plastering or finishing unlike the black and white traditional blocks. In which, add a huge time and cost saving benefits by shortcutting the time required to apply the plastering works and eliminate the plastering materials and the preforming manpower costs.

2.3. The gypsy block weigh.

Compared to cement or lime blocks, gypsy blocks are significantly lighter, making them easier to handle and install, reducing (load) on the building's foundation in which saves building reinforcement costs and are easier to build, which means the building manpower can build more in single day, which in return saves time and cost.

The following table demonstrate the surface mass of the gypsy blocks in compare with cement and lime blocks for 10cm thickness.

Table (1): the difference in surface mass comparison between gypsy blocks, cement block and lime blocks

Block type	Single block size (cm)	Surface mass (Kg/m2)	Breaking load (KN)
Cement block (1, 2023)	40x20x10	178	9
White lime block (5, 2016)	60x20x10	51	4
Gypsy block (2, 2020)	65x50x10	70	5.7

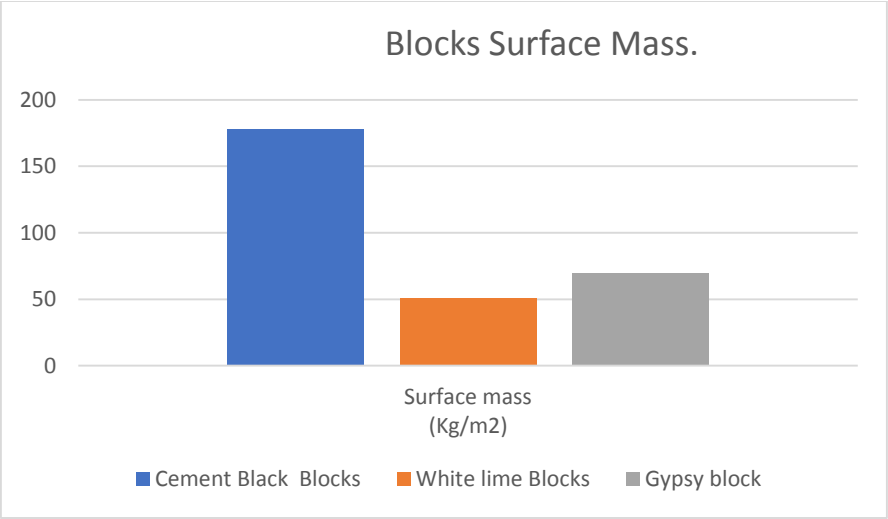

Chart 1: Blocks Surface Mass compression chart

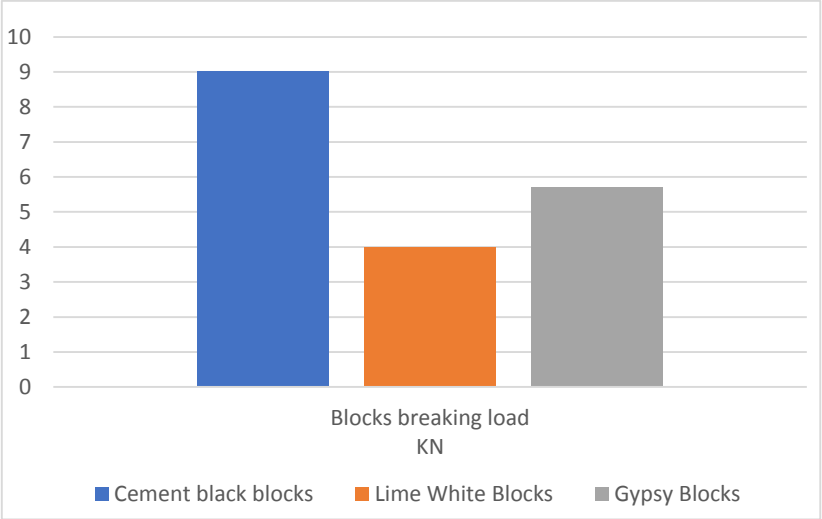

Chart 2: Blocks Breaking Load compression chart.

2.4. The gypsy blocks Thermal insulation properties

Gypsy blocks gypsum component offers thermal insulation, which can improve energy efficiency in buildings which in return reduce electrical loads which saves some energy costs.

The following table shows the cement, white lime and gypsy blocks thermal conductivity measurements for 10cm thick block sample per each.

Table (2): the thermal conductivity comparison between gypsy, cement and white lime blocks

Block type	**Thermal conductivity W/mk**
Cement block (1, 2023)	0.7
White lime block (5, 2016)	0.6
Gypsy block (3, 2016)	0.3

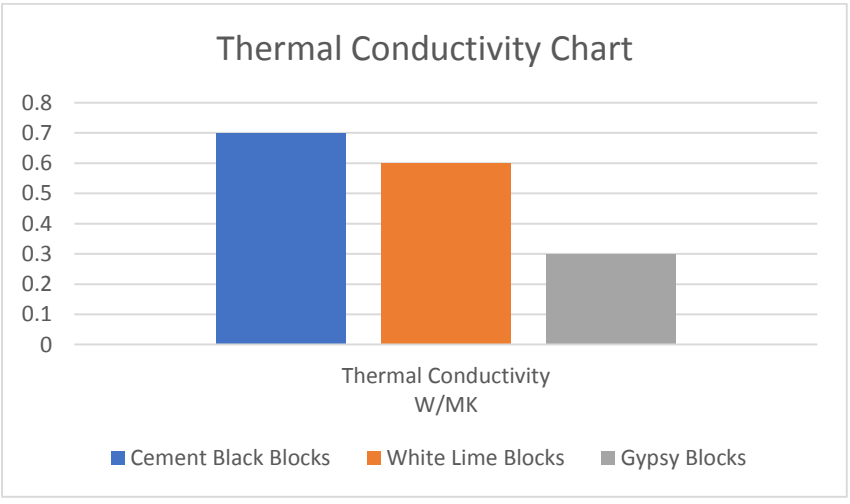

Chart 3: Thermal Conductivity Compression Chart.

5.5. The gypsy block water and moister isolation properties

Gypsy blocks, while commonly used in construction, do have the best qualities when it comes to water and moisture resistance, which can be used in wet areas such as pools, toilets.

The following table shows the cement, white lime and gypsy blocks water absorption measurements after 2 hours samples fully immerged test for 10cm thick block sample per each.

Table (3): 2 hours immerging test water absorption comparison between Gypsy, Cement and White lime blocks.

Block type	**blocks water absorption %**
Cement block (1, 2023)	9.5
White lime block (1, 2023)	6
Gypsy block (4, 2017)	0.4

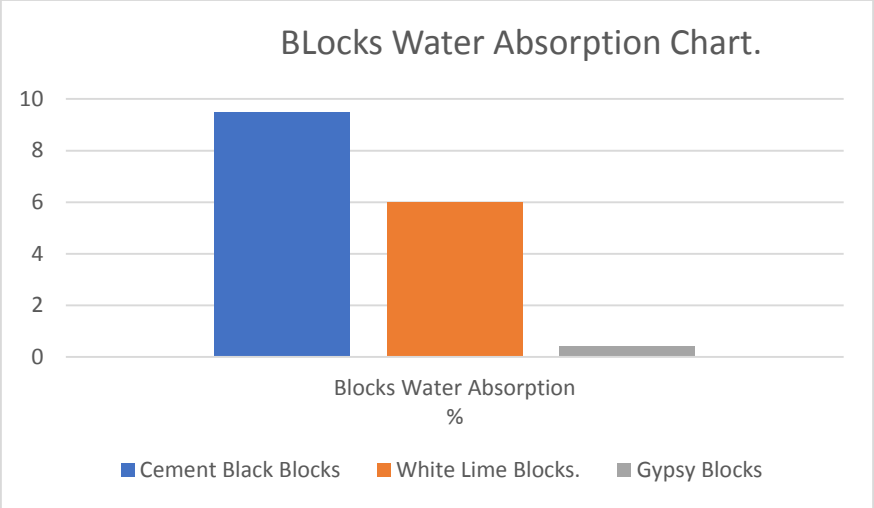

Chart 4: Water Absorption Compression Chart.

2.6. The gypsy block sound insolation properties.

Gypsy blocks offer decent sound insulation properties for non-load bearing interior walls, making them a suitable choice for many everyday construction applications, due to their mass and density, effectively dampen sound waves, offering better soundproofing than traditional drywall.

The following table shows the cement, white lime and gypsy blocks soundproofing acoustic insulation test for 10cm thick block sample per each.

Table (4): sound acoustic insulation comparison between Gypsy, Cement and White Lime blocks.

Block type	acoustic insulation dB
Cement block (1, 2023)	30
White lime block (1, 2023) (5, 2016)	40
Gypsy block (3, 2016)	40

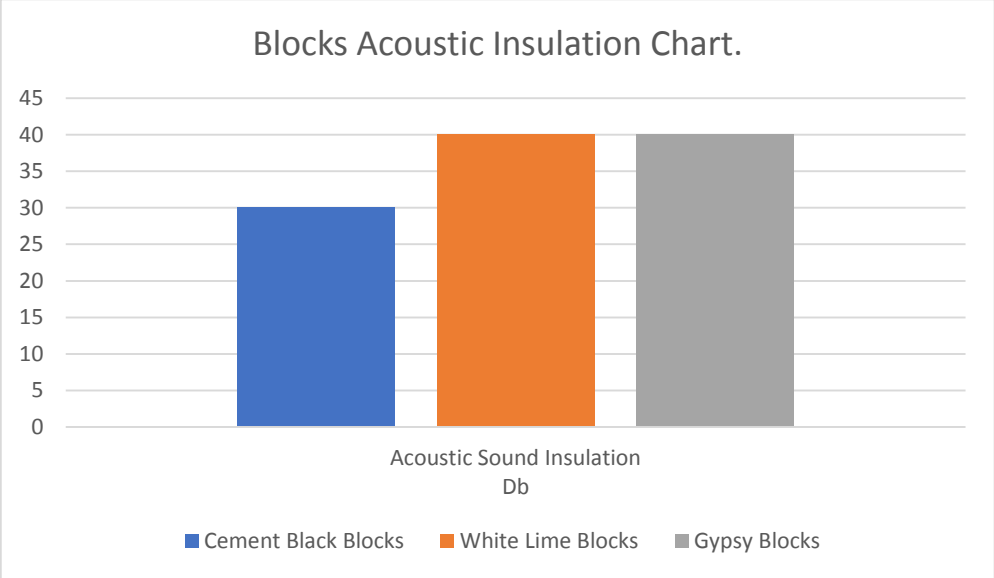

Chart 5: Blocks Acoustic Insulation Compression Chart.

2.7. The gypsy blocks fire resistance properties.

Gypsy blocks boast impressive fire resistance properties, making them a valuable choice for building safety and kitchen areas due to gypsy blocks hydrated Crystal Structure.

The following table shows the cement, white lime and gypsy blocks fire resistance rate test for 10cm thick block sample per each.

Table (5): fire resistance rating comparison between Gypsy, Cement and White Lime blocks.

Block type	Fire Resistance Rating (min)
Cement block (1, 2023)	90
White lime block (6, 2017)	60
Gypsy block (3, 2016)	180

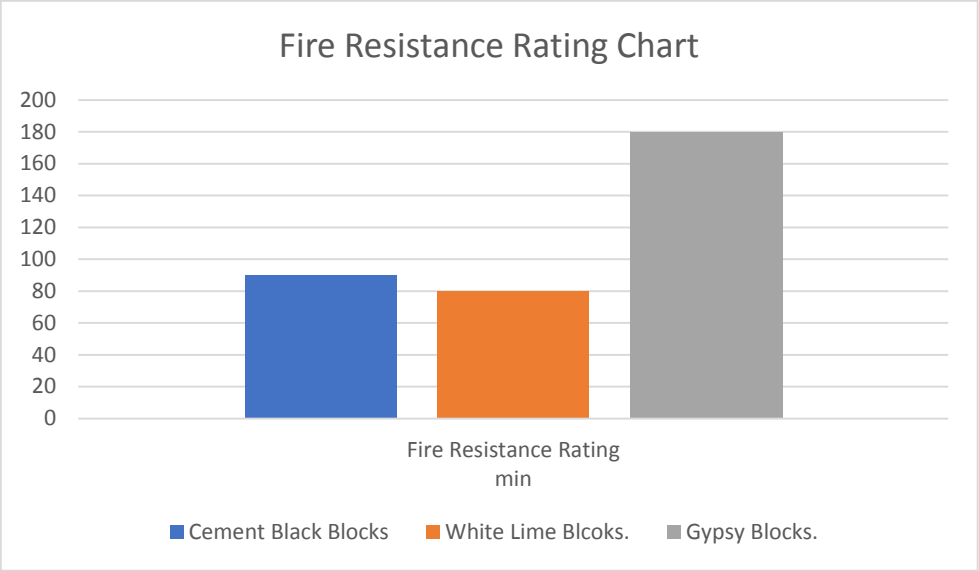

Chart 6: Fire Resistance Rating Compression Chart.

3. The Study Results and Discussing

The above results shows that the gypsy blocks are the only blocks with smooth surface that requires no plastering works before applying the finishing layer. In addition, the data in table (1-3) indicate that the gypsy blocks are lighter than the cement black block by 60% but the black blocks have a higher load bearing capacity by 40%. The white blocks are lighter than the gypsy blocks by 29%, but the gypsy blocks have a higher load bearing capacity by 30% more. Moreover, as shown in table (1-4) the gypsy blocks temperature insulation ability are twice the ability of the black cement and white lime blocks. Additionally, as indicated in table (1-5) the gypsy blocks are better water resistance material than the cement black and white lime block, as shown in the sample fully immerged test the gypsy blocks water absorption is almost zero in compare with black blocks 9.5% and white blocks 6&. Furthermore, the gypsy blocks can isolate sounds better that their peers as been displayed in table (1-6) acoustic test that resulted the gypsy block sample with 40 dB units in compare with the black and white blocks that resulted in 30dB30dB. Last but not least, the gypsy blocks can resist fire more than the white and black blocks as demonstrated in table (1-7) 500C oven test results that shows the gypsy block ability to withstand fire for 180 minutes which is twice the time of the black and white blocks that resulted 90 minutes each.

The study results for the blocks superior quality comparison points can be summarized in the following table and chart:

Table (6): Summary table.

Blocks type	Cement Black Blocks.	Lime White Blocks.	Gypsy Blocks.
Quality Point			
Lighter Surfess Mass		1	
Greatest bearing load capacity	1		
Best thermal insulator			1
Best water isolator And moisture resistance			1
Best sound insulator			1
Best fire resistance			1
Overall quality points	1	1	4

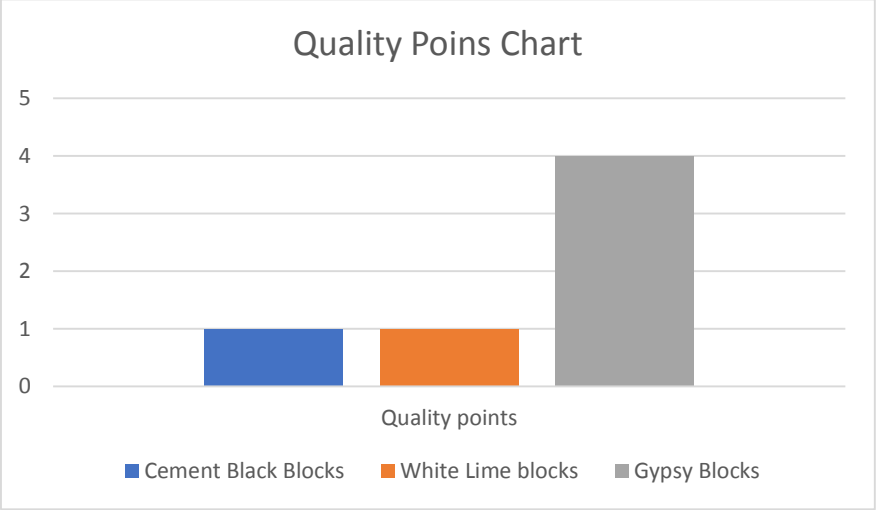

Chart 7: Summary Chart overall quality points Compression Chart.

4. The Study Conclusion

The gypsy blocks are the better modern era material construction chose for the interior non-bearing walls for the blocks properties and economical values that supress the cement black and white lime blocks starting with the gypsy blocks smooth surface that delete the need of the plastering stage, Furthermore, being a light wight materials that tools less load on the buildings structure and less pressure on the building man power that results in more work activity per day and less building reinforcement work and cost especially when building extensions in aged buildings.

Moreover, the gypsy blocks are better material choice for wet areas due to its superior water and moister resistance properties. Additionally, gypsy blocks offer effective sound isolation as they can reduce the sound intensity passing through the wall by 40dB, make it better chose for comfort in quite places like residential buildings and hospitals. Add to that, the gypsy blocks have afire resistance ability to stand active fire up to 180 minutes, which make the gypsy block safe materials for construction locations and kitchen areas.

5. The Study Recommendations

It is not recommended to build the gypsy blocks as exterior façade without applying the external isolation layer or when fixing a heavy load baring materials such as marble or steel frame façade. Furthermore, the gypsy blocks should be supported by the block's special gypsum adhesive powder, after mixing with water. Add to that, the gypsy blocks should be supported by the block's special gypsum adhesive powder, after mixing with water. More than that, the gypsy blocks should be supported by the block's special gypsum adhesive powder, after mixing with water. Also, the gypsy blocks should be cut using the mechanical saw only to avoid damaging the blocks interior component. Last but not least, it is recommended to use screws instead of nails to avoid damaging the blocks surface.

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Career Craft (A Student Training and Freelancing Platform)

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Abstract

As the world continues to rely on technology in all aspects of life, the demand for Information Technology graduates with sufficient background knowledge and necessary practical skills has never been higher. Computer science students are required to keep track of advancements and new trends in the field while maintaining good depth in present technologies. Unfortunately, many fresh graduates face significant challenges when entering the workforce, lacking practical experience and technical skills in the field. To mitigate this problem, students need more exposure to real-world experience and work in a job market environment. This paper presents the design and implementation of Career Craft, a platform that intends to enhance students' programming and problem-solving skills by providing programming tasks that students compete to solve. Teachers develop and publish programing tasks and students solve them in order to gain points. A teacher is assigned as project manager and selects a group of students based on expertise and experience to develop the requested service. This exposes students to the real-world job environment and provides them with hands-on freelancing experience in these areas. By using the system, students can increase their employability by working as freelancers for clients. The system improves students' skills, increases their chances of employment, and increases their income, while helping clients obtain quality services.

Keywords: Career Craft, Freelancing, Training Platform, Programing Skills, UI/UX, Web Development.

1. Introduction

The field of web development has seen significant growth in recent years, as businesses and organizations increasingly recognize the importance of having a strong online presence. This has led to a high demand for professionals with skills in areas such as User Interface/User Experience (UI/UX) design, web development, and web security. In response to this issue, many universities have begun to offer experiential learning opportunities, such as internships and co-op programs, in which students can apply their knowledge in real-world settings and gain practical experience. However, these opportunities can be limited and often only available to a few students, leaving many others without the hands-on training they need to succeed in the workforce.

Information Technology (IT) students suffer from insufficient practical skills due to limited time in laboratories and lack of motive. They are also unaware of issues related to market needs and job requirements. There is a gap between academic knowledge and professional skills that students need after graduation. Different skills that students acquire during their years of study do not fulfill the capabilities that employers expect. Moreover, IT fresh graduates are sought after in the market and considered valuable assets for companies. Therefore they have limited time to prepare and apply for jobs before these positions are occupied. Attaining the required job skills during education years saves students time and gives them advantages in securing the best job positions.

Undergraduate students commonly seek part-time and full-time jobs while studying to financially support themselves. According to (National Center for Education Statistics, 2022), 40% of full-time undergraduate students enrolled in US colleges in 2020 were employed. The types of jobs usually offered to undergraduate students are low-income entry jobs which are unrelated to students' major of study. This has disadvantages such as having to work for many hours to earn sufficient income. Moreover, students waste a lot of time working, when they could have been studying or resting. Furthermore, long working hours and night shifts leads to lack of sleep and fatigue, which negatively influences students' focus during lectures and also reduces their assignment and exam grades.

Students are often faced with limited opportunities to receive the necessary training and experience to keep up with the rapidly changing technology landscape. They attend job fairs or reach out to companies that provide training and employment opportunities, but these opportunities often come with very low salaries and limited opportunities for advancement. In this paper, we address this problem by providing students with the opportunity to receive training, work on real projects,

and earn money, all while still studying. This is achieved by developing Career Craft, a software platform that trains IT students towards enhancing the practical side of their major and introduce them to the job market early on.

1.1. Research Objectives

The ultimate goal of the platform is to ensure that students have the necessary skills and experience to succeed in their future careers. This goal is realized by the following objectives:

1. Provide students with practical experience in the fields of web development, UI/UX design, and web security.
2. Enhance the practical skills of students to meet the demands of the market and increase their chances of getting hired.
3. Improve the reputation of the university by showcasing the capabilities of its students through the successful completion of client projects.
4. Generate financial benefits for both students and the university through client projects.

1.2. Research Importance

The significance of this work is that implementing and utilizing the platform ensure that students engage in software development and are exposed to real-world experience during their years of university enrolment. In addition, student gain experience in programming problem solving and software development. Moreover, implementing Career Craft platform creates a university environment that simulates the market to prepare university students for their future jobs.

2. Related Work

The study in (Edupuganti and Ramyakanth, 2017) investigated the development and implementation of an online grading system to improve the accuracy and efficiency of grading for educators. The system used an online interface for students to submit assignments and for instructors to grade them. Results showed that the system reduced the time and effort required for grading and increased the accuracy and consistency of grades. However, the study also identified some limitations and challenges such as technical issues, training needs, and concerns about academic integrity.

The authors of (Brantmeier and Richardson, 2015) explored the effectiveness of task-based language teaching (TBLT) in promoting student practical skills in language learning.

They found that TBLT increased students' motivation, engagement, and practical skills in a variety of language learning tasks. They also highlighted the importance of providing clear instructions, appropriate feedback, and meaningful tasks that are relevant to students' interests and goals. TBLT however requires extensive planning and preparation by teachers, and might not be suitable for all types of language learning goals or contexts.

A mathematical model for ranking students of online IT courses was developed in (Dronyuk et al, 2019) based on students' academic performance. The proposed model utilized fuzzy logic and weighted averaging to calculate the overall score of each student. The results of the study indicated that the model was effective in ranking students and identifying those who require additional support or interventions. However, the study identified the need for further refinement of the model and the inclusion of other factors that may impact student performance. Moreover, no guidance was specified on how the model could be implemented in practice or how it could be adapted for use in different contexts.

The study in (Al-Ansi and Elrehail, 2017) aimed to investigate the impact of student satisfaction and university reputation on the financial performance of universities. The study was conducted on 16 private universities in Yemen, and the results showed that both student satisfaction and university reputation have a significant positive effect on university financial performance. The study suggested that universities should focus on improving student satisfaction and enhancing university reputation to increase their income. This study did not consider other factors that may affect the financial performance of universities, such as funding sources and government policies. In addition, the study used a small sample size and relied on self-reported data, which may be subject to response bias and social desirability bias.

The effectiveness of project-based learning in enhancing the parallel programing and soft skills of computer science students was investigated in (Younis et al, 2021). The authors conducted a design study with a pre-survey and a post-survey. The control group involved 247 students divided into 51 groups. Each group was assigned 5 projects and allowed two weeks to complete each project. The evaluation showed that group study and collaboration influenced students' ability and extent to learn parallel programing and soft skills, proving the effectiveness of project-based learning.

In this paper we present Career Craft, a software platform that motivates students to focus on the practical side of their specialization and exposes them to a real-world market environment. On one hand, the platform increases programing and problem-solving skills by providing small tasks that

students can solve to earn points. Students are promoted to a higher level as they collect points, which encourages competition. Additionally, the platform enables clients from outside academic institutions to make requests for developing software systems within the institution. This allows students to gain hands-on experience in software development. Using this system, students can increase their employability by working as freelancers for clients. The proposed system focuses on three key IT areas: web development, UI/UX design, and web security. The platform has four functions:

- Admin: in charge of running the platform and maintaining its functionality.
- Manager: responsible for creating and adding tasks to the platform as well as managing software projects.
- Student: solves tasks and participates in teams to develop software projects.
- Client: interested in purchasing a software system.

The rest of the paper is organized as follows: Section 2 explains the necessary approaches to enhance student skills. Section 3 describes the design of the proposed platform. Section 4 demonstrates the implementation of the platform. Section 5 concludes the paper.

3. Student skills enhancement

There are a number of factors that contribute to enhancing students' skills and facilitate securing a job following graduation. These include technical skills, training, experimental learning, and keeping up with advancements in the field of computer science.

3.1 Technical skills

Technical skills include the practical knowledge that is used to solve tasks related to IT such as programming, data analysis, graphics design etc. To enhance students' technical skills, it is essential that they receive technical training while they are still in school. This training can take the form of internships, workshops, and hands-on projects, allowing students to gain practical experience. By doing so, students are better prepared to enter the workforce and have a competitive edge in the job market.

3.2 Training

One study conducted by the Freelancers Union and Elance-oDesk (now Upwork) (Freelancers Union, 2014) found that freelancers are more likely to find skill-related training valuable to the

work they currently do, rather than a college education. 70% of full-time freelancers participated in skill training, compared to 49% of full-time non-freelancers. Freelancers seek training to enhance their skills in areas that affect freelancers the most: technology, networking, and business management.

3.3 Up-to-date knowledge

Students in the field of computer science need to keep up with the rapid pace of technological change. The technology industry is constantly evolving, and students must be equipped with the latest skills and knowledge to remain competitive. Technical training provides students with the opportunity to update their skills and remain marketable as the job market evolves.

3.4 Experiential Learning

A recent study by the National Bureau of Economic Research (NBER) (Barr and Turner, 2020) found that students who participated in experiential learning opportunities were more likely to be employed after graduation and to earn higher salaries than their peers who did not participate in such programs. The study also found that these benefits were most pronounced for students in fields such as computer science and engineering, where hands-on training is particularly important.

The benefits of experiential learning extend beyond the students themselves. Companies that offer internships and co-op programs often report improved productivity and increased innovation, as students bring fresh perspective and new ideas to the workplace. Additionally, by providing training and mentorship to students, these companies are able to cultivate a pipeline of skilled workers and build relationships with the universities and training programs with which they partner.

In light of the above-mentioned requirements, it is clear that there is a need to prepare students with necessary skills prior to graduation. Providing student with a system that facilitates practical training and real-world experience in their field of study is a step towards achieving this goal.

4. Methodology

Career Craft is a comprehensive web-based platform that offers a range of opportunities for students who are interested in pursuing a career in web security, UI/UX design, or web development. In addition, the platform is designed to help clients find highly skilled and experienced professionals who can provide quality services in their respective fields. The platform offers a variety of tasks that students can complete to practice their skills and gain real-world

experience. These tasks are categorized by service type, allowing students to focus on the area in which they are most interested. The platform also employs a ranking system to classify students based on the number of tasks they have completed. The higher a student's rank, the more likely they are to be selected for client projects. This provides students with a practical opportunity to work on client projects and further develop their skills, while also making them more attractive to potential employers.

4.1 System elements

The platform consists of tasks that students solve to compete, and roadmaps to guide them and explain how to solve these tasks. It also consists of client projects in which students enroll after creating a group supervised by a teacher to develop the requested project.

4.1.1 Tasks

There are three types of tasks in the platform, namely web development tasks, UI/UX design tasks, and web security tasks. The difficulty of each task is determined by the manager, and is assigned a corresponding number of points based on its level of difficulty. The platform has three levels of difficulty: easy, medium, and hard, and each task can only be solved by a single student.

There are two types of web development tasks: back-end and front-end. Easy tasks are directly submitted to the platform. On the other hand, after solving medium and hard web development tasks, students are required to submit a link to the repository of their solution on their GitHub account.

For UI/UX design tasks, students are required to upload a .rar file containing all the screens required for the task. In the case of web security tasks, the platform offers CTF (Capture the Flag) challenges for the students to solve, and they are required to submit the flag found on the given URL. For easy web security tasks, students only need to submit the flag, while for medium and hard web security tasks, they need to write a report explaining how they found the flag.

4.1.2 Teams

In the Career Craft platform, the students are given the opportunity to form teams or join existing ones, depending on their preferences. Once a student creates a team, they can apply as a team for client projects. To join an existing team, the student must enter the unique invitation link, which is created automatically upon the team's creation. This feature provides students with the chance to collaborate and engage in team-based projects, thereby enhancing their skills in teamwork and

project management, which are highly valued in the workforce. Additionally, it fosters a sense of community and encourages the students to interact with their peers, facilitating knowledge-sharing and peer-learning opportunities. Overall, this feature adds an essential layer of interactivity and collaboration to the Career Craft platform, which helps students develop their practical skills and knowledge in the fields of web development, UI/UX design, and web security.

4.1.3 Client projects

A client who is interested in purchasing a software system applies through the platform. The client must specify the desired service in details and upload all necessary information including timeframe. Upon receipt of the request, the manager establishes the number of necessary team members required to undertake the project, and subsequently, will release the project for student applications. Upon conclusion of the application period, the manager will then screen the candidates to determine the most suitable team members for the designated roles, and subsequently form a team for the specific project. Once the team is established, the manager will initiate the project development phase and update the progress of the project on the platform which is reflected to the client.

4.1.4 Roadmaps

Roadmaps are an integral feature of the Career Craft platform, offering a simple overview of the background knowledge required to work in each of the three fields, namely web development, UI/UX design, and web security. In addition, these resources provide students with a clear understanding of the skills they need to develop and the types of tasks they will be expected to complete in a professional environment. Managers are entrusted with the responsibility of creating, editing, and updating these roadmaps. The roadmaps are designed to be comprehensive and offer a detailed description of each service, including the theoretical and practical aspects. This feature is essential to ensure that students can develop a strong foundation and practical skills, which they can use to solve real-world problems in their respective domains. Additionally, managers have complete autonomy to update the roadmaps regularly to keep pace with the dynamic nature of these domains, and incorporate the latest advancements, which are necessary to stay competitive in the industry.

4.2 System functions

Career Craft platform has four users with specific functions that are necessary for the platform to operate effectively. Following, the system functions are described.

4.2.1 Admin

The admin is responsible for the following tasks:

- Ensure the smooth flow of data and services.
- Manage users and responding to their requests.
- Backups, recovery and report generation.

4.2.2 Manager

The manager is in charge of the following:

- Receive client projects and publish them for students.
- Specify the number and specialty of positions required for clients' projects.
- Create, edit, or delete tasks, and rate the solution of tasks submitted by students (for non-automated graded tasks).
- Setup and manage meetings with students (rank upgrade and project meetings).
- Create, edit, or delete roadmaps for students.

4.2.3 Student

The student is the primary user of the platform with the most interaction. The platform provides students with the following capabilities:

- Solve tasks to upgrade their rank.
- Apply for client projects published by managers.
- Create or join teams.
- Read roadmaps published by managers.
- Manage profile (select an avatar, nickname, and main specialty: web developer, UI/UX designer, or web security).

4.2.4 Client

The client has the following features:

- Request software projects.
- View the progress of ongoing projects.
- Rate students who participated in project development.

4.3 Points and ranking system

The Fibonacci sequence (Fibonacci sequence, 2023) is a series of numbers in which each number is the sum of the two preceding numbers. It starts with 0 and 1, and then each subsequent number is the sum of the previous two. The sequence is: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, and so on.

The Fibonacci sequence is often used in various fields, including mathematics, computer science, and finance. One common use of the Fibonacci sequence is as a ranking system. The idea is to assign points to different levels or ranks based on the Fibonacci sequence. The higher the rank, the higher the points.

Following are some examples of games that have used the Fibonacci sequence as a ranking system:

- Bloons Tower Defense 4 (Bloons Tower Defense 4, 2023): in this tower defense game, the amount of money earned per pop is based on the Fibonacci sequence.
- Angry Birds Space (Angry Birds Space, 2023): in this game, the power-up system is based on the Fibonacci sequence.
- The Legend of Zelda: Skyward Sword (Nintendo, 2023): the number of collectible Gratitude Crystals required to earn various rewards is based on the Fibonacci sequence.
- Runescape (Runescape, 2023): this Massive Multiplayer Online Role-Playing Game (MMORPG) uses the Fibonacci sequence to calculate the experience points earned for certain skills.
- Final Fantasy (Final Fantasy, 2023): this popular role-playing game series uses the Fibonacci sequence to determine the strength of some of the game's monsters and bosses.

The ranking system utilized in this project is based on the Fibonacci sequence as well, and it starts from level 2 with the rank *F*. The mathematical equation shown in Equation (1) is used to calculate the points for each rank as follows:

$$y = \text{fibonacci(x)} \times 100 \qquad (1)$$

where x is the level of the rank.

The system has eight ranks from *F* to *S*, where *F* is the lowest rank and *S* is the highest. To reach a higher rank, a student must accumulate a certain number of points based on the Fibonacci sequence. The point ranges of ranks are as shown in Table. 1.

Rank	Start Point	End Point
F	0	100
E	101	200
D	201	300
C	301	500
B	501	800
A	801	1300
S	1301	2100

Table. 1. Point range of ranks

Students can upgrade their rank by clicking on the *Upgrade Rank* button once they have accumulated sufficient points for the next rank. However, to upgrade from rank *D* to *C*, students must first request an interview with a manager. The manager will then review the student's profile, assess his capabilities and make a decision accordingly.

In addition to rank-based points, tasks also have their own difficulty levels. There are three levels for task difficulty: Easy, Medium, and Hard. The minimum and maximum number of points for each difficulty level are shown in Table. 2.

Level	Minimum Points	Maximum Points
Easy	5	10
Medium	40	50
Hard	80	100

Table. 2. Task Difficulty Points

It is the responsibility of the manager to assign the difficulty of each task and specify number of points awarded to the students when correctly solving the task.

In conclusion, the ranking system is based on the Fibonacci sequence, which assigns point values to different ranks. The higher the rank, the higher the points. The system also includes task difficulty as well as stars.

5. Implementation and Results

Career Craft platform was developed using a number of powerful tools. JavaScript (JavaScript, 2022) was utilized to develop the front-end of the platform, and XAMPP (XAMPP, 2022) was used to create and test the web server. The database management system used was MySQL (MySQL, 2022). For improved user experience, Vue.js (Vue.js, 2022) was selected to design and build the user interfaces. Two frameworks were utilized: Visual Studio Code (Visual Studio Code, 2022) for frond-end development and Laravel (Laravel, 2022) for back-end development. For debugging, Xdebug (Xdebug, 2022) was used.

The implementation of the system involved several stages, including the development of the front-end and back-end architecture, the design and implementation of the Application Programing Interface (API), and the testing and deployment of the system. Throughout the implementation process, the focus was on building a scalable, secure, and user-friendly system that can meet the needs of intended users.

5.1 System architecture

The system architecture consists of a front-end built using the Vue.js JavaScript framework, a back-end built using the Laravel PHP framework, and an API that connects the two.

5.1.1 Front-end architecture

The front-end architecture is built using Vue.js framework, which provides a modular and scalable approach to building user interfaces. The Vue.js framework allows creating reusable components that can be easily integrated into the application, improving the overall maintainability of the system.

5.1.2 Back-end architecture

The back-end architecture is built using Laravel framework, which provides a robust and secure foundation for building web applications. Laravel provides a powerful set of features, including database migrations, authentication, and authorization, that make it easy to develop complex web applications.

The front-end components communicate with the back-end through the API. It provides a set of endpoints that return which returns data in JSON format. This data is then displayed in the user interface using Vue.js data binding and component rendering.

5.1.3 API architecture

The API architecture is designed to provide a secure and scalable interface for connecting the front-end and back-end. The API is built using Laravel's built-in RESTful API functionality. The API also includes authentication and authorization mechanisms to ensure that only authorized users can access sensitive data.

The system architecture for this web-based system is designed to provide a scalable and secure platform for building complex web applications. The Vue.js front-end, Laravel back-end, and JSON-based API provide a powerful combination of technologies that allow for the rapid development of complex web applications.

5.2 Development Process

The development process for the system utilized several tools, including XAMPP, VS Code, Firefox browser, and Postman.

The web server was set up using XAMPP, creating a local development environment to test the code and ensure its smooth running. XAMPP was used to create a MySQL database and Apache server to host the web application.

VS Code was used as the code editor to write and edit the code for the system. It was found to be a highly efficient and user-friendly tool for coding in HTML, CSS, and JavaScript. It was also used to integrate with Git to manage the source code and track changes.

Firefox was used as the web browser to test the functionality of the system, allowing the testing of the responsiveness of the web pages, as well as the overall look and feel of the user interface. Postman was used to test the functionality of the system by sending and receiving JSON format API requests. It was found to be a highly useful tool for testing the system's functionality and ensuring that it worked as expected.

Throughout the development process, best practices for coding were followed, including the use of version control and commenting on the code. Regular code reviews and testing were performed to ensure the quality of the system.

5.3 User interface

Following we display and explain client, admin, manager and student screens.

5.3.1 Client Screen

The client screens, shown in Figure .1, allows new clients to register and existing clients to access their account. It also enables clients to submit their project requirements, and to view the progress of their projects.

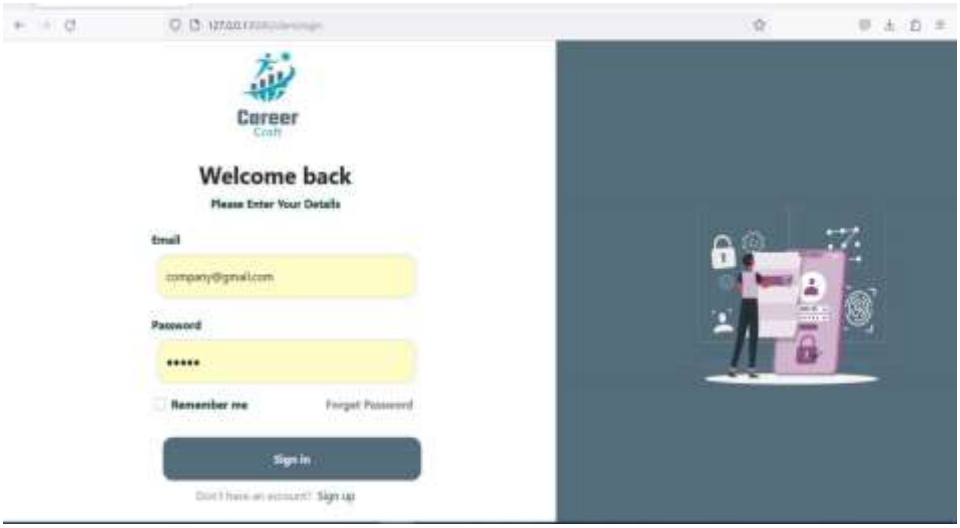

Figure. 1 Client Login Screen

5.3.2 Admin Screens

The Admin Dashboard comprises various screens, including the Admin Add Manager screen and the Manager List for Admin screen. The Admin Add Manager screen allows the admin to add new managers to the system, and the Manager List for Admin screen displays a list of all managers and their details, such as their names, email addresses. The Admin Dashboard screen is shown in Figure .2. helps the admin manage the system and managers efficiently.

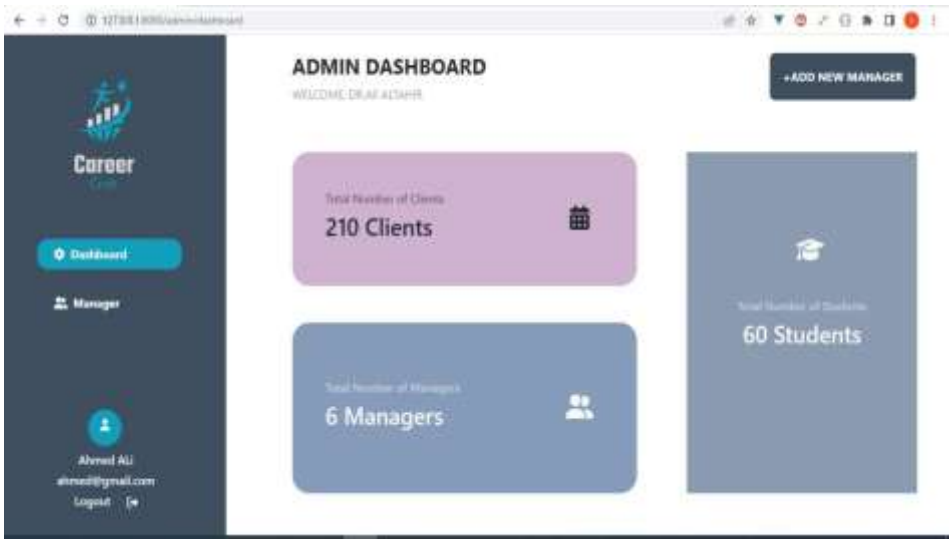

Figure .2 Admin Dashboard Screen

5.3.3 Manager Screens

The Manager Dashboard includes several screens that help managers effectively manage projects and teams, illustrated in Figure .3 throughout Figure .6. The Manager Project Request screen shown in Figure. 3 allows managers to view project requests and approve or reject them. The Manager Approved Projects screen illustrated in Figure. 4 displays a list of approved projects along with their status. The Manager Teams Selection screen enables managers to select team members for projects. The Task Management screen shown in Figure. 5 allows managers to manage tasks. The Manager Rank Interview screen helps managers evaluate candidates and rank them. The Manager Roadmaps Management screen assists managers in creating and managing roadmaps. Finally, the Manager Submitted Tasks screen shown in Figure. 6 displays all completed tasks and allows managers to review them.

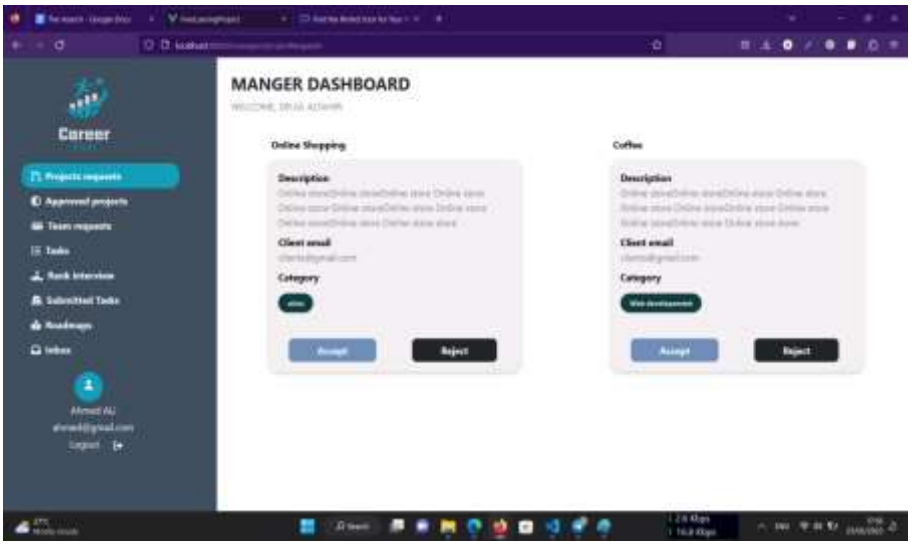

Figure .3 Project Request Screen

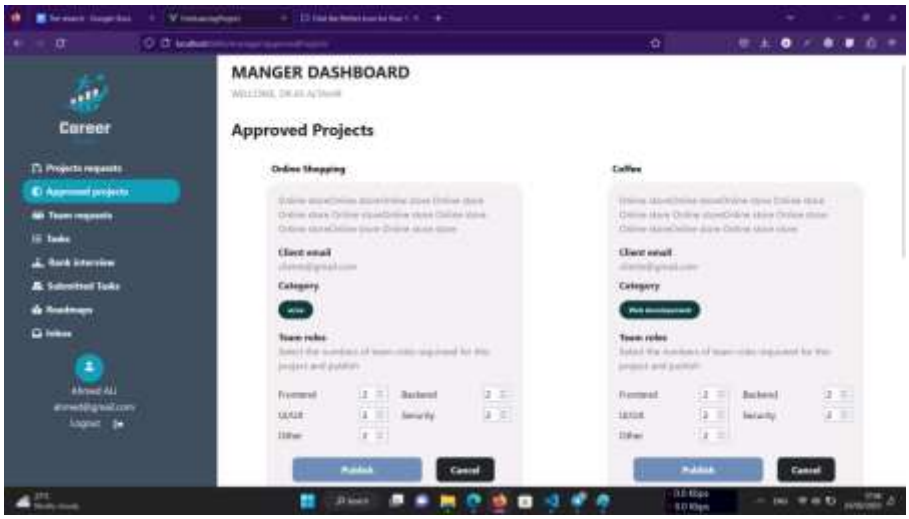

Figure .4 Approved Projects Screen

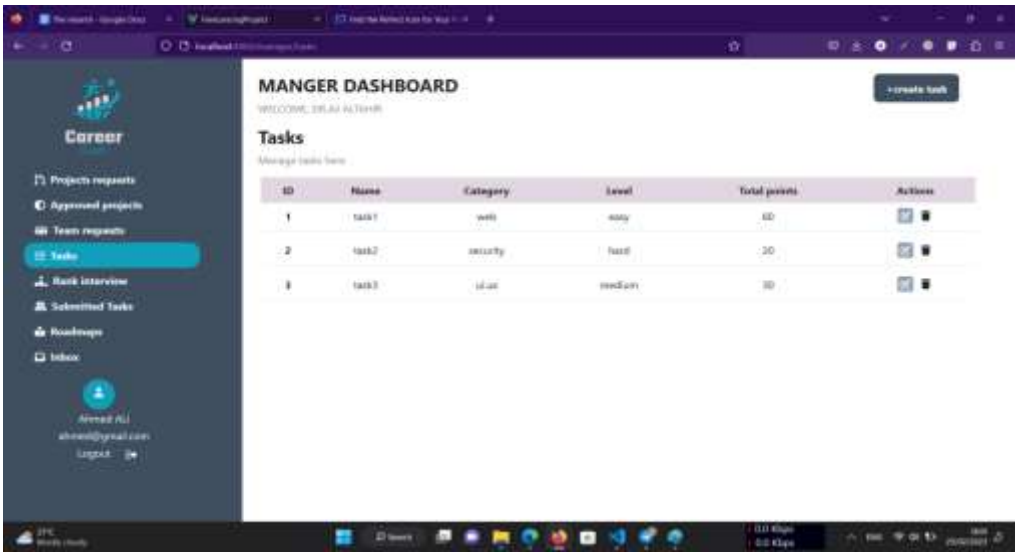

Figure .5 Task Management Screen

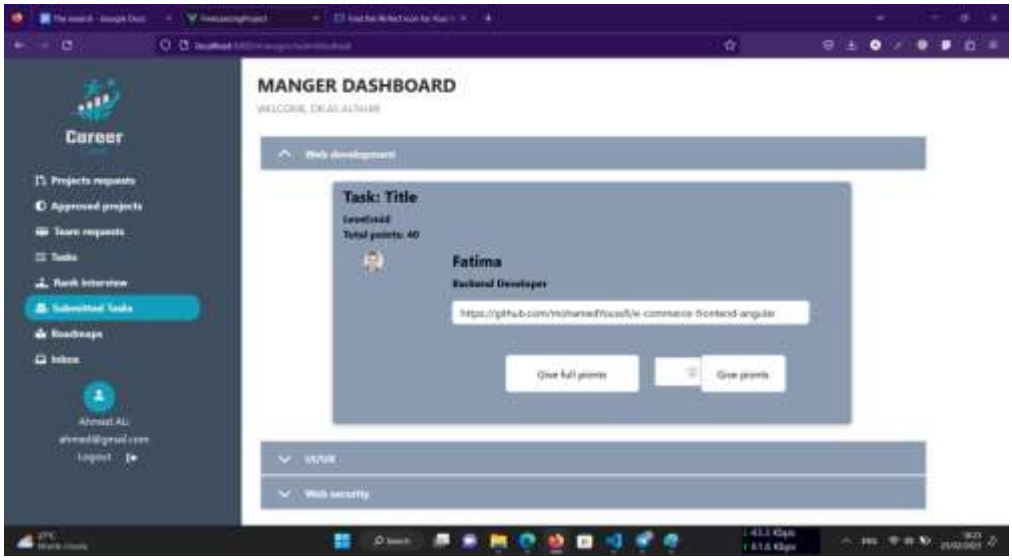

Figure .6 Submitted Tasks Screen

5.3.4 Student Screens

The Student screens shown in Figure .7 throughout Figure .10 include a Select Role and Nickname screen where students can choose their role and create a nickname. They can then select an avatar to represent themselves on the platform as can be seen in Figure. 7. The Student Profile Overview screen shown in Figure. 8 displays their progress, such as the number of Magic Cubes earned and the number of completed Platform Quests and Real Quests. The Student Platform Task screen illustrated in Figure. 9 shows the tasks published by the manager, while the Student Clients Project screen displays the approved projects of the client published by the manager.

The Student Roadmaps screen allows students to view roadmaps published by the manager or the client. Students can also receive notifications on the notification screen as Figure. 10 shows.

Figure .7 Avatar Selection Screen

Note that the term Quest here means Task while Magic Cubes mean the points. Platform Quests refer to the tasks created and published by managers whereas Real Quests imply approved projects of clients published by the project manager.

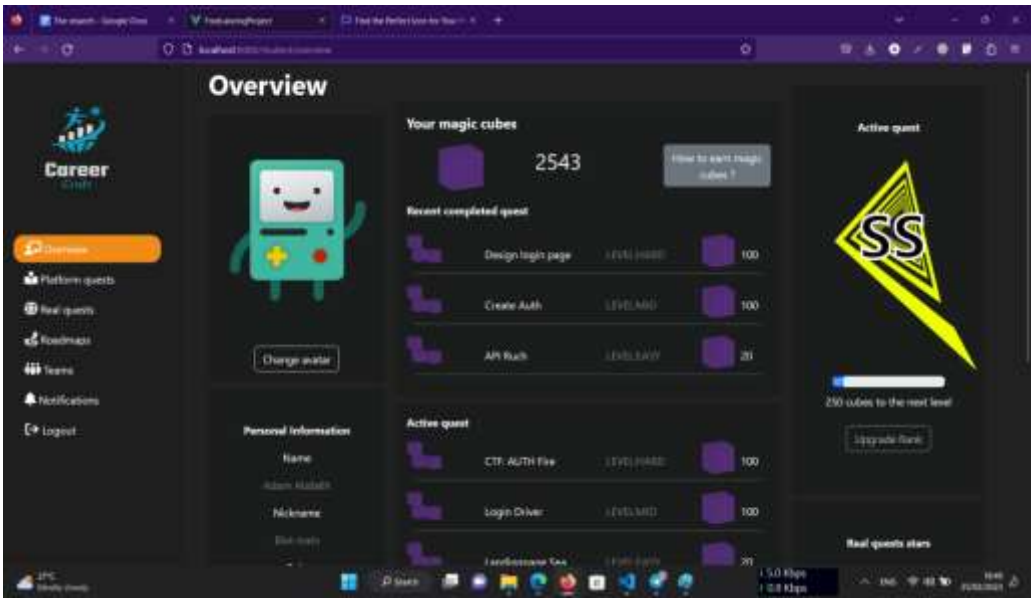

Figure .8 Student Overview Screen

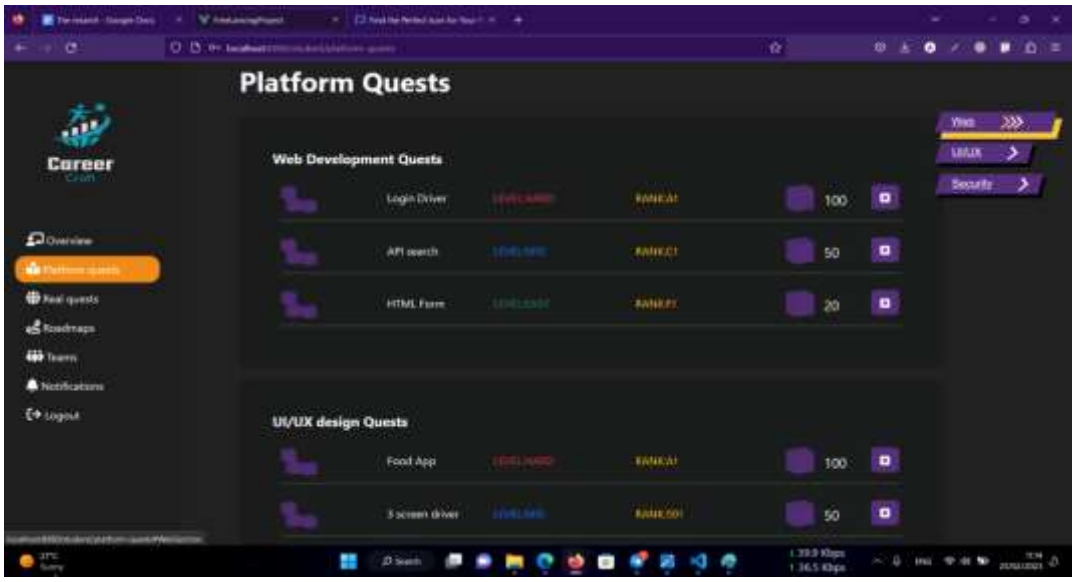

Figure .9 Student Platform Task Screen

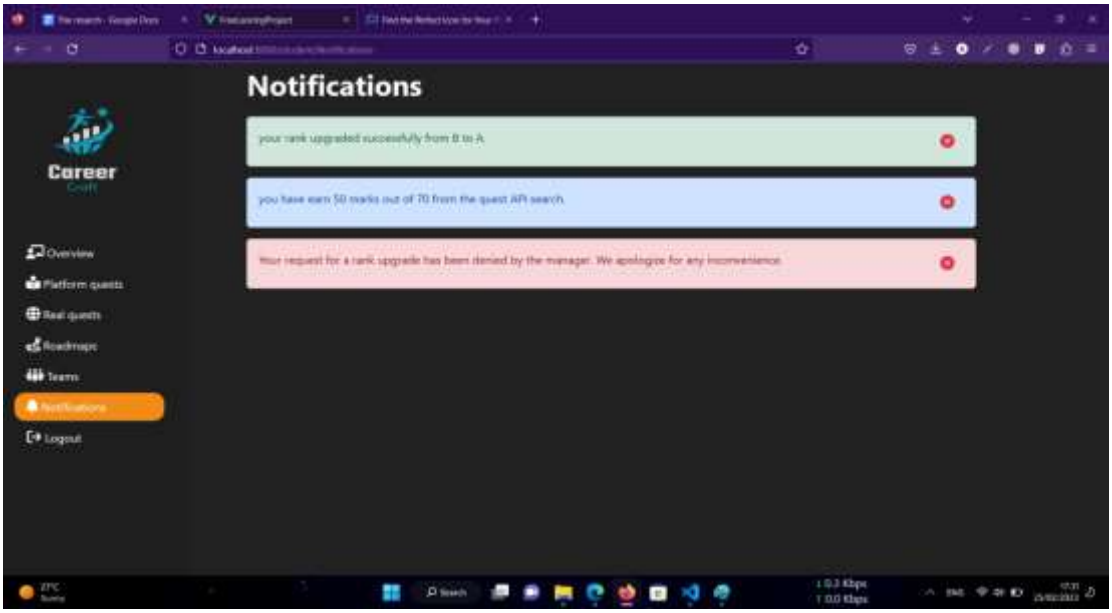

Figure .10 Student Notifications Screen

5.4 Testing

To ensure the quality and reliability of the system, a comprehensive testing process was employed, including unit testing, integration testing, and user testing. Unit testing involved testing each individual unit or component of the system in isolation. This helped to identify and fix any defects or issues with each component before they were integrated into the larger system. A variety of testing frameworks and tools, such as Jest and Enzyme, were used to automate the process of unit testing.

Integration testing was performed to verify that the individual components of the system worked together as expected. This involved testing the interaction between different components and ensuring that they integrated seamlessly with each other. Tools such as Selenium and Cucumber were used to automate integration testing.

User testing was conducted to ensure that the system met the needs and expectations of targeted users. A series of user testing scenarios were designed and executed, based on real-world scenarios, to ensure that the system was both functional and user-friendly. Feedback from users was gathered and used to refine and improve the system.

6. Conclusions

Providing students with practical training and hands-on experience in the field of web development, design and web security is essential for their success in the workforce and for meeting the demands of the job market. A platform that provides students with opportunities for experiential learning is an important step towards bridging the gap between the skills that students learn in the classroom and the practical skills that are required in the workplace. This paper has presented the design and implementation of Career Craft, a software platform that aims at training Information Technology students in programming to improve their problem-solving skills and exposing them to the real-world market environment. Implementing and using the platform encourages students to spend extra time on programming by motivating competition among them and enrich their experience preparing them for programming jobs in the future. Furthermore, it enhances the reputation of the academic institution and generates financial benefits through the successful completion of client projects.

7. Recommendations

To further improve the platform, we plan to design messaging features to allow communication between students, managers, and other stakeholders. This will help create a sense of community among the students, as well as provide them with a platform to communicate and collaborate with their peers and managers. In addition, we also plan to create tournaments that set challenges for a limited time to increase competition among students.

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