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OMAINTEC JOURNAL OBJECTIVES

The magazine aims to be a distinctive platform through:

- Creating common ground of discussion among researchers, academics and Arab specialists in the operation and maintenance, facilities management and asset management sectors.
- Encouraging research in the operation and maintenance, facilities management and asset management sectors, and proper management of properties. The magazine will conduct research, scientific reviews or technical studies on the following topics in these sectors:

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Asset Management

facilities Management

Transformation for Asset Management

Strategy planning in facilities & asset management

Operations and Maintenace Standards

Maintenance Performance Indicators

Total cost of ownership

Environment Management Systems

Safety Management Systems

Energy Management

Health and safety polices

KPI Methodologies And definition

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SMART BUILDING MANAGEMENT SYSTEMS FOR MANAGING WORKPLACE AND SUSTAINABILITY

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November 2022

Abstract

The Covid epidemic and the economic crisis around the world the last 2 years have shifted sustainability and workplace optimisation from long-term goals to urgent, short-term priorities. In relation to sustainability and according to the Global Alliance for Buildings & Construction, 2020 the building sector represents 35% Of the World Energy Consumption 38% Of the World CO2 emissions. In relation to workplace management organizations are now focusing on innovative and smart workplace strategies to improve the wellbeing and productivity of their employees while using space in a cost-effective and sustainable way.

The performance of our buildings and the productivity of the users depend on our ability to optimise the workspace and built environment based on real sustainability data. It is therefore important to understand that the way we manage and maintain our buildings plays an enormous part in achieving the wellbeing of our people and a net-zero future.

Until recently the available maintenance management system tools have not been available for us to collect, analyse, visualise and act on energy and workplace related data that truly allows facility and building managers to optimise sustainability, productivity, resilience and risk. This has now changed and in the last few years we have seen emerging, state of the art integrated facility and maintenance workplace software platforms which allow us to manage and transformation of our buildings into smart buildings.

This paper covers how traditional facility, asset and maintenance management systems have evolved into intelligent systems, transforming buildings and assets into smart and sustainable entities. These smart facility and maintenance management platforms are integrating and connecting buildings, people and processes, by eliminating data silos and aligning solutions into one shared information platform. They empower all building and asset stakeholders with actionable and meaningful insights towards a sustainable and clean future.

Such systems have initiated from Computerized Management Maintenance Systems (CMMS) and Computer Aided Facility Management (CAFM) systems evolving into Integrated Workplace Management Systems (IWMS) that incorporate multiple disciplines, technologies and data into a single universal platform. They combine property, space, asset, maintenance and energy management functionality under one platform, with data driven decision support system for making intelligence and energy conservation decisions.

Key Words

Sustainability, Facility Management (FM), Workplace, Asset Management, Smart Building, Space Management, Energy Management, Digital Transformation, Artificial intelligence, BI, IoT, BIM, CMMS, CAFM, iWMS, BMS, Digital Twins

Audience

The paper will be useful to persons involved in managing facilities, buildings, space, assets, energy, people and ESG strategies from different departments within an organization. It provides facility and asset maintenance operations and their management teams with a clear understanding of what are the current workplace management systems and technologies in the market. It also explains on how these emerging technologies, related functionality and data can manage sustainability efforts and their workplace environment. The paper provides organizations stakeholders with the understanding on how these new tools will help them efficiently implement, monitor and meet their ESG strategy and objectives.

Executives from all departments of an organization will be able to understand how achieving sustainability goals and wellbeing of their people is tightly related on how we manage maintenance, facilities, buildings, assets, space and occupants. Professionals from all organization departments will benefit including, facility and maintenance management, engineering, construction, finance, HRM and IT.

Introduction

The evolution of Technology is driven by business needs and the need to manage sustainability efforts and objectives and wellbeing of our people is no exception. So far the business driving for application software technology in relation to facility and assets maintenance were automation, productivity and cost effectiveness. Facility, maintenance and real estate management are now faced with new complexities. Situations like the Covid era has once more reminded us of the importance of managing space and hygiene. The business drivers are therefore shifting focus to providing a better place for people to work and leave and the need of energy management, CO2 reduction and general sustainability. Maintenance, workplace and data driven Management systems have emerged that allow organization to manage these objectives.

Many organisations lack good data to gain transparency and insights for optimisations and decision-making. Data is often spread across many sources like spreadsheets, documents, or isolated software products. So far different systems in the market covered the role of individual such needs, each with its own data silos. These separate systems have created incompatibilities, unreliable and uncertain results and heavy software maintenance costs.

Corporate FM and real estate managers are requiring an in-depth understanding of their company's maintenance data and how these related to sustainable transformation. There is demand for reliable and integrated information systems for operational data about their buildings, spaces and usage in relation to maintenance and their environment. They would like to monitor how changes in occupancy in combination of asset performance effect the suitability of a building and how this information can be analysed and converted to knowledge and decision making.

This created the need towards tightly integrated and automated systems combining property, space, asset, maintenance and energy information management data under one platform. The result is what we call today Integrated Workplace Management Systems (IWMS). IWMS systems, apart from eliminating multiple data silos converging them into a single data platform, they provide technologies which allows the automation and performance monitoring of our buildings transforming them into smart buildings.

A smart building is one that uses technology to enable efficient and economical use of resources, while creating a safe and comfortable environment for occupants. Internet of Things (IoT) sensors, energy meters, Building Management Systems (BMS), decision support systems and artificial intelligence (AI) are amongst some of the technologies that are used to transform a building into a smart building to control and optimize its performance. IWMS systems provide the infrastructure and technology to integrate to all these sensors, energy meters and actuators, gathering activity data on various aspects within the building so it can be analysed and utilised to find out which operations can run more efficiently.

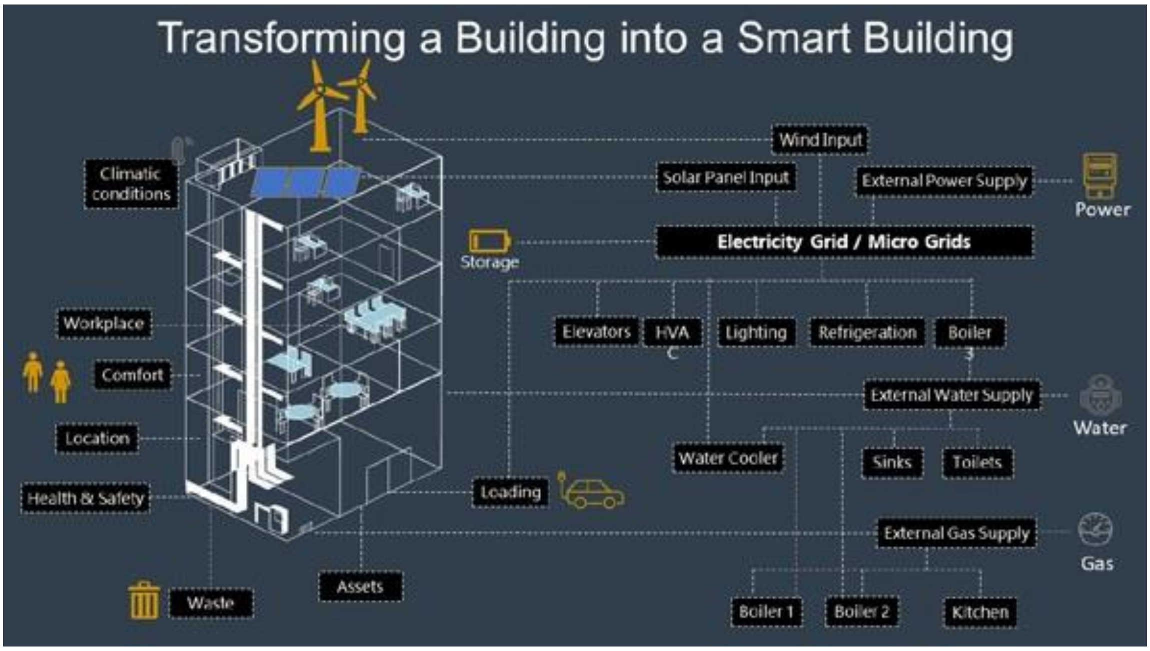

Diagram 1: Energy and Workplace data that can be collected from Smart Buildings using iWMS

An IWMS will provide a tight integration of data silos combining properties, space, asset, maintenance and energy related information. The information connectivity will be supported by various IoT sensors, energy meters and BMS systems connecting areas and assets to the IWMS platform converting your buildings into smart buildings. IoT sensors will be able in real time to measure occupancy, noise level, temperature, humidity, carbon dioxide, equipment data, energy data, meter readings and equipment status

IWMS using these data collected will be able to manage

a) Setting your Environmental Social and Governance (ESG) objectives

b) Collecting and measuring the information

c) Analyze the information stored and produce insight information related to trends, progress and issues.

d) Use the dashboards and reports to identify improvement, run audits and adjust the scope of the corrective actions and projects

e) View and compare compliance against organization, international and national regulations

The performance of our buildings and the productivity of the users depend on our ability to optimise the workspace and built environment based on real sustainability data using IWMS. Combining the integrated property, space, asset, maintenance and energy data with 'business processes' in an integrated software (IWMS) solution is a key precondition to continuously identify and execute cost efficiency and quality improvement initiatives in any facility and real estate management organisation.

How are IWMS systems used to manage Sustainability

Integrated Workplace Management systems (IWMS) allow you to create an eco structure where all data can provide a value into meeting your sustainability and general your ESG strategy objectives. IWMS systems combine all the possible property, space, maintenance and energy data under a big data integrated platform, with the ability to collect data using IoT sensors, meters and intelligence BMS systems. The way they work to accomplish this is by collecting huge data from all sources, cleansing the data so that it can focus on valuable information, grouping the results into specific data silos of information and converting them to knowledge.

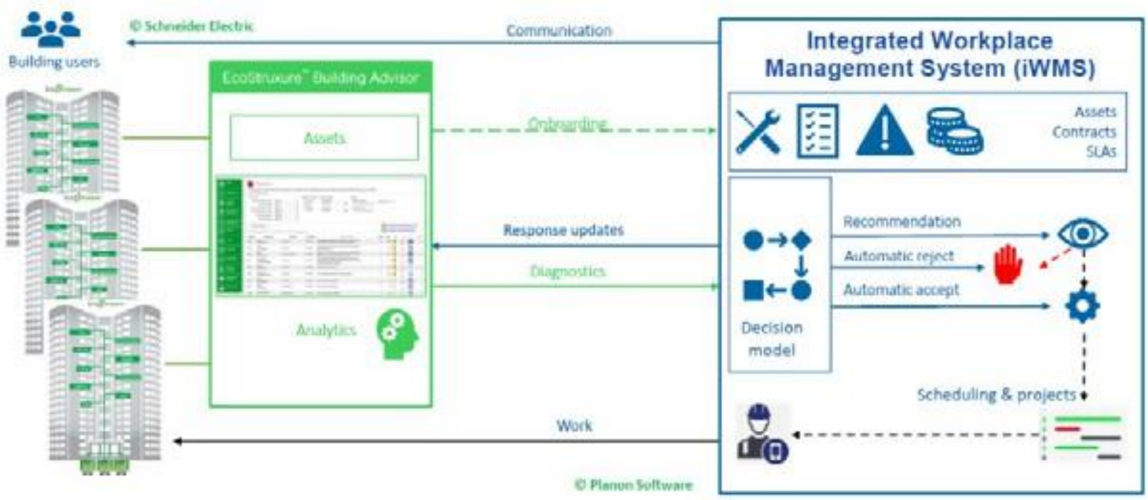

Diagram 2: IWMS Smart Buildings data flow diagram

As shown in the above diagram an IWMS solutions captures detailed diagnostic data from building equipment and indoor conditions, and converts this information into knowledge through data-enabled workflows. For example, real-time alerts on Chiller faults are automatically transferred into the IWMS platform. The IWMS solutions can automatically trigger workflows that direct interventions such as adjusting maintenance priorities. This knowledge related data is taken into the IWMS decision support system subsystem where Artificial Intelligence (AI) algorithms coupled with other best practices data are evaluated and suggestions are either provided and specific actions to rectify issues are taken. Exceptions (not known cases) are routed to Help Desk systems where maintenance tickets are created with specific instructions to technicians to carry out inspection and provide feedback.

This lifecycle of events continues until the best method is identified and applied. The system learns from these cases which helps it next time to make better decisions and the cycle continuous.

The information collected and the performance derived from this information from smart buildings are used for matching long-term sustainability goals with actions, monitoring progress, and providing data to prove compliance (and in many cases going above and beyond compliance) with regulations.

The diagram below outlines how the energy management functionality of an IWMS manages sustainability and monitors an organization's ESG strategy. This allow users to obtain an insight into the performance of our assets and report on energy consumption and CO2 emissions, realizing your Environmental Social and Governance (ESG) ambitions in the built environment, and prove footprint reduction.

Diagram 3: IWMS Enterprise Sustainability Management workflow

The process starts from your ESG strategy specific objectives. The derived ESG objectives in relation to energy conservation and CO2 emissions reduction are entered into the IWMS system. The Energy Management Subsystem (ESM) of the IWMS collects information and transforms them into knowledge as shown in diagram 2. This information is monitored and compared to the set ESG objectives.

The overall IWMS enterprise sustainability management submodule provides detailed dashboards and reports to identify progress and compliance as shown in diagram 4 below.

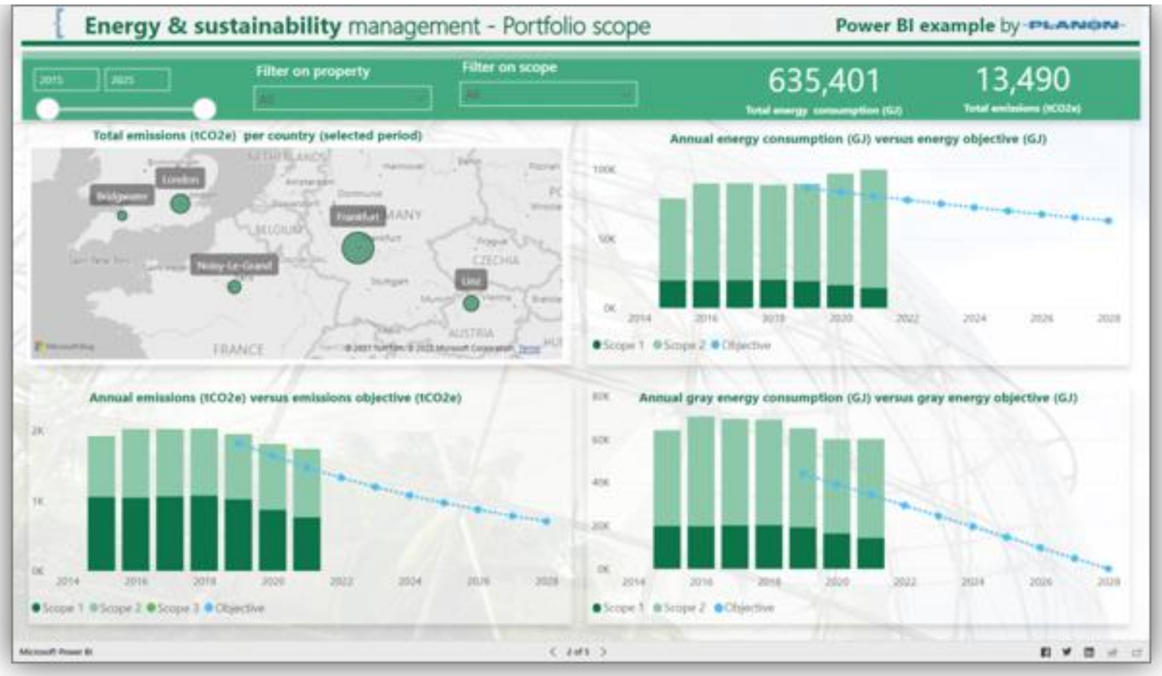

Diagram 4: IWMS Energy Management KPIs and Dashboards

A successful IWMS strategy connects workers and assets using the IoT and generates the data needed to optimise the workspace from a total life cycle perspective: energy efficiency, maintenance management, renewable energy integration and optimisation of other building technologies. Analytics tools and algorithms are used by the IWMS to further analyse results. From the derived results specific recommendations are provided to improve further the ESG objectives. Additional monitoring suggestions are also provided enhancing the data required to produced knowledge data.

Benefits of integrated Workplace Management Solutions

IWMS provides real-time data reporting for individual buildings and for whole property portfolios. This can mean high-level insights and dashboards for accounting and reporting, and in-depth analysis at an asset level to support on-the-ground decisions and provide the tools to execute on them

There are a number of benefits that Integrated Workplace Management Systems provide to an organization. These include:

• Meeting your ESG Objectives. Being able to set, monitor and improve your Environmental, Social and Governance strategy and objective.

• Providing a better environment for your people. Ensure the wellbeing and productivity of an organization employees while using space in a cost-effective and sustainable way

• Improved data quality. An IWMS replaces standalone solutions with a single system, becoming 'the single source of truth'. This improves data quality control and consistency. The IWMS can be integrated with other applications in your IT landscape to eliminate redundancy and differences.

• Lower IT support costs. An IWMS simplifies an organizations IT infrastructure because it eliminates standalone or legacy systems and makes sure the same version is used across the organisation. Therefore, application managers have fewer systems to maintain and can update and upgrade the software centrally. It makes their work easier, more effective and more productive.

• Process standardisation. With the use of pre-configured workflows based on best practices you can standardise processes, moving away from situations where multiple solutions and applications rule. It ensures continuous alignment and improved communication between business domains during the entire lifetime of the software.

• Better decision making. An IWMS offers you an integrated view and therefore a more complete understanding of your real estate and workplace portfolio. It combines information about the real estate portfolio, spaces, assets, maintenance and services activities, and so on. This not only helps you to react faster, but also to plan ahead.

All this adds up to mean that the financial benefits of IWMS include direct and indirect cost savings, capital cost avoidance, and opportunities to increase both revenues and returns on property investments. It also enhances the governance of the organisation by providing transparent data to investors, staff, customers, suppliers, regulators and any other stakeholders

Conclusion

Digitation has become a necessity to manage everything and the wellbeing of our people and sustainability is no exception. Integrated Workplace Management Systems combine property, space, asset, maintenance and energy management functionality under one platform, with data driven decision support system for making intelligence and energy conservation decisions.

The performance of our buildings and the productivity of the users depend on our ability to optimise the workspace and built environment based on real sustainability data using IWMS. Combining the integrated property, space, asset, maintenance and energy data with 'business processes' under an integrated software (IWMS) solution is a key precondition to continuously identify and execute cost efficiency and quality improvement initiatives in any facility and real estate management organisation.

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The Role of Nano Size Additives in Enhancing the Sustainability of Asphalt Concrete

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Abstract

Asphalt concrete pavement practices repeated flexural stresses caused by vehicular traffic throughout its service life. The resistance to such stresses could be enhanced by incorporation of Nano size additives for partial replacement of mineral filler. In the present investigation, an attempt has been made to introduce fly ash and Silica fumes into asphalt concrete mixture as partial substitute of mineral filler. Asphalt concrete slab samples were compacted in the laboratory at optimum binder content of 4.9 % using roller compaction. The optimum percentages of fly ash and Silica fumes are (4 and 2) % by weight of binder respectively. Beam specimens were extracted from the slab samples and subjected to dynamic flexural stresses with the aid of four points bending beam test under three constant microstrain levels of (250, 400, and 750). The change in the resistance of the mixtures to repeated flexural stresses was monitored through the elapsed time required for initiation of micro cracks. After 3 seconds of repeated loading, the flexural strength of the control asphalt concrete mixture was (450, 150, and 80) kPa under (750, 400, and 250) microstrain levels respectively. On the other hand, the flexural strength of asphalt concrete mixture treated with silica fumes was (720, 200, and 90) kPa under (750, 400, and 250) microstrain levels respectively. However, the flexural strength of asphalt concrete mixture treated with fly ash was (180, 110, and 75) kPa under (750, 400, and 250) microstrain levels respectively. It was concluded that implementation of silica fumes exhibit significant enhansement of high flexural strength as compared with the control or fly ash treated mixtures. Such Nano size additive is recommended to enhanse the sustainability of asphalt concrete.

Key Words

Nano Additives, Silica Fumes, Fly ash, Flexural Strength, Microstrain, Elapsed Time, Asphalt Concrete.

Introduction

Kakar et al. 2019 demonstrated the significance of additive to improve the asphalt binder adhesion properties with aggregate. The addition of different fillers such as hydrated lime, fly ash, silica fume, cement, and bag-house fines are known to increase the rut resistance of asphalt mixture as stated by Bahia et al., 2001. Jie et al. 2017 addressed that the incorporation of additives can enhance the adhesion properties of the asphalt-aggregate interface. Sarsam, 2022 revealed that implementation of micro size additive (coal fly ash) exhibits longer fatigue life of asphalt concrete regardless of the microstrain level practiced by the mixture. However, asphalt concrete mixture treated with nano size additive (silica fumes) exhibits higher flexural stiffness of asphalt concrete regardless of the microstrain level practiced by the mixture. Al-Mohammedawi and Mollenhauer, 2020 identified the influence of active fillers such as limestone, cement, ladle slag, and silica fume on the rheological properties and the resulting fatigue behavior of cold bitumen emulsion mastic. The assessment was supported by chemical analysis for the filler-bitumen emulsion. Bitumen emulsion was mixed separately with the fillers to prepare the mastics. Results show that the rheological performance and the fatigue damage resistance depend not only on the filler inclusions but also on filler type and chemistry. The viscoelastic properties of geopolymer grouting material with different content of silica fumes and fly ash are studied by Li et al., 2022. It was observed that the fly ash significantly increases the shear stress while the silica fumes reduce the shear stress. It was concluded that such additives exhibit higher chemical adhesion and specific surface area, respectively. Sarsam and Mashaan, 2022 reported that the fatigue life of asphalt concrete after incorporation of additives was monitored as under three constant micro strain levels of (250, 400, and 750). It was concluded that Fly ash exhibit lower susceptibility to long-term ageing process as compared to other mixtures, while silica fumes exhibit lower susceptibility to moisture damage as compared to other mixtures. Khan et al., 2020 investigated the effects of different fillers on some properties of asphalt concrete mixtures. Two filler types, silica fumes and marble dust were used to investigate the effect of filler/asphalt ratio on the characteristics of asphalt mixtures. It was concluded that the mixtures with 50% silica fume and 50% marble dust have greater stability than all the other percentages used in a Marshall mix. All other percentages of filler have lower stability and voids which are out of range. Mixture having 50% silica & 50% marble dust has only 13.5 mm flow value which is greater than all other percentages. Khodary, 2016 assessed the effect of silica fumes on the properties of asphalt concrete which was used for base course. Structure and morphology of the Silica fume were investigated by a series of laboratory experiments. Specimens with different modification levels of silica fume (2, 4, 6, 8 and 10) % by weight were tried. The test result revealed that adding silica fumes can improve both stability and strength. The addition of mineral fillers can significantly change the fatigue damage resistance and the rheological response of the mastic as reported by Lesueur et al., 2016. Underwood and Kim, 2011 reported that fillers strengthen the binder through the three main mechanisms of chemical interaction, particle geometry, and volume filling. The volume filling and particle geometry are considered as mechanical reinforcement, while volume filling is caused by adding more solid particles to the system, resulting in high stiffness. Onyelowe et al., 2020 investigated the influence of using fly ash as a modifier to enhance the mechanical properties of Asphalt for a sustainable pavement construction. The Marshall Stability behavior of the hot mix asphalt when mixed with fly ash was assessed. The results showed that the addition of fly ash of 15% by weight in the asphalt mixture was observed to have increased the stability by 3.7 %. It was concluded that incorporating fly ash in the asphalt concrete mixture had improved the rheological and performance characteristics while reducing cost and unfavorable environmental impacts. Buczy et al., 2017 stated that mineral fillers can be chemically grouped into active and inactive fillers, depending on their reactivity within bitumen emulsion. Limestone, which is considered as inert filler, is classified as inactive fillers because of the mineral composition and is usually employed as a stiffness regulator by adding solid particles to the binder matrix. As little or no chemical reaction is expected, it maintains the viscoelastic response. The aim of the present work is to assess the role of Nano Size Additives in enhancing the sustainability of asphalt concrete in terms of flexural strength. Silica fumes and fly ash will be implemented as partial substitute of filler in the asphalt concrete mixture. Specimens will be prepared at optimum binder and tested under dynamic flexural stresses. The change in the flexural strength will be monitored and compared.

Materials and Methods

The materials implemented in this work are locally available and usually used for asphalt pavement construction.

Asphalt Cement

Asphalt cement of penetration grad 40-50 was assessed in this work. It was obtained from AL-Nasiriya Refinery. Table 1 presents the physical properties of asphalt binder..

Table 1. Physical properties of asphalt cement

Property	Testing condition	ASTM, 2015 Designation No.	Value	SCRB, 2003 Specifications
Penetration	25°C, 100 gm 5 sec	D5-06	42	40-50
Softening Point	(ring &ball)	D36-895	49	-
Ductility	25°C,5cm/mi	D113-99	100 +	>100
Specific Gravity	25˚C	D70	1.04	-
After thin film oven test properties D1754-97				
Penetration	25°C, 100gm, 5 sec	D5-06	33	-
Ductility of Residue	25°C,5cm/mi	D113-99	83	-

Fine and Coarse Aggregates

Crushed coarse aggregateswith a nominal maximum size of 19 mmand retained on sieve No. 4 was obtained from AL-Ukhaider quarry. The fine aggregates consist of crushed and natural sand mixture (passing sieve No.4 and retained on sieve No.200). It was obtained from the same source. The aggregates were washed, and then air dried and separated into different sizes by sieving. Table 2 present the physical properties of aggregates.

Table 2. Physical Properties of Coarse and Fine Aggregate

Property	Value	ASTM, 2015, Designation No.
Coarse Aggregate		
Bulk specific gravity	2.542	C127-01
Water absorption %	1.076%	C127-01
Wear % (lose Angeles's abrasion)	18%	C131-03
Fine Aggregate		
Bulk specific gravity	2.558	C128-01
Water absorption %	1.83%	C128-01

Mineral Filler

Limestone dust is implemented as mineral filler in the present investigation. It was obtained from Karbala governorate. The filler passes sieve No.200 (0.075mm). Table 3 present the physical properties of the mineral filler.

Table 3. Physical Properties of Mineral Filler (Limestone dust).

Bulk specific gravity	% Passing Sieve No.200
2.617	94

Fly Ash

Fly ash of class F was obtained from local market. Table 4 present the physical properties of fly ash, while the chemical composition of Fly Ash is listed in Table 5.

Table 4. Physical Properties of Fly Ash

Maximum Sieve size (micron)	% passing	Specific gravity	Specific surface area (m^2/kg)
0.075	98	2.645	650

Table 5. Chemical Composition of Fly Ash

Chemical composition	Percent	ASTM C-618, 2015 Requirement (%)
SiO_2	61.95	……….
Fe_2O_3	2.67	………...
Al_2O_3	28.82	…………
CaO	0.88	………….
MgO	0.34	5.0 max
Na_2O	0.26	1.5 max
Loss on ignition	0.86	6.0 max

Silica Fumes

Silica fumes were obtained from local market as a fluffy powder, Table 6 presents its physical properties, while Table 7 shows the chemical composition of the Silica fumes.

Table 6. Physical Properties of Silica Fumes

Maximum sieve size	PH value	Density (kg/m^3)	Specific surface area (m^2/kg)
Passing sieve (0.075 mm)	4.5	2.6455	200000

Table 7. Chemical Components of Silica Fumes

Chemical Composition	Percent
SiO2	99.1
Fe2O3	35.0 P.P.M
Al2O3	<o.o35
TiO2	<0.006
CaO2	0.03
MgO	52.0 P.P.M
SO3	<0.07
Loss on ignition	0.7

Selection of Aggregate Gradation for Asphalt Concrete

The selected aggregates gradation in the present investigation follows SCRB, 2003 specification for dense graded wearing course pavement layer. It has 12.5 mm nominal maximum size of aggregates. Table 8 shows the selected aggregate gradation.

Table 8. Gradation of Aggregate for Wearing Course as per SCRB, 2003

Sieve size (mm)	19	12.5	9.5	4.75	2.36	0.3	0.75
Selected gradation	100	95	83	59	43	13	7
SCRB, 2003 Specification limits	100	90-100	76-90	44-74	28-58	5-12	4-10

Preparation of Modified Asphalt Cement

Modified asphalt cement binder is prepared by using the wet process. In the wet process, asphalt cement was heated to 150°C and then the fly ash or silica fumes were added in powder form using various percentages of each additive. The mixture was blended in a mixer at a blending speed of about 1300 rpm and the mixing temperatures of 160°C was maintained for 20 minutes to promote the chemical and physical bonding of the components. The optimum percentages of fly ash and Silica fumes are (4 and 2) % by weight of binder respectively. Details of the mixing procedure and selection of the optimum percentages could be found in Sarsam and Al-Lamy, 2015.

Preparation of Asphalt Concrete Mixture and Specimens

The fine and coarse aggregates were combined with mineral filler to meet the specified gradation for wearing course. The combined aggregates were then heated to 160ºC before mixing with asphalt cement. The asphalt cement or the modified asphalt binder was heated to 150ºC to produce a kinematic viscosity of (170±20) centistokes as recommended by SCRB, 2003. Then, the binder was added to the heated aggregate to achieve the desired amount and mixed thoroughly by hand using a spatula for two minutes until all aggregate particles were coated with thin film of the asphalt binder. The optimum asphalt content of 4.9% was implemented. The optimum binder percentage was determined based on Marshall Trial mixes using various asphalt percentages. Details of obtaining the optimum binder content could be found in Sarsam and Al-Lamy, 2016. The asphalt concrete mixtures were casted in a slab mold of (400 × 300 × 60) mm and subjected to roller compaction to the target bulk density for each binder type according to EN12697-33, 2007. The applied static load was 5 kN while the number of load passes depended on the asphalt type in mixture and was determined based on trial-and-error process. Details of the compaction process could be referred to Sarsam, 2005. The compaction temperature was maintained to 150°C. Slab samples were left to cool overnight. Beam specimens of 50±2 mm high, 63±2 mm wide and 400 mm length were obtained from the compacted slab sample using the diamond-saw. The total number of beam specimens obtained was twelve, while the number of casted slabs was three.

Repeated Flexural Bending Beam Test

The four-point repeated flexural bending beam test according to AASHTO T321, 2010 was implemented to identify the influence of additives on the fatigue life of asphalt concrete beam specimens at intermediate pavement operating temperature of 20°C and under three types of constant strain level, (250, 400, and 750) microstrain. The various microstrain levels were tried to simulate various modes of loading in the field. During the flexural fatigue test, the beam is subjected to repeated four-point loading. The load frequency is usually set to 5 Hz. A repeated haversine (sinusoidal) load is applied to the two inner clamps on the beam specimen with the outer clamps providing a reaction load. This setup produces a constant bending moment over the center portion of the beam (between the two inside clamps). Beams were subjected to a repeated flexural bending load. Figure 1 demonstrates the four-point flexural bending test setup.

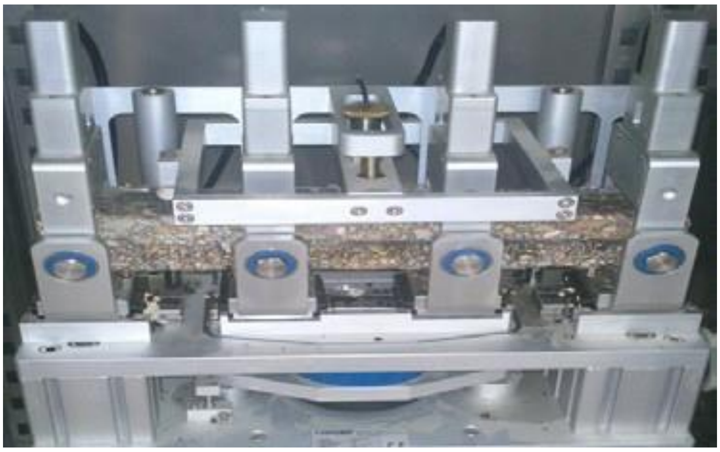

Figure 1. Four points flexural bending test setup.

Results and Discussion

Influence of Microstrain Level on the Flexural Strength

Figure 2 demonstrates the variation in the flexural strength of asphalt concrete beam specimens at the early stages of practicing the repeated flexural stresses. The resistance of the mixture to the applied stresses increases sharply after one second and reaches its peak values, then decline as the loading proceeds.

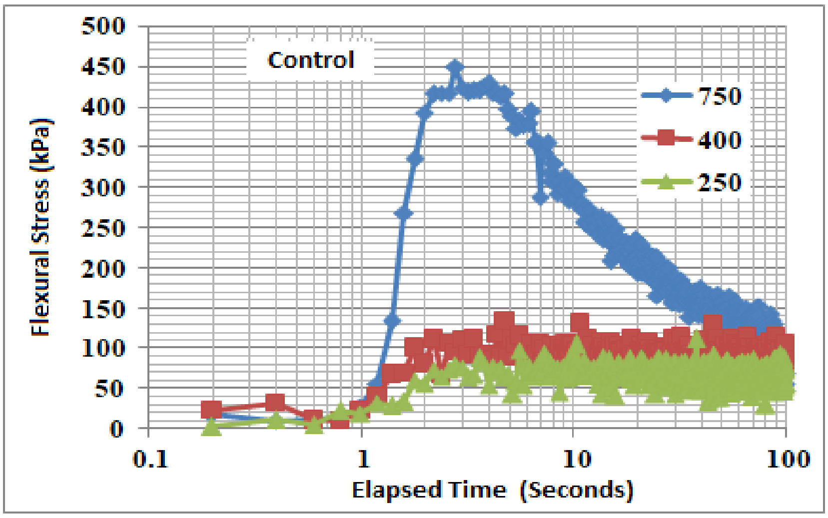

Figure 2. Variation of flexural strength under various microstrain levels of control mixture

This could be attributed to the initiation of micro cracks after reaching and exceeding the endurance capacity of the mixture to resist the stresses. Higher resistance to the flexural stresses could be noticed at higher microstrain level of 750. However, the variation in the flexural strength is limited after 100 seconds as demonstrated in the Figure. After 3 seconds of repeated loading, the flexural strength of asphalt concrete mixture was (450, 150, and 80) kPa under (750, 400, and 250) microstrain levels respectively. On the other hand, after 100 seconds of load repetitions, the flexural strength declines to (140, 100, and 70) kPa under (750, 400, and 250) microstrain levels respectively. Such behavior was in aggrement with the work reported by Sarsam, 2022.

Influence of Silica Fumes on Flexural Strength

Figure 3 exhibits the variation of flexural strength under various microstrain levels of silica fumes treated mixture. Similar trend of flexural strength among the microstrain levels could be observed. However, the implication of silica fumes additive exhibit higher flexural strength of asphalt concrete as compared with the control mixture. This may be attributed to the fact that the Nano size additive can fill more voids and exhibit stiffer mastic in the asphalt concrete mixture. After 3 seconds of repeated loading, the flexural strength of asphalt concrete mixture was (720, 200, and 90) kPa under (750, 400, and 250) microstrain levels respectively. On the other hand, after 100 seconds of load repetitions, the flexural strength declines to (160, 120, and 100) kPa under (750, 400, and 250) microstrain levels respectively. It can be revealed that implication of silica fumes into the asphalt concrete mixture as particial substitute of the filler had improved the flexural strength by (60, 33.3, and 12.5) % under (750, 400, and 250) microstrain levels respectively. Similar finding was reported by Khan et al., 2020.

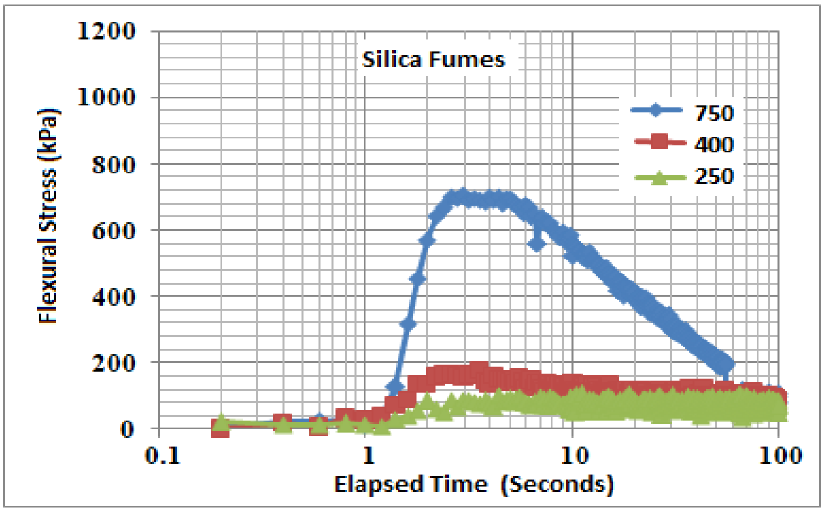

Figure 3. Variation of flexural strength under various microstrain levels of silica fumes treated mixture

Influence of Fly Ash on Flexural Strength

Figure 4 demonstrates the variation of flexural strength under various microstrain levels of Fly Ash treated mixture. The trend of change in the flexural strength was the same as that of the control or the silica fumes treated mixtures. After 3 seconds of repeated loading, the flexural strength of asphalt concrete mixture was (180, 110, and 75) kPa under (750, 400, and 250) microstrain levels respectively. On the other hand, after 100 seconds of load repetitions, the flexural strength declines to (100, 80, and 60) kPa under (750, 400, and 250) microstrain levels respectively. It can be revealed that implication of Fly Ash into the asphalt concrete mixture as particial substitute of the filler causes decline of the flexural strength by (60, 26.6, and 6.2) % under (750, 400, and 250) microstrain levels respectively. Such behavior agree with Li et al., 2022.

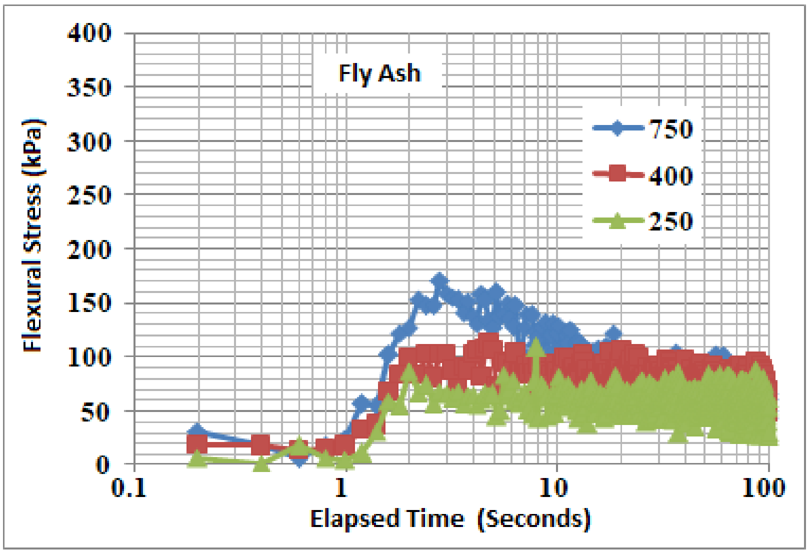

Figure 4. Variation of flexural strength under various microstrain levels of Fly Ash treated mixture

Conclusions

The following conclusions could be addressed based on the limitations of materials and testing program.

1- For control mixture, the flexural strength of asphalt concrete mixture was (450, 150, and 80) kPa under (750, 400, and 250) microstrain levels respectively after 3 seconds of repeated loading. On the other hand, after 100 seconds of load repetitions, the flexural strength declines to (140, 100, and 70) kPa under (750, 400, and 250) microstrain levels respectively.

2- Implication of silica fumes into the asphalt concrete mixture as particial substitute of the filler had improved the flexural strength by (60, 33.3, and 12.5) % under (750, 400, and 250) microstrain levels respectively.

3- Implication of Fly Ash into the asphalt concrete mixture as particial substitute of the filler causes decline of the flexural strength by (60, 26.6, and 6.2) % under (750, 400, and 250) microstrain levels respectively.

4- Implication of Nano size additive as partial substitute of mineral filler is recommended to enhanse the sustainability of asphalt concrete.

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OMAINTEC Journal
(Journal of Scientific Review)

ENERGY SAVINGS THROUGH ENVELOPE SEALING

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Abstract

The aim of this document is to demonstrate the analysis done to identify building envelope issues and adaptation of latest technologies by maintenance team to seal gaps effectively thereby significantly reduce leakage of conditioned air from the buildings. This is a new approach to rectify the gaps in the building that are mostly invisible to the naked eye and enables to measure the leakage before, during and after the sealing activity. Airtightness of buildings are essential to reduce carbon footprints especially when the buildings leak large quantities of conditioned air besides letting in unconditioned humid air causing additional cooling load to the buildings. Adaptation of new envelope sealing technology had enabled our Supercomputer facility building in KAUST to save energy significantly as well as reduction in deterioration of assets.

Key Words

Maintenance, Carbon footprint, Energy savings.

Introduction

The King Abdullah University of Science and Technology (KAUST) in Thuwal, Saudi Arabia offers state-of-the-art facilities, expert academic staff, and a world-class curriculum. These are among the reasons why KAUST is one of the fastest growing research universities in the world with a high-quality research output ranked globally among its peers.

Located on the Red Sea, facilities across its core campus have always been challenged with extreme weather conditions since opening in September 2009. KAUST has tried multiple options to eliminate these issues.

The Al Khawarizmi building on the KAUST campus (Fig. 1) includes the university's Supercomputing Laboratory, home to the region's top performing supercomputer. Ranked as one of the world's fastest, KAUST's Shaheen II Cray XC40 supercomputer houses computing clusters for scientific and engineering research. Shaheen also services industrial, governmental, and other educational institutions both within the Kingdom and internationally.

Fig 1. Al Khawarizmi Building at KAUST

Since the building opened, infiltration of humidity through the building envelope of its penthouse mechanical room was causing significant problems. Remedies carried out earlier had sealed visible openings in the envelope but there were several gaps that were either not visible or inaccessible to repair. Sensors and alarms were set off during the high humidity months, shutting down the mechanical equipment and triggering evacuations for the building's occupants.

The Facility Management team at KAUST had spent significant time attempting to manually seal the mechanical room's envelope, as well as analyzing air sealing methods that ultimately would interfere too much with the building's operation, take too long, and cost too much.

Eventually, KAUST turned to AeroBarrier's envelope air sealing solution to address the problem, along with Advanced World Trading (AWT) to implement the solution. AeroBarrier is a non-toxic, water borne acrylic GreenGuard Gold certified sealant.

2. Methodology

2.1. Thorough Planning to Ensure Success

KAUST had conducted detailed thermal imaging of the building envelope to assess the extent of leakage (Fig. 2). There has been a limitation to pressurize the building as the leakage through bigger openings were significantly higher that masks the smaller openings. Intrusive methods of inspections were also conducted to assess the nature of the breaches in envelope, however, many areas were inaccessible due to concentration of utility networks especially HVAC ducting and electrical conduits.

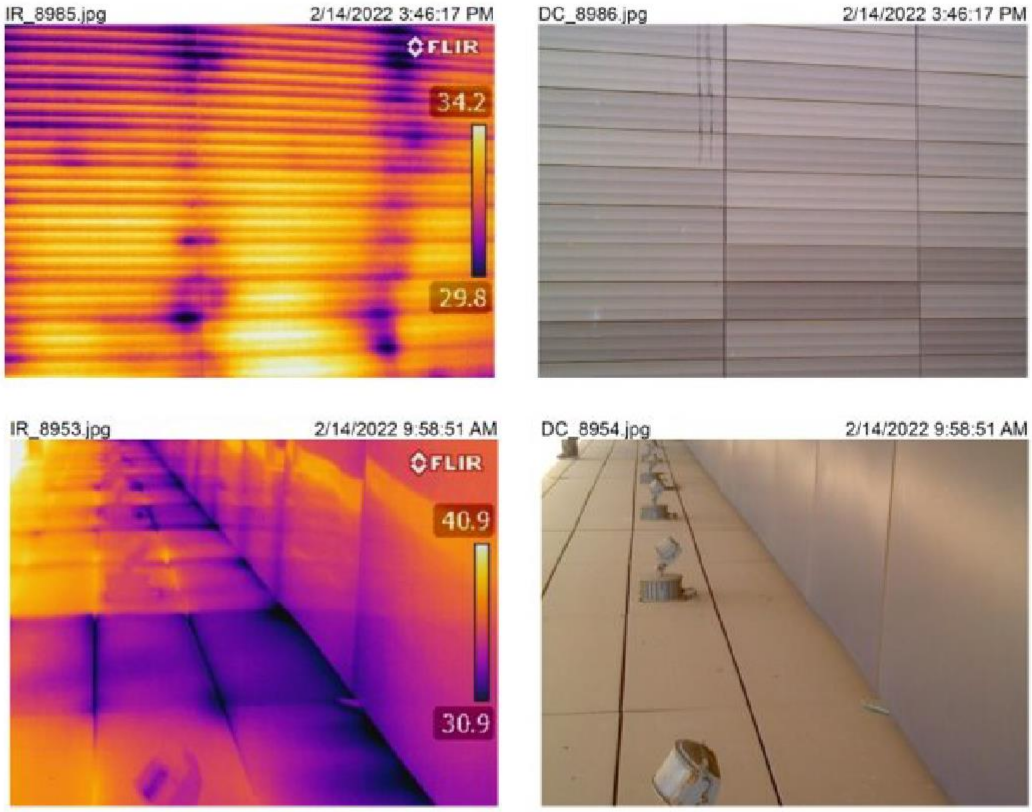

Fig 2. Thermal scan of Building Envelope

KAUST did an assessment of mechanical sealing of envelope but concluded that manual sealing will not seal the envelope to achieve required air tightness. This had prompted KAUST to search for new methods and technologies that will enable sealing with little or no impact on the building operation or occupants and at the same time durable, efficient, and economical.

Aeroseal technology was used in KAUST earlier for sealing the leakage of HVAC ducts and had provided good results. KAUST also learned about another product from the same manufacturer, Aerobarrier, which was being used for sealing the buildings in the Unites States. The technology, however, is new to the Middle East and application to a larger enclosed area in the range of 68,000 sft. was never tried before.

A team from KAUST, AWT Services, and AeroBarrier conducted careful planning prior to the start of air sealing to ensure the project's success. The large area of building envelope surrounding the 457' x 150' mechanical room (Fig. 3) needed to be sealed.

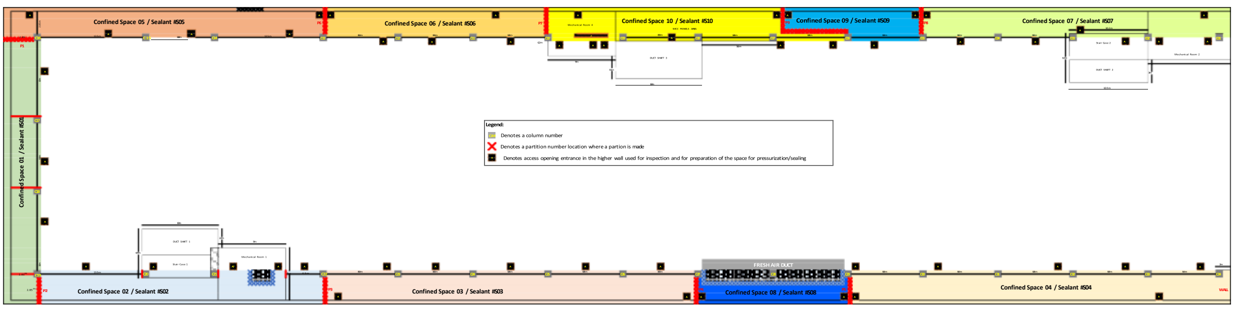

Fig 3. Layout of Mechanical Room at level 5

Considering unique exterior wall construction and campus site constraints, a detailed air sealing plan needed to be developed in advance of being on site to do the actual air sealing work. The team planned to air seal the mechanical room's exterior walls in segments, with the north, south, and east walls each subdivided differently based on their construction. The west wall is constructed of solid block and didn't need to be sealed.

Third party exterior thermal imaging assessment and visual inspections showed previous, manual seals of leaks and pipe penetrations were shearing. Further a few gaps in the exterior wall less than 1.2cm (0.47") in size were also found. The plan of execution was to seal the space between the vapor barrier and inner gypsum wall thereby ensuring airtight chamber around the building. Team performed initial blower door tests which showed leakage as high as 60 ACH50 in some segments of the building envelope.

2.2. Flexible Technology and Team Navigate Unique Building and Site Challenges

The building envelope construction of the building's mechanical room, as well as the building's location on the KAUST campus presented some challenges that were successfully resolved through key advantages provided by the air sealing system.

• Air sealing without the need to remove the terra cotta panels used as the mechanical room's exterior finish (Fig. 4).

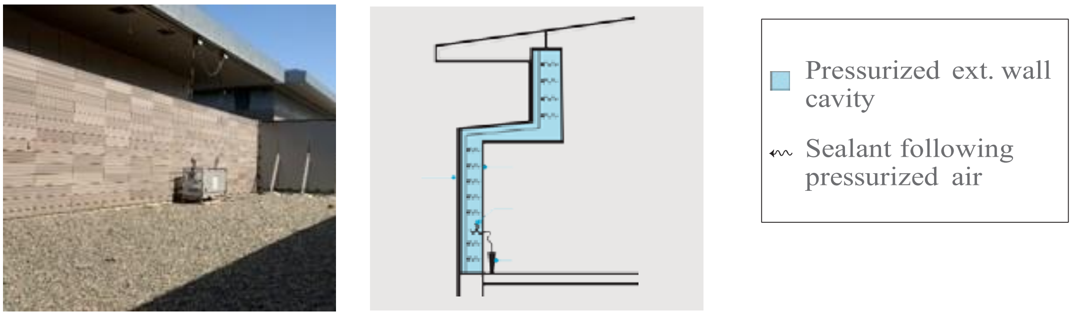

Fig 4. Exterior wall of Mechanical Room

• Placing sealing stations so that their atomized sealant spray did not get into the mechanical room's interior, air handling units, and ductwork.

• Air sealing around several HVAC motor control center (MCC) panels. These clusters of electrical and control pipes required special attention and preparation as part of the air sealing process.

• Conducting the air sealing while ensuring that sealant and debris didn't fall onto a major pedestrian circulation spine underneath and near the building.

• Working around the university's high traffic periods and not creating any disruption to the building's occupants' work schedules.

• Shorter duration of the rectification works compared to the traditional methods of sealing the envelope.

2.3. Applying Sealant Within the Exterior Wall Cavity

Air sealing system pressurizes a space using a blower door and fan, then sprays an atomized sealant mist into that space, causing the sealant to follow the pressurized air escaping through leaks in the building envelope and sealing those leaks. Since avoiding contact between the atomized sealant and the mechanical room equipment was critical, the cavity inside the exterior wall was pressurized and sealant was sprayed directly into the wall cavity to accomplish the air tightness goal for the mechanical room building envelope (Fig. 5).

Due to its size, the exterior envelope was sealed in smaller segments. Two different types of sealing station placements were used to seal from the inside of the exterior wall cavity, leveraging the team’s creativity and technical expertise.

Temporary access panels were cut through the interior finish drywall to provide access into the confined space of the wall cavity for further inspection, setup, and preparation work to be carried out, and ultimately to provide access points for the blower door and sealing stations.

For each segment of the envelope, the blower door was then placed into a temporary access panel to pressurize the wall cavity (Fig. 5). Most segments of the envelope were sealed by then deploying sealing stations against the interior face of the exterior wall at these access panels while inserting the spray nozzles inside the cavity and then spraying the sealant mist directly inside (Fig. 6).

Fig 5. Pressurizing exterior wall

Fig 6. Sealing Station

In a small number of envelope segments, the wall cavity was deep enough to place the entire sealing station inside the wall so that sealant could then be sprayed into the pressurized cavity (Fig. 7). The unique sealant technology and capabilities enabled this customized envelope air sealing approach.

An additional area included a series of control panels that controlled the mechanical equipment, and many conduits that were not possible to get in between and behind to seal the exterior wall. The team successfully sealed this area by constructing temporary walls of framing and plastic film to both pressurize this space and protect the control panels during the sealing process (Fig. 8).

Fig 7. Sealing station inside Exterior Wall

Fig 8. Sealing inaccessible areas behind conduits

The monitoring system included a Main Control Unit, laptop and software managed the entire process, recording air tightness and leakage reduction in real time.

3. Results

3.1. Verified Air Sealing Results Lead to Energy Savings, Broader Application

Working together, the team achieved airtightness levels below 3 ACH50, a 94% reduction in the mechanical room building envelope air leakage (Fig.9). An estimated $126.8K in annual operational savings are being realized through reductions in both university staff's time responding to sensor alarms and sealing envelope air leaks, as well as the elimination of the building evacuations that had caused reductions in productivity for staff working in the building.

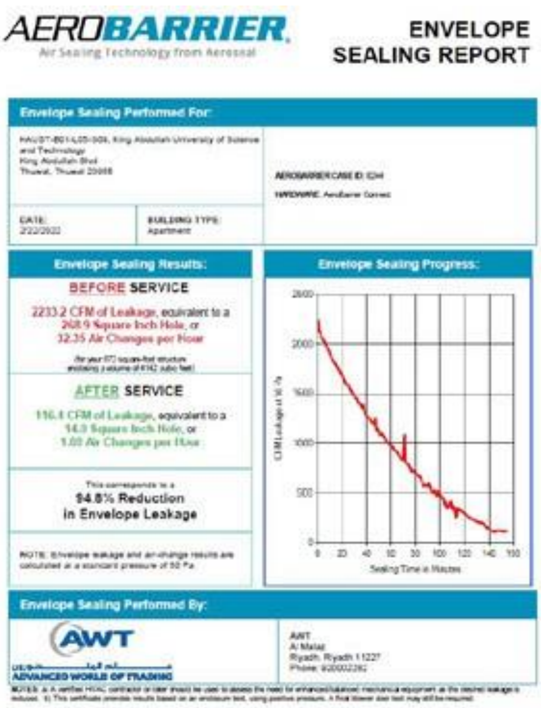

Fig 9. Sealing report of Section 9

These results were achieved with no damage to the HVAC equipment and minimal disruption to building occupants, operations, and the surrounding campus. The building envelope was successfully sealed in less than two months, a dramatically shorter project than the 10-12 months that would have been needed with other air sealing methods.

4. Conclusion:

The unique air sealing approach using waterborne acrylic sealant was a breakthrough as it reduced the cost and time for rectification of the air leak and infiltration through the building envelope. The effectiveness of the material in reaching and sealing the inaccessible and tiny gaps had a 94% improvement in the air tightness and the value of 2.2ACH50 was achieved (against target value of 3.0 ACH50 as per IECC standards) for all sections of the building envelope in the penthouse floor of the building. There has been a remarkable improvement in the condition of the space – elimination of space condensation, savings in energy and elimination of business interruptions.

4.1. Post Sealing Observations

Condensation during humid months July – September 2022 was not observed in the mechanical room unlike in the previous years. There was a considerable reduction in cooling demand for the space. Thermal scan results after the sealing confirmed the envelope tightness as there were no cold spots observed in the scans (Fig. 10).

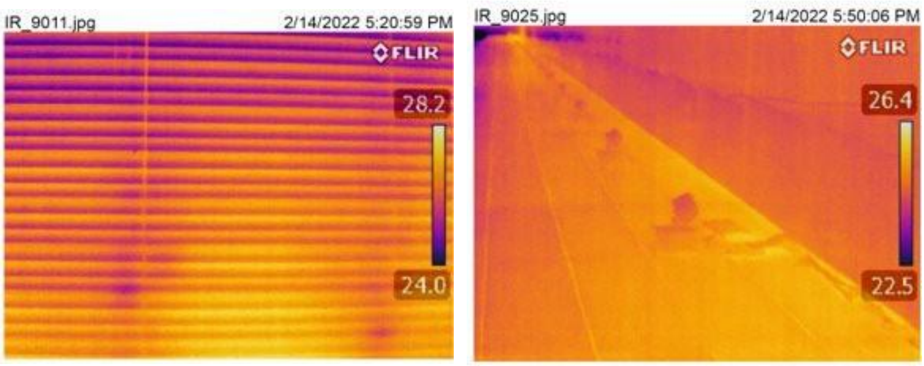

Fig 10. Thermal scan results after sealing

Acknowledgements

AeroBarrier envelope sealing technology is a breakthrough when it comes to sealing the building envelope, allowing contractors to literally dial-in desired airtightness. AeroBarrier replaces inconsistent, unreliable manual air sealing with an automated process that delivers guaranteed results.

Advanced World Trading (AWT) is an installer of AeroBarrier in Saudi Arabia and specializes in indoor air quality (IAQ) management and infection prevention. AWT was very professional in their approach in planning and timely execution of the project. The project was completed in two months' time without causing any adverse impact to the functional building.

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OMAINTEC Journal
(Journal of Scientific Review)

SMART BUILDING MAINTENANCE QUALITY SYSTEMS MANAGEMENT OF SUSTAINABILITY

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Abstract

The paper gives a model of the method of handling and controlling the management of building maintenance quality systems in terms of the quality system. The paper includes mechanical and electrical operating instructions, operating warnings, and a maintenance program for devices and machines inside buildings.

Smart Building Maintenance Quality Systems Management and control in the smart building management systems will be opening up unprecedented possibilities in the Building Management System (BMS), otherwise known as a Building Automation System (BAS) which is an automated (computer) control system in buildings that controls and monitors mechanical and electrical equipment for the building such as air conditioning, heating, ventilation, lighting, power systems, fire systems, security systems, Internet of things sensors, energy and gas meters, access control, water management, sewage management, parking management and also services. All this is through the advanced electronic system which is based on the computer installed in the buildings that meet all needs.

There are many problems inside the buildings that are not controlled, either because there is no system or a system that does not work so to make sure that the system inside the buildings works efficiently is to adhere to a quality system and implement a maintenance program for the devices inside the buildings and to preserve the national economy and reduce the losses resulting from all of this is done through the application of the quality system inside the buildings.

The steps of the maintenance process inside the buildings include the following:

1. Maintenance and repair of all devices and machines inside the buildings.

This is to ensure the quality of the devices and machines, maintenance and repair of all devices and machines to ensure their continuity of work without sudden interruption, including the list of devices that are subject to periodic maintenance and the preventive maintenance program, and all of this is recorded in the maintenance file.

2. Calibration and adjusting measuring, checking, and testing equipment to ensure that it performs the required tasks

The paper concluded with recommendations it is necessary to the maintenance of all devices and machines inside buildings that all measuring, then calibrate all examination and testing devices used in the measurements by the planned calibration and control and subjecting them to the quality system for individuals and devices and the existence of a management monitoring maintenance system for smart buildings.

Keywords

Maintenance - Quality Smart Building -: Sustainability

1. Introduction

Over the years, maintenance concepts and procedures have gone through different stages of development in thought and performance, and until recently, the common concept of maintenance was the reaction after the occurrence of the problem which in turn led to large losses, whether financially represented in assets or human in loss of lives [3, 10]. Because of what Egypt owns of real estate assets of public buildings and heritage buildings, and what modern technologies have produced in terms of means, tools, and techniques in the field of maintaining these buildings in general, it was necessary to preserve these assets and ensure their sustainability through optimal operation and maintenance, as the preservation and sustainability of these real estate assets They are among the most important indicators against which to measure the progress and progress of countries[2].

2- A quality strategy maintenance for smart buildings

Quality management of maintenance for smart buildings is based on quality control not only in maintenance operations but in general in the activities of studies, design, and supervision of project implementation. Because The problems in maintenance go back to the beginning of the stages of the project life cycle in studies, design, and supervision of implementation and to expand the perspective of comprehensive maintenance through the integration of roles in the various stages of the project, so we must focus on the requirements of operation and maintenance in the design guidelines and standards and technical specifications for construction and architectural materials, electrical works, mechanical works, security and safety In addition to equipment, supplies, all facilities, selection of systems, characterization of equipment and fixtures, tests and receipts [8]. Therefore, there should be specific joint relationships between designers and operators that must be taken into account in the various stages of design. Information and the exchange of project cycle stages should also be determined according to the requirements of each stage, [1] as illustrated in Figure 1.

And to activate and develop the management of building maintenance quality systems in line with the scientific renaissance in the world, and to be characterized by modern, accurate devices, and to be equipped with modern computers, electronic display devices, audio systems, and surveillance cameras. Also, the presence a system that does not work due to a malfunction of the devices and machines, due to the lack of preventive and periodic maintenance.

This research makes a plan for quality management of maintenance systems of all devices and machines inside buildings and how to implement a quality system in terms of verifying the implementation of maintenance procedures. Building management systems are commonly implemented in large projects involving electrical, and mechanical, The primary function of Heating Ventilation, and Air Conditioning (HVAC) systems is environmental management inside the building by controlling the temperature, carbon dioxide levels, and humidity inside the building. As an essential function in most building management systems, it also controls the heating and cooling and manages the systems that distribute this air throughout the building (eg. via actuating fans or opening/closing valves) so it controls the combination of heating and cooling to up to room temperature.

The secondary function is the detection of the level of carbon dioxide (CO_2) which is human-generated then mixing the outside air with waste air to increase the amount of oxygen while at the same time reducing heat/cooling losses.

2.1 Building management systems (BMS)

Building management systems (BMS) are a critical component of energy demand management. BMS represents 40% of a building's energy use, and if the lighting was added the percentage will be around 70%.

In addition, BMS is sometimes linked to access control (gates and door control access that allows entry and exit to the building) or other protection systems such as closed circuit television (CCTV) and motion detectors (Figure 2). Fire alarm systems and elevators are also sometimes linked to the building management system, for example, if a fire is detected, the system can close the valves in the ventilation system to prevent the spread of smoke and send all elevators to the ground floor and stop them to prevent people from using them in the event of a fire Figure 3.

2.2 Optical sensors

The optical sensors (motion detectors) are rays of light that work when the flow of energy is disrupted by something moving in the path of the light beam it will be given an alarm. Photo sensors can be used not only to alert you to intruders with an alarm but also to anyone entering your space with a buzz or a bell (Fig. 4).

2.3 Thermal monitoring systems

Infrared night vision thermal camera, Long range rail surveillance camera Integrating the visible camera, near-infrared laser lighting with thermal Camera, multifunction (Fig 5).

2.4 Anti-theft alarm systems

Anti-theft alarm systems, are characterized by extreme sensitivity to detect any unwanted movement in the space of the facility or the house to be secured because the system is equipped with sensors of a high degree of sensitivity, which sound the alarm in the event of detection of infiltration of any kind and contact the security services, agencies and people Who are selected immediately (Fig. 6).

2.5 Electronic Access Control System

Electronic Access Control (EAC) system uses computers to solve the limitations of mechanical locks and keys. Use the search to search on mechanical keys. The system will also list the name of the list, its appearance, if the door is forcibly opened or kept long, after opening it. Road systems and wooden locks can also be controlled (Fig.7).

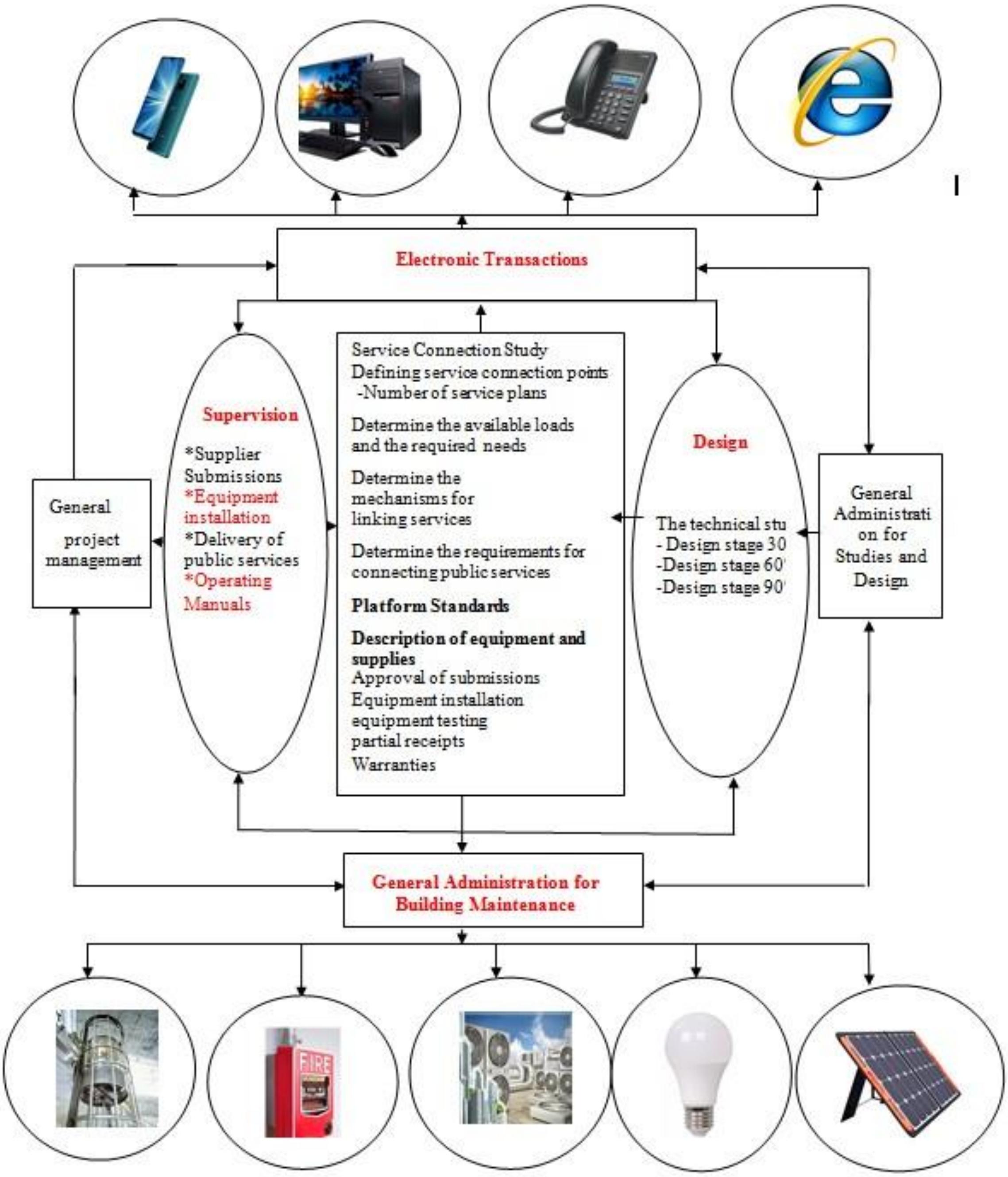

Figure 1: Relationship diagram between designers, supervisors, and operators
Maintenance steps Maintenance steps Maintenance steps

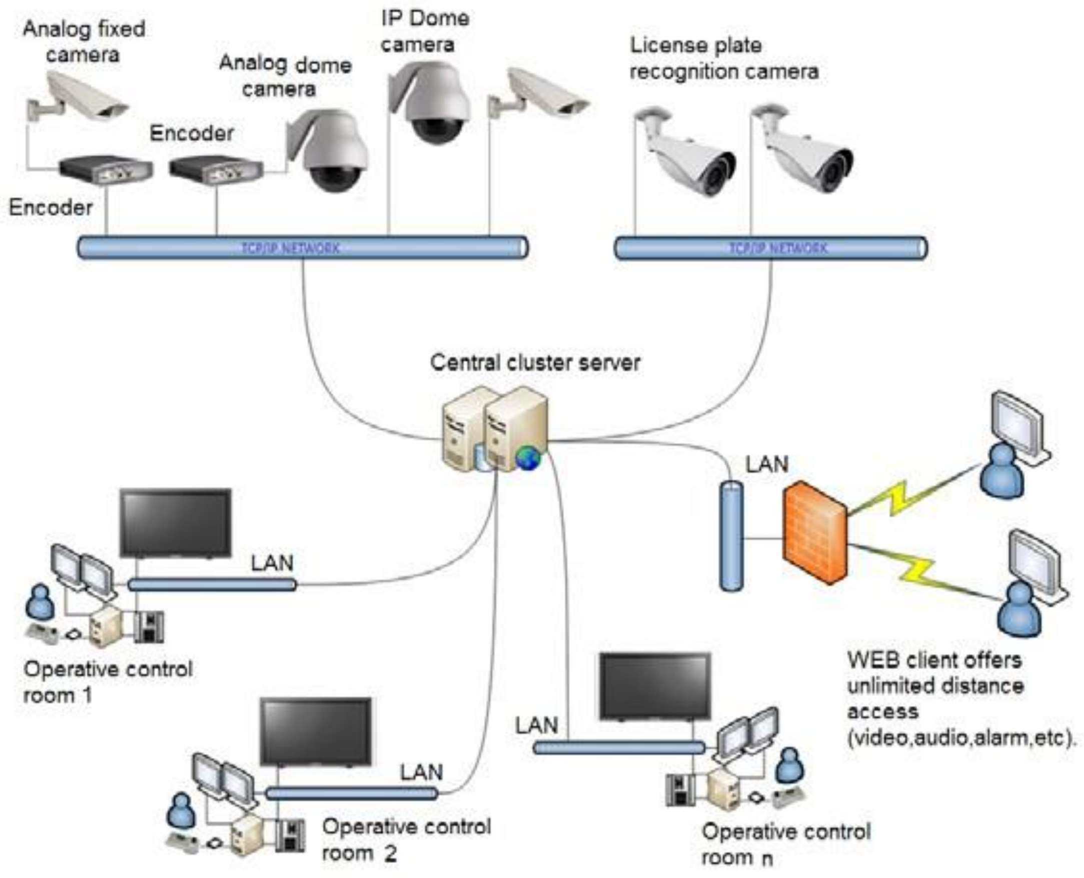

Figure 2: Closed-circuit television (CCTV) Surveillance Systems for Building

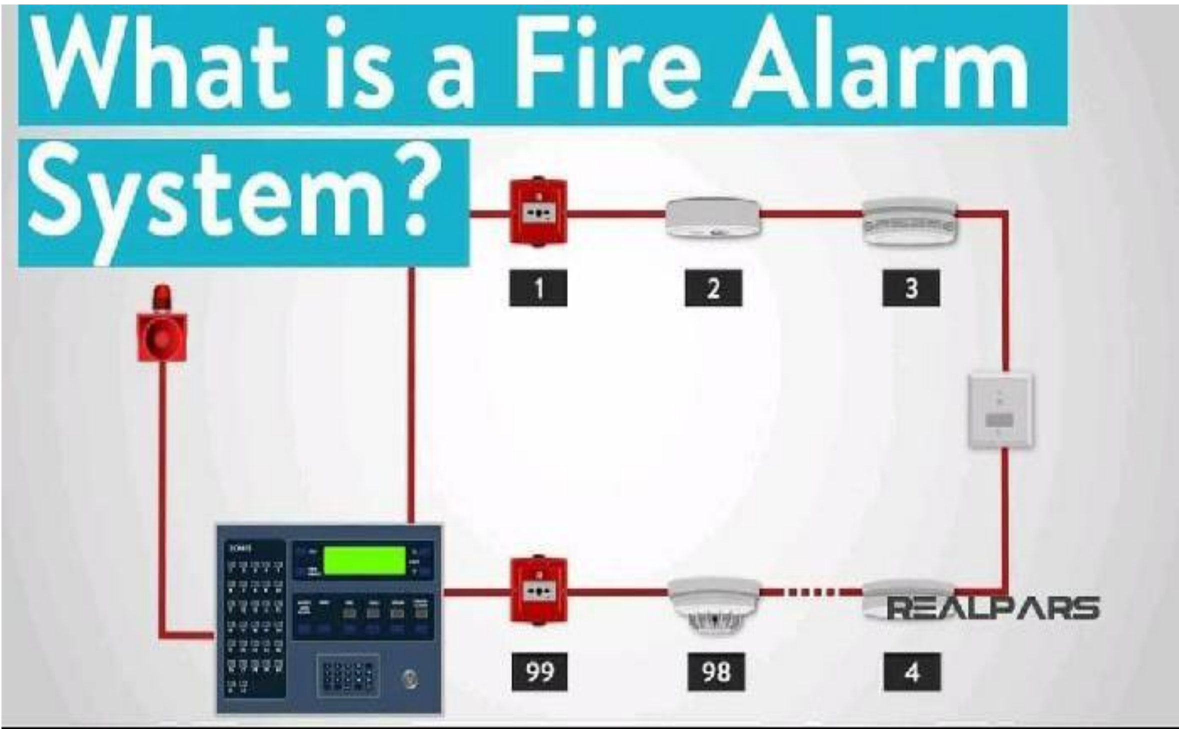

Figure 3: Fire Alarm Systems

Figure 4: Optical sensors

Figure 5: Thermal monitoring systems

Figure 6: Anti-theft alarm systems

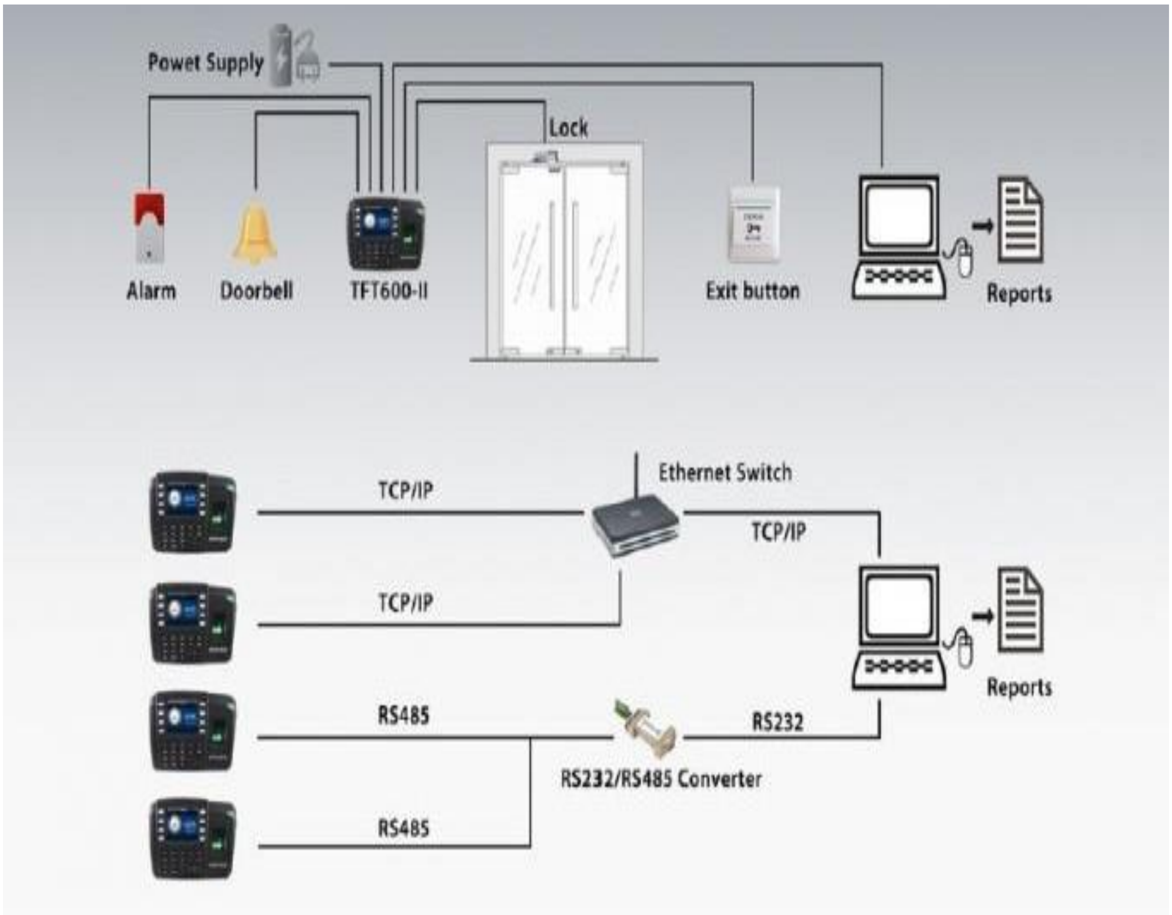

Figure 7: Access Control System

3- Management of operation, maintenance, security, and safety requirements

The principles of operation and maintenance management are applied to all systems and elements of public and heritage buildings. The criterion of efficiency of operation and maintenance management is one of the most important elements of the success of the life cycle of buildings and ensuring its sustainability, compared to the capital invested in the construction and operation of buildings. The application of the principles of operation and maintenance management helps to provide conditions for a stable operation that reduces the expected risks during operation and improves the quality of the internal environment, ensuring the highest levels of security and safety, and providing a healthy, safe and risk-free environment.

Figure (8) shows the general scope and requirements for building management systems, which include:

-Documenting the owner's understanding of the importance of buildings.

-Understand the needs and expectations of stakeholders, users, and participants in operations and maintenance.

-Defining the responsibilities and roles of each party participating in the system, to achieve the success of operations and maintenance.

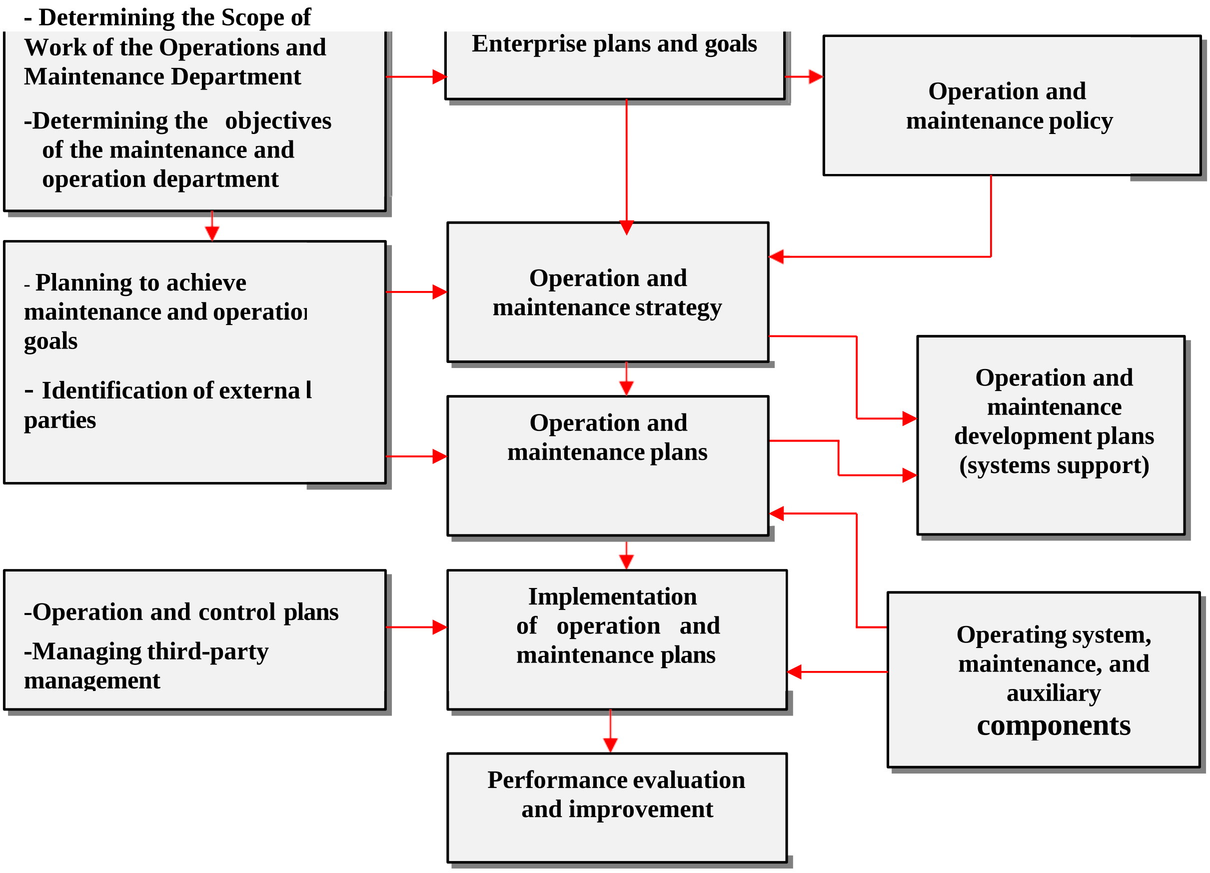

Figure 8: General scope and requirements for operation and maintenance management

3.1 Achieving sustainability through operations and maintenance

Operation and maintenance work must be planned and implemented within the general framework to achieve sustainability in its economic, environmental, and social dimensions. Where targets are set for energy and water consumption, reduce the negative impact on the environment, achieve thermal, visual, and acoustic comfort requirements, prepare and implement an operation and maintenance plan, identify performance indicators related to achieving sustainability goals, monitor the performance of operations and maintenance, and compare actual performance measurement results with the planned targets, and include the following objectives:

-Achieving energy efficiency in buildings.

- Achieving efficiency of using water.

- Achieving efficient consumption of materials and resources and reducing materials and emissions that pollute the environment.

- Achieving air quality in the building (ventilation, thermal, visual, and acoustic comfort).

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3.2 Operation and maintenance information systems

In light of the rapid technological development in information systems and databases and their employment in architectural and engineering design and construction methods, the building owner organization must take advantage of information systems applications in developing operation and maintenance work to document and monitor all strategies, plans, implementation mechanisms, operating results, performance measurement, asset register, accident record, and record Risks, all responsibilities, tasks, documentation and review mechanisms. Computerized Maintenance Management Systems (CMMS) are an effective way to manage assets, schedule maintenance, track work orders, and spare parts, and evaluate the condition of building systems and components.

3-3 Building Information Modeling (BIM) to manage operations and maintenance

Success in the operation and maintenance phase of the building's life requires integration with the previous phases during the design and construction. Most of the owners of buildings and facilities are currently preparing digital models for all building elements and systems using the technology known as Building Information Modeling-BIM. Where all architectural, structural, and electromechanical elements are represented in a 3D digital way (BIM 3D Model). During the construction phase, data on costs and schedules are added to produce a five-dimensional model (BIM 5D Model) that contains all the actual details of implementation (As Built). The building owner can also add information tracking the elements necessary to achieve sustainability to be a six-dimensional model (BIM 6D Model), and add operation and maintenance information to form a seven-dimensional model (BIM 7D Model).

This technology allows documenting information on every element from design to construction and ending with operation and maintenance. This technology helps those responsible for operation and maintenance to link maintenance programs and instructions with building elements in a digital form. These digital systems also contribute to monitoring energy and water consumption, indoor climate quality, and achieving security and safety in the building to achieve sustainability goals and green buildings while achieving the building's economic and operational goals.

The owner of the building or the organization responsible for the operation and maintenance of the building must use computer technologies or building information modeling, as these methods help to manage the operations and maintenance operations with the highest possible efficiency and know the condition of each element in the building accurately and link digital models with simulation applications to achieve goals Rationalizing energy consumption and other applications that contribute to achieving sustainability and the quality of the building's internal climate while rationalizing spending[6]. When preparing a digital building information form for the management of operations and maintenance, it must include the following elements, Figure 9:

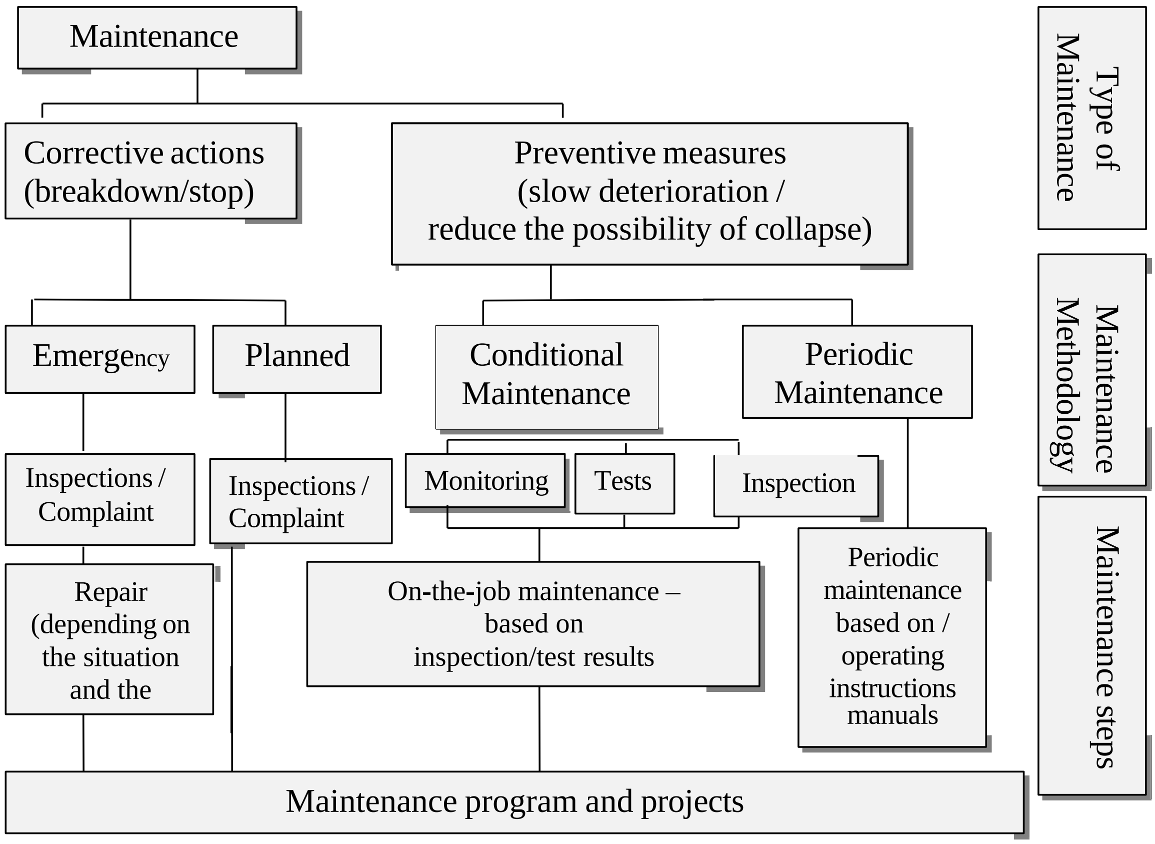

Figure 9: Organizational Structure of Maintenance Procedures

3-4 Preparing the building operation and maintenance manual

The Building Operation and Maintenance Manual is one of the deliverables that a construction contractor makes to a building owner, and is usually part of the initial and final receipt documents. The guide is developed with the start-up of the building and continuously throughout the life of the building. If the construction contractor does not prepare this manual, the owner of the building must assign a specialized consultant or assign the company operating and maintaining the building to prepare a manual for the operation and maintenance of the building. The guide includes basic data on the design and specifications of all building systems and elements, setting performance targets in the operating phase, regular maintenance and correction schedules, and means of assessing the condition and monitoring the performance of building systems and elements, to maximize operational performance, maintaining the building, saving operating expenses, and avoiding damage to the building that reduces the life of the building. The virtual building avoids the high cost of maintenance work and avoids damage to the security and safety of building users, maintenance personnel, and passers-by.

The guide includes information and data about the systems and elements of the building dating back to the design and construction phases. In particular, the electrical and mechanical contractor(s) and suppliers have a primary responsibility to provide information on the building's electromechanical systems and maintenance instructions for each component. The building operation and maintenance manual contain, at a minimum, the following information:

- A description of the elements, systems, and construction works of the building and the technical specifications of each element and system.
- Actual implementation drawings and specifications (As-Built Drawings & Specs)
- Product Data Sheets for all building elements
- Cleaning and maintenance instructions
- Health, safety, and fire prevention instructions from manufacturers and implementers
- Testing and Commissioning Certifications
- Warranties from the original manufacturer or the guarantees provided by the contractor (Warranties and Guarantees)

3-5 Building Management System (BMS)

The primary function of building management systems is to manage the internal environmental conditions within a building, i.e. temperature, in such a way that energy is saved as much as possible. Building Management System (BMS) system based on a computer- installed in buildings that are used to control and monitor mechanical and electrical plants, including heating, ventilation, air conditioning (HVAC), lighting, power systems, fire systems, and security systems.

Effective and well-used BMS systems provide the essential management tool required by building managers to ensure effective energy monitoring and management and user comfort. In addition, it enables building managers to provide the optimum working environment while reducing costs. Effective use of a building management system enables optimum building performance by extending the operating life of equipment and systems by reducing loads and operating hours. Therefore, maintenance and capital costs are reduced, and less built-in energy is consumed through equipment replacement and upgrade.

The BMS will show increases in energy use due to equipment failures or modifications to operating parameters. For example, heating valves open when a building needs cooling. The building management system may also indicate that the air conditioning is started hours before the entire building is occupied due to the activities of security personnel. With this information on hand, the engineering manager may rectify these problems through consulting or engineering solutions.

In the absence of a Building Management System, the impact of such events can be masked by seasonal changes, changes in occupancy levels, or the evolution of technology. A building management system if properly configured with a sufficient number of precisely defined control points is the only way a building manager can be alert for problems that may remain undetected until annual inspections or external audits are conducted.

The BMS is also an essential tool for identifying opportunities to improve energy intensity, for example, improving the size and number of lighting intervals, providing meaningful reports to the Care Environment Committee on issues and opportunities, and enabling fault identification, maintenance planning, and energy-saving upgrade.

3.6 Smart Building

A smart building is one in which basic equipment and assets, such as air handlers, coolers, boilers, lighting, etc., can communicate with other machines. Where there is a detailed management system to control and improve all parts.

A smart building aims to provide useful services that help make its users more productive, safer, and at the lowest cost and with the least impact on the environment. A smart building improves and reduces energy use, can operate with clean energy sources, and puts the security of occupants and quality of life first. These priorities not only mean physical safety, such as fire suppression and alarm systems, but also health security - high-quality air and water, and more.

Equipment and systems in a smart building must be connected and able to communicate from one machine to another. For example, a building's chiller can receive weather data from the outside and occupancy information from the inside, so it only operates when needed to maintain the optimum temperature for its occupants.

What makes all of the above work so well? The availability of small, sophisticated, and affordable sensors connected through the BMS allows it to analyze and use the data generated by these sensors to manage and improve operations. Intelligent building systems can use the generated data to monitor performance, track the location of equipment and assets, detect potential operating problems and improve preventive maintenance efforts.

Buildings today are complex chains of structures, systems, and technology. Over time, every component within the building has been developed and improved, allowing us to independently select the lighting, security, HVAC, and systems. Today, we seek to build, work in and live in smart buildings as the right thing to do. Many governments and industry regulators set standards for the construction and management of facilities to meet environmental, safety, and sustainability requirements. Leadership in energy engineering and design (LEED) is an accreditation program approved by building owners and managers to certify compliance with government and subjective requirements [9-4].

3.7 Green building leadership is LEED

LEED (Leadership in Energy and Environmental Design) certification is one of the most widely recognized standards for sustainability, and an excellent way to demonstrate your building's environmental credentials. LEED is the green building rating system for green buildings that are healthy, efficient, energy efficient and cost effective.

LEED Certification Minimum Requirements

Comply with environmental regulations and standards.

-Must meet the threshold of floor area requirements.

-Meet a minimum of building occupancy in terms of the number of users.

-Maintain a reasonable site boundary.

-Be a permanent building.

-Share energy and water usage data.

3-8- Operating instructions and warnings for devices and machines in the building

3-8-1 Mechanical Instructions

Mechanical instructions are one of the main factors in evaluating the efficiency of devices, so the following must be ensured:

-The catalogs of all equipment and machines must be read before operation.

-The water tank must be full for water pumps.

-Check the oil level of the hydraulic pumps.

- The absence of any apparent obstacles hindering the pumps.

-The fuel tank is full and sufficient.

3-8-2 Objectives of sustainable operation and maintenance of the electrical system in buildings and

electrical instructions

3-8-2-1 Objectives of sustainable operation and maintenance of the electrical system in buildings

- Improving the electrical energy efficiency in the building.

- Maintaining the life span.

-Protection from electrocution and electrical fire hazards.

- Using Pro-Diagnostic maintenance and additional diagnostic maintenance before the fault occurs to locate the technical malfunction.

- Using a proactive maintenance system before the damage occurs instead of a reactive maintenance system

after the damage occurs instead of Reactive maintenance.

- Use of automated smart control and monitoring systems throughout the day.

- Using modern maintenance tools, equipment, and systems to reduce maintenance costs and maintain operating

time. i.e. (Reducing the time of preventive maintenance + reducing the number of maintenance workers + reducing the

consumption of spare parts + monitoring the operation of equipment within the limits of the design capacity)[6-7].

3-8-2-2 Electrical Instructions

In this section, you must make sure of the following:

- The presence of an electric current in the operation panel with the appearance of the main supply bulbs.

-All major and minor switches are ON.

-The three phases in the volt switch are intact and all of them read 380 volts between phases and read 220 volts between each phase and the earth.

- All switches to operate the devices are placed on automatic mode.

- If any device stops, the ignition switch is placed in the OFF position.

- When turning on any device manually, the power key is placed in the HAND position.

-When the red indicator light appears, it means that there is an overload so reset is done, which is an internal situation in the control panel until the red indicator light signal disappears, and when it repeats, this device is stopped and the maintenance is informed to detect it to remove the cause.

-When you hear any sound other than the usual sound of operation, The device is turned off and maintenance is reported

- It should be noted that the optimum ampere reading for the operation of all devices separately during normal

operation. In the case of the high ampere, the device is turned off and maintenance is reported

- When the green indicator light appears, it indicates that the devices are working in good condition.

3-8-3 Operation Warnings

All equipment and machinery catalogs must be read before operation.

It is forbidden to operate the pumps without water to prevent damage to the gaskets.

- When servicing any pump, the two sub-clamps are closed for expulsion and withdrawal of the pump for which maintenance is to be carried out while leaving the rest of the other valves open to ensure the continuity of the system's operation.

- Water tanks must be constantly cleaned and purged of all solid materials to not cause damage to the pumps, and to ensure that the main intake valves are not clogged with any suspended materials.

- Pumps need good ventilation.

3-9 Maintenance of systems

1) The procedures for applying mechanical requirements, such as ventilation, cooling, and heating installations, maintenance and operation, and requirements for protection against fire hazards, must be checked according to the standards specified by the manufacturer[5].

2) The following is a statement of the required systems maintenance records, to ensure the availability of a good system for follow-up and documentation as shown in the following table (1):-

Intake fans (Air or draw fumes)	Chilled Water Generating Units (Water Chiller)	Air conditioning, refrigeration and ventilation equipment system	Firefighting and alarm system
Centrifugal pumps	Escalators and electric walkers	Electric elevators	Boilers
Electrical generator		Cooling towers	Chiller

Table (1): Maintenance records of mechanical systems

3-9-1 Steps of the maintenance process

The steps of the maintenance process are summed up in laying the foundations and means that make all devices and equipment inside the buildings in the best operating condition and permanently maintain raising performance and efficiency rates through:-

-Conducting a periodic, continuous, weekly check on all devices, machines, and equipment as included in the preventive maintenance program.

-Establishing a program for early detection of damage and determining the life span of each part of the building's devices and equipment.

-The importance of informing the competent authority about the existence of machines or devices that need spare parts the maintenance company submitted an offer for the required spare parts and this offer is examined technically and financially before being approved by the competent authority.

-Always ensure the correctness and safety of maintenance and repair.

-Attention to achieving industrial security in all devices, machines, and equipment.

-Submitting a detailed weekly report on maintenance work.

3-9-2 Program for repair and maintenance of machines, machines, and equipment

Maintenance work for all parts of the machine/equipment is as follows: -

3-9-2-1 Inspection of electrical parts and accessories

• The electrical circuit (connections - cables) is detected if the electric current is connected or not.

• On and off switches are detected.

• The control circuit is detected (conductor-overload switch.....)

• The inspection shall review the entire above before operation.

3-9-2-2 Inspection of mechanical parts and accessories (mechanical actuator connectors

Rotating mechanical parts and their accessories (ball bearings, belts, oil pumps, taps, pump gaskets, etc.............) are detected.

3-9-2-3 Inspection of the oil pump

a) Oil tank b) oil lines or oil hoses

c) Valves (exits and inlets) d) filters (exits - inlets)

e) Inspection of pressure control parts

f) The oil itself is detected and the degree of viscosity is determined using a viscometer

3-9-2-4 Inspection of the auxiliary parts and accessories

Checking (pressure gauges - current and voltage meters - temperature gauge - temperature sensor).

4- Maintenance and repair of equipment and machinery in the building

The purpose of maintenance is to ensure the quality of the devices and machines, and maintenance and repair of all devices and machines to ensure their continuity of work without sudden interruption. This is for all devices and machines in the building.

4-1 Responsibilities

a. Head of the maintenance unit. b. General supervisor of maintenance.

4-2 Forms

a. List of building equipment b. Preventive and periodic maintenance program

c. Maintenance record d Examination report of device and machines

e- Request to replace a spare part f. Weekly report

g. Installation report. h. Varieties of reflux

4-3 Maintenance work instructions

All catalogs of devices and machines.

4-4 Steps off maintenance

a. The general supervisor of maintenance works identifies and codes the devices and machines that are subject to the building's preventive maintenance program.

b. The head of the maintenance unit ensures that a maintenance log is prepared for a machine or device, and the data and specifications of the device are recorded.

c- The head of the maintenance unit reviews and approves the maintenance program at the beginning of the year on the planned dates based on:

* Specifications of the machine. *Maintenance instructions in catalogs

* Machine life history of the machine is included in the maintenance record.

* Experience with maintenance personnel. * Devices menu

According to the maintenance program, the maintenance team undertakes the maintenance work, under the supervision and follow-up of the building maintenance supervisor.

e. After completing the maintenance work on the machine or equipment, the unit technician completes an inspection report, then signs it and presents it to the general supervisor of maintenance work, who confirms that all required maintenance items are completed with work instructions and then approves the inspection report.

f. The general supervisor ensures that the maintenance program is implemented.

g. The administrative supervisor of the building updates the data in the maintenance record for a machine or equipment that has been periodically maintained.

h. If new spare parts are needed to complete the maintenance work, the maintenance technician shall obtain the approval of the maintenance manager to replace the spare parts, which contains the estimated price of the piece.

i. The technician, the user of each device or machine, reports sudden malfunctions on the form. The technician of the maintenance unit checks the equipment and completes the form prepared for this, and submits it to the general supervisor of maintenance, who in turn directs the maintenance procedure. Spare parts are installed and making an installation report.

j. The general supervisor of maintenance works analyzes the technically and financially submitted quotations, inspects the devices, and prepares the technical examination and the parts returned with the maintenance unit.

K - Weekly reports are prepared and compiled periodically by the general supervisor of maintenance work. This report is submitted to the maintenance manager through meetings (reviews of the senior management of the work system) and includes:

* Develop visions for the development of devices and machines for future needs.

* Sudden malfunctions and their causes.

* Extent of adherence to the maintenance plan.

* The condition of the devices and machines and the extent of the need for the replacement process.

* Resources and additional costs to implement the maintenance and repair plan.

* The most important problems and obstacles facing the maintenance work.

M- Putting files on the computer for maintenance work, which the computer operator performs, and doing a BACK-UP for these files.

5- Calibration work and adjust measuring, inspection, and testing equipment

5- 1Purpose

It is to ensure that all measuring, inspection, and testing devices used in the building can be relied upon and that their measurements and indications are relied upon by the planned calibration and control.

5-2 Scope of application

All measuring, inspection, and testing devices in the building.

5-3 Calibration Responsibilities

a. Head of the calibration unit in the building. B. The general supervisor of calibration work in the building.

5-4 Forms

a. A statement of the list of devices that are subject to calibration b. Calibrated device tracking card

5-5 Work Instructions

Hardware Catalogs.

5-6 Calibration

The calibration supervisor performs the calibration of the building's equipment on the planned dates according to the periodical.

The calibration supervisor also records the data of the devices and machines and records the actual calibration date and the upcoming calibration. The device follow-up card and the issuance of (the calibration certificate), which is approved by the head of the calibration unit, and a copy of it is kept with the maintenance and calibration supervisor, and the original is kept with the head of the calibration unit.

6- Conclusion

Based on the study, the following can be concluded:

1. There must be the management of quality systems for the maintenance of smart buildings.

2. Operating instructions for building machinery and equipment must be clear and periodic training should be carried out.

3. Adoption of the maintenance program and applied monitoring to maintain the building's machinery and equipment.

4. Checking the quality system periodically and applying it well.

5. All building equipment and machinery must be calibrated.

6. There should be positive, multiple, sudden and continuous periodic administrative control.

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Sustainable roads precast Concrete blocks units by using construction recycled aggregate

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Abstract

The concerte wastes and its production process are one of the most environmental problem notonly in Egypt but also in the our planet, so the allorganizations in whole world plan an significant role to get rid off this problem that's by some exertions has been made toward solving this problem like some regulationsor standards or some environmental projects for this purpose.

The main objective of this paper to investigate the physical and chemical properties of coarse aggregates is made using crushing and grading of construction wastes from different sites and landfill locations around Giza and Cairo.

The results showed that the construction wastes could be transformed into useful recycled coarse aggregate and its properties suitable for most green concrete disgen mixes applications in Egypt. From the results obtained, The construction wastes showed the chemical and physical properties are complie with the egyptian code for aggregates in most properties and not complie in Impact value and absorption.

The construction wastes can be used as raw material for road blocks and bariers to over came the waste issues not only in egypt but also all world countries

Abstract

wastes, sustainable, blocks

Introduction

Sustainability can define as meeting the needs of the present without compromising the ability of the future generations to meet their own needs; this definition was created by the World Commission on Environment and Development of the United Nations (World Commission on Environment and Development report,1987).

Sustainable constructions are those constructions which are concern with the minimizing of environmental impact, while optimizing it economically capability. The size of construction industry all over the world is growing at a faster rate, the huge construction growth boosts demand construction materials. Due to continue mining the availability of aggregates; the main constituent of concrete, has emerged problems in recent times, therefore, there is need to find a replacement to some extent.

The most commonly and widely used building material in the world is concrete; with the used of large amount of concrete; pollution is becoming more and more serious. The classical materials produced from the natural resources which use in construction such as concrete, bricks, hollow blocks, solid blocks, pavement blocks, and tiles. This will pose a bad effect on the environment due to continuous exploration and diminishing of natural resources quantities. Moreover, various toxic substances such as high concentration of carbon monoxide, sulfur oxides, nitrogen oxides, and suspended particulate matters are invariably emitted to the atmosphere during the manufacturing process of construction materials. The emission of toxic matters contaminates air, water, soil and aquatic life, and thus influences human health as well as their living standard atmosphere (Król and Błaszczyński, 2013). CO_2 is known to be greenhouse gas that contributes to the global warming. Portland cement production, which create one of the biggest problems to the cement industry sustainability is the decrease the limestone quantities, this will effect in economics of cement and concrete industries, the new technologies should be created to produce a concrete with minimum limestone contain, however, it raises the amount of CO_2 on atmosphere and other solid wastes. That is being serious environment and atmospheric pollutant. This is happening because of fact that producing cement clinker involves very well-known reaction called calcination of calcium carbonate. Unfortunately there is no technology to reduce carbon dioxide emission of clean Portland cement. The exception of this is multicomponent cements which are produced with an addiction of by-products of fossil fuel combustion or metallurgy industry.

The recycling of solid wastes in civil engineering applications has undergone significant development over a very long time. The exploitation of marble dust, fly ash, blast furnace slag, silica fume, recycled aggregates, calcium carbide residue, foundry sand, etc., in construction materials show some examples of the success of that research. The absence of sustainable practices in construction sector in Egypt led to the lack in environmental data. From strategic perspective,

Three main categories of waste have been identified which are based on the source of the waste and the level of care that needs to be taken in disposal; such as waste from manufacturing activities, packaging items and discarded electronic devices, as well as garden waste and sewage sludge (Ngoc et al., 2009).

Tsai et al. (2004) defined the hazardous waste as a waste or a combination of waste of a solid, semisolid, liquid, and contained gaseous or sludge form, which can pose a substantial present or potential hazard to human health or the environment. Hazardous wastes are mostly generated by industries and commercial operations and from community activities, or as the by-product of manufacturing processes which can release gasses and particles into the atmosphere (Delgado et al., 2007). In some case environmental depletion may result from a discharge to a waterway which would result in a lethal habitat and death of aquatic species such as fish and invertebrates.

Industrial waste may have a high risk of toxicity and be classified as hazardous waste due to containing materials that are actually or potentially hazardous to humans and other living organisms (Hu et al., 2009). Whereas, 'urban' wastes mainly include municipal solid waste (MSW), commercial and industrial (C&I) waste, and construction and demolition (C&D) waste. The compositions of MSW include textiles, metals, glass, plastics, paper and organic materials. C&D waste often represents the largest proportion of total waste generated, which accounts for 34% of the urban waste generated within countries, and mainly include concrete, masonry, wood and asphalt (Moh and Manaf, 2017).

Solid waste is trash or garbage, refuse, and other discarded solid materials, which is commonly made up of household waste such as plastics, plastic bottles, tins, cans, paper, and glass (AlSalem et al., 2009). The solid wastes might cause or contribute to increases in mortality, serious illness and environmental depletion, especially toxic chemical and heavy metal pollutions discharged from factories (Duan et al., 2008).

Tsai et al. (2004) indicated that the positive benefits of an increase of recycling programs that can not only reduce facilities required for disposal but conserve energy, cut pollution, and preserve natural resources. Furthermore, Hasome et al. (2001) explained that recycling unused products would save environmental and natural resources as well as minimizing greenhouse gas emissions.

Wilson (2002) reported that recycling of resources currently in the waste stream is an option that many municipalities have implemented in recent years. For example, in England, 37.6% of total waste going to landfill has been diverted from landfill through recycling programs.

3- Research Significance

The aims of this study was to describe the characteristics and performance of reusable construction solid wastes to minimize its environmental negative effect, and discuss how the green concrete would be able to achieve sustainable construction.

The present study includes a study of the production new mix designs of concrete which have been conducted may be used in construction of road field to make concrete production more sustainable, mainly focusing on reducing the consumption of natural resources.

This study focuses on estalish the using of construction waste on the properties concrete mixes and the ability of using this mixes on sustainable roads precast concrete blocks production.

4- EXPERIMENTAL

The present study was designed to investigate the replacement of the aggregates, sand and cement on the mechanical properties of the hardened concrete, and then focused on characteristics and analysis of concrete materials manufacturing.

4.1 Materials:

4.1.1 construction wastes

The construction wastes used in this study was brought from many local areas in Giza and Cairo.

And it were prepared in this study by manual crusher the it whashed by clean water then sevied it with a grain size of 1- 4 mm as showed in (figure 1 to 3).

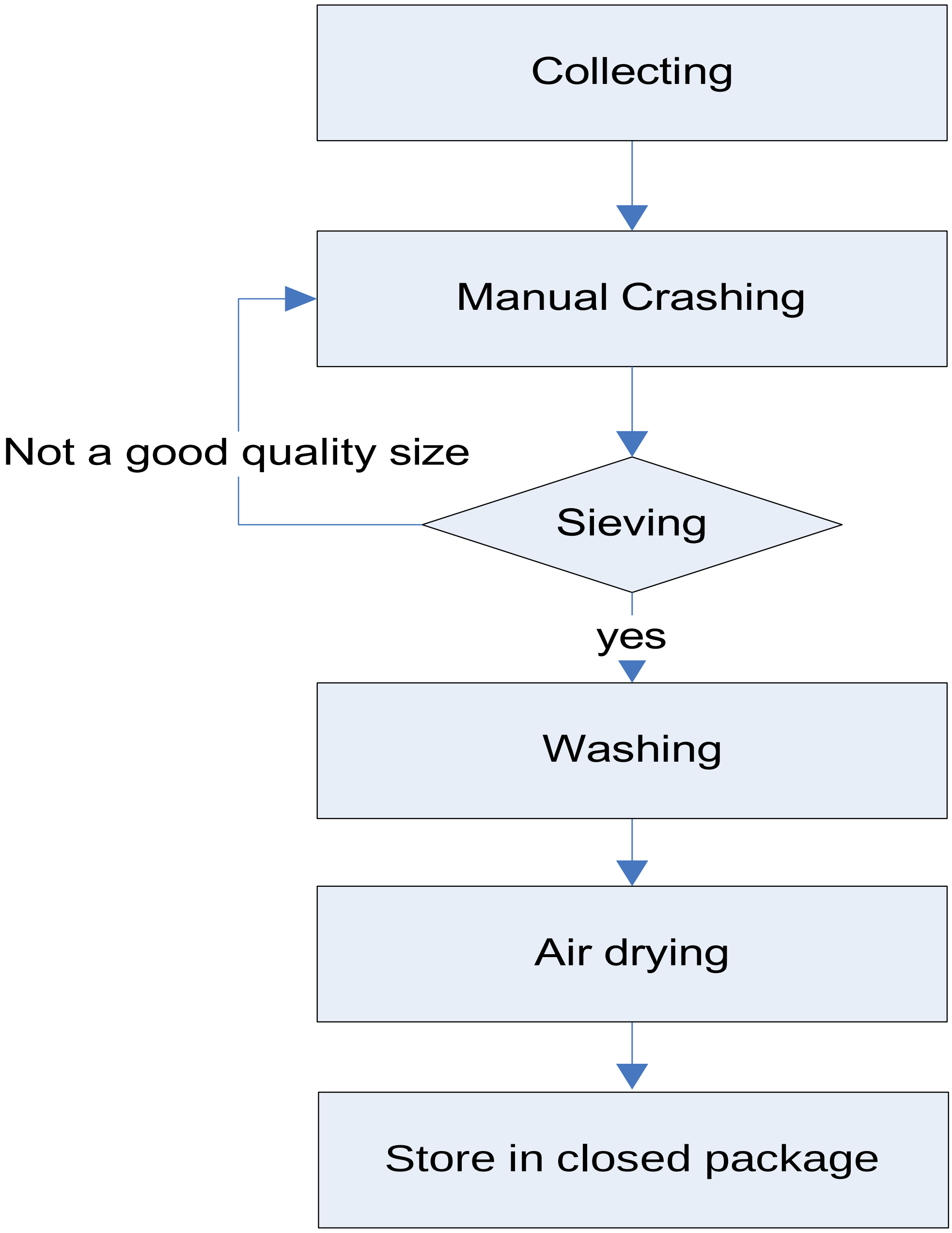


Figure (1):construction wastes prepartion processes

Figure (2):construction wastes collection locations

Figure (3):construction wastes after the preparion processes

The construction waste used in this study collected from many local areas in Egypt, the physical and chemical properties as Table (1) as following:

Test / Materials	Bulk density t/m³	Absorption %	fineness content %	Abrasion index %	Impact value %	Chloride content %	Sulphates content %
Demolition waste	1.2	5.5	0.8	36	31	0.017	0.02
Egyptian code limit	--	≤ 2.5%	≤ 3%	≤ 30%	≤ 45%	≤0.04%	≤ 0.6%

Table (1): Physical and Chemical Properties of Foundry Sand and Demolition Waste

Test	Chloride content %	Sulphates content %
Results	0.010	0.1
Egyptian code limit	≤0.04%	≤ 0.6%

Table (2) chemical properties of construction waste

The results of chemical analyses presented in Table 3 indicate suitable chloride and sulphate content of clay bricks waste. Chloride and sulphate content ranged from 0.011% to 0.04% of water-soluble clay bricks waste. Thses results showed that the chloride and sluphate conctent were less than the egyptian code limets .

bricks waste. Thses results showed that the chloride and sluphate conctent were less than the egyptian code limets

Test	Bulk density kg/m3	Water Absorption %	fineness content %	Abrasion index %	Impact value %
Results	1.2	5.5	0.8	26	31
Egyptian code limits	--	≤ 2.5%	≤ 3%	≤ 30%	≤ 45 %

As can be seen in Table 3, construction wastes had bulk denisty 1.2 t/m3 so The bulk density of construction waste is lower than that of natural aggregates. The lower value of loose bulk density of construction waste may be attributed to its higher porosity than that of natural aggregates. However, the construction wastes had nearly twice the absorption of egyptian code limte and were more porous. So abrasion results shows that construction wastes used in this investigation were lower than the limets of egyptian code. And the impact value is lower than egyptian code limets In this respect, construction wastes had a more uniform hardness compared to than for natural aggregates

4.1.2 Ordinary Portland cement (OPC)

The cement that had been used is ordinary Portland cement with nominal particle size of < 90 μm. The chemical composition and physical properties of Portland cement represent in Table (1,2)

Properties / Material	Initial Setting Time	Final Setting Time	Specific gravity
Portland Cement	72 min	178 min	3.16 g/cm^3

Table (4) Physical Properties of Portland cement

Properties / Material	Oxides (Weight %)									
	SiO_2	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**SO_3**	**L.O.I**	**Na_2O**	**K_2O**	**Cl^-**
OPC	20.78	5.19	3.65	63.41	1.18	2.48	2.63	0.32	0.34	0.03

Table (5) Chemical Composition of Raw Materials of OPC

4.1.3 Natural Sand

The crushed sand is mainly used as fine aggregates in concrete mixes and it came from Upper Egypt.

4.1.4 Water

Tap water used for both mixing and curing in mixes preparation

4.2 Testing Assisting Processes

4.2.1 Preparation of the Mixes

In this study is shown in Table (6) which measured the effect of replacement of the aggregates and sand by alternative materials as following mixes:

- M1: in which the natural sand, natural aggregates and cement were used
- M2: in which the natural aggregates was replaced by demolition waste and the other components as M1

Mix	OPC (g)	NS (g)	NA (g)	DW (g)	Water (g)
M1	3500	7500	11500	--	1800
M2	3500	7500	--	11500	2100

Table (6): Mix proportions.

Different mix designs were prepared in this study. These mixes are divided into three groups; the standard cubes of size (150x150x150) mm have been used in this study. For the compressive strength test, three cubes were tested at each age of hydration (7, 28 and 90 days) and the average value was recorded.

Fig. (4): Tested cubes

The mixing was performed using dry mixing for all materials followed by addition of mixing water after the dry mixing.

4.2.2 Testing

A. Curing

For different concrete mixes, immediately after molding, the cubes were cured in humidity cabinet (100%R.H.) at 37±2°C for 24h under water until the required time of testing; 7, 28, 90 days.

B. Stopping of the hydration

The stopping process created for the required time by collected the crashed cubes and put in oven (Technomedica) at 105°C for 3 hours

5- The results

5.1 Slump test:

The slump test was done during the first minute or immediately and after 30 minutes (STO and ST30) of the above mixes were given in Table (7)

Mixture I.D.	Slump test (cm)	
	STO	ST30
M1	16	12.1
M2	16	11.5

Table (7): slump test

The results declared that some samples have decreasing rate on the slump value than the other mixture.

These results may be attributed to the presence of recycled wastes material as replacement materials for sand and coarse aggregates, as show of mixes results during the first minute, the results may be as same in M1 and M2 as 16 cm, that was due to the uses of recycle aggregates has the same quality on the slump results which agreed with (Dimitriou,2018)

water absorption values for M1 and M2 were 2100 kg so the partially replacement may give more good results as reported by (Torres,2017).

The slump values at 30 minutes showed that all slump of all mixes decreased might be this due to the hydration reaction of cement on these trails and the change of the plastic state to be in hardened state.

The mix M1 have less decreasing if compared with other mixes and it show that the slump value 12.1 cm in other word it loss 3.9 cm of its slump value but in M2 it loss 4.5 cm to be 11.5 cm that was due to the fines as reported by (Parthiban,2017)

5.2 Setting Time:

The initial and final setting times were recorded as Table (8)

Mixture I.D.	Setting time (hours)	
	Initial	Final
M1	4.1	7
M2	4.2	7.3

Table (8): Setting times

The results showed that the mix M1 initial setting time was approx. 4 hours but final setting time was 7 hours that was due to the reaction of concrete component with water specially the cement which effect on it and other components like sand and coarse aggregates.

But the initial setting time of mix M2 showed that 4.2 hours thus the final setting time in mix M2 was 7.3 hours so to the above results the initial and final setting time was more than the M1 or control mix this may be explained by presence recycled fine and coarse aggregates which increased water – cement ratio led to increase the setting time.

5.3 Water absorption:

The mixes have been tested and all results were recorded in Table (9)

The principal mechanism responsible for water transport during the absorption process is hydrostatic pressure due to the capillary suction. Therefore, the microstructures of concrete, that is, the porosity and pore distribution or micro cracks play a crucial role in the velocity of water ingress. As mentioned above, the cracking direction and connectivity may also influence the speed of water penetration into the samples. Therefore, to fully represent the role of micro cracking, the main water absorption direction is made to be parallel to the compressive loading direction or perpendicular to the tensile loading direction.

Mixture I.D.	Water absorption (%)
M1	0.6
M2	0.93

Table (9): Water absorption results

The water absorption per unit density (1000 kg/L) for M1 and M2, were 0.6 %, 0.93 % respectively as shown in Figure (4-6). The effect of replace aggregates has been increased its water absorption as compared to that of control mix. However, the water absorption of M2 was slightly higher than M1 as shown in Table (10).

recycle aggregates as fully aggregates replacement material has been effect on its water absorption so the C-S-H gel formation has reduced the pore size which resulted in lower water absorption in M1.

The water absorption gives an idea of the total pore volume, but is not representative for the permeability of the concrete.

5.4 Compressive strength:

The compressive strength tests were conducted on the hardened concrete cubs after 7, 28 and 90 days of hydration. The compressive strength results of the hardened concrete mixtures were listed in Table (10) and the results of compressive strength were analyzed to study the effect of age on strength development

Mixture I.D.	Compressive strength (kg/cm^2)		
	7 days	28 days	90 days
M1	185	294	289
M2	170	267	265

Table (10): Compressive strength results at the different ages of hydration

The results were also compared to a control mixture in order to illustrate the decreasing in compressive strength as a result of full aggregates replacement.

In addition, the results of compressive strength were analyzed to study the effect of age on strength development

Table (10) clearly showed that all the concrete mixes made of OPC mixed with different type of aggregates have lower compressive strength than those control mix M1 at all curing ages (7,28 and 90 days).

For example, the concrete mix specimens make of mix M2 recorded a strength of 172 kg/cm2 at 7 days, while the strength of control mix M1 was 188 kg/cm2 at the same age. Therefore, the reason behind this strength not affected by full replacement of natural coarse aggregates by recycled aggregates as reported by (Dimitriou,2018) as the results in this study but (Özalp,2016) disagreed with the results and suggested that the recycled aggregates have direct affect in compressive strength due to the rate of water absorption which affected in strength processes.

However, concrete mixes produced at age 28 days which attained a compressive strength of 268 kg/cm2 for the M2 at the same age were collectively lower than the conventional control mix that displayed strength of 291 kg/cm2.

The compressive strength results for the mixes were slightly lower at 90 days of hydration than the results at 28 days like in M1 which recorded that 289 kg/cm2 and the other mixes showed as M2 recorded 265 kg/cm2,

5.5 Morphology and microstructure

Scanning electron microscopic (SEM) examination was carried on the hardened concrete mixes (M1 and M2).

This SEM study was done in order to analyze the microstructure of different hardened concrete mixes and to compare the results with the microstructure of the hardened control concrete mix M1.

Also the results SEM observation were used to confirm the results of other properties of the different hardened concrete mixtures such as ,normally, the results of compressive strength and water absorption.

5.5.1 Control concrete mix M1

The SEM micrographs of the control concrete mix (M1) after 7 days this figure displayed with porous structure that containing pores. Also it can be seen the existence of many $Ca(OH)_2$ crystals connected to the nearly amorphous C-S-H gel which indicate that the hydration process is not completed and also explains the low records of compressive strength for the control concrete mix (M1). Also, the same micrograph shows that the calcium silicate hydrates (C-S-H) gel was engulfing feel with calcium hydroxide (CH).

At the age of 28 days, the SEM micrograph shown in Figure (6) also indicates the existence of (C-S-H) hydrate needles and the more dense structure of the hardened concrete mix of M1 that matches the high strength results.

Figure (5) still showed the $Ca(OH)_2$ crystal needles and cracks for the mixture that is jointed to the C-S-H gel after 90 days of hydration , however, which also confirms the strength results reported in this study.

It is also noticed from the figures that both size and quantity of the needle like calcium silicate hydrates at the age of 7 days have been lessened at the ages of 28 days and 90 days which is due to the completion of the hydration process in order to produce more C-S-H gel. This explains the high results of strength for the hardened concrete mixes at the age of 28 days in comparison to the results at the age of 7 and 90 days.

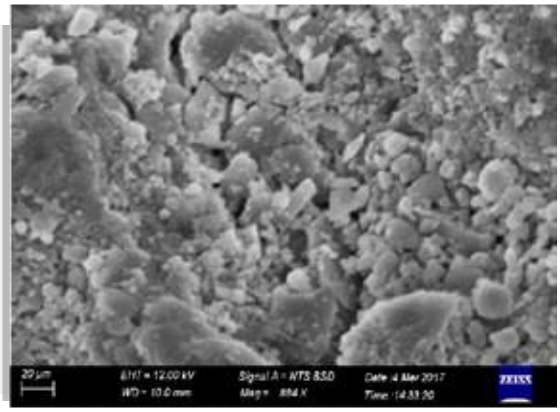


Fig.(5): SEM micrograph of the control mix M1 at 7days of hydration.

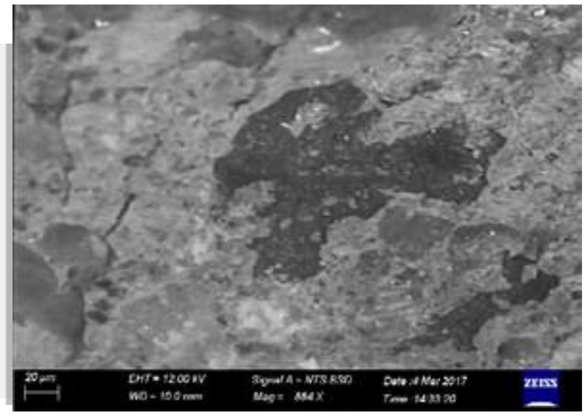
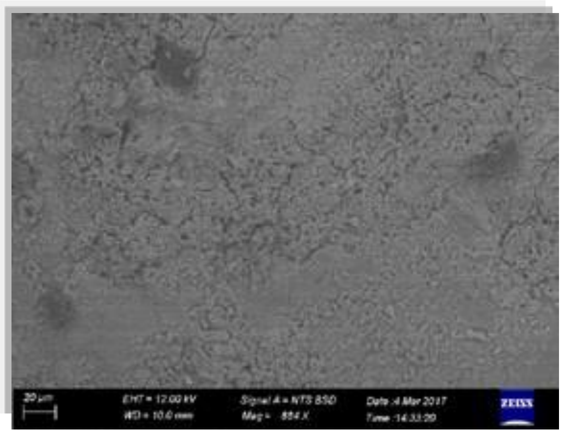


Fig.(7) : SEM micrograph of the control mix M1 at 90 days of hydrati



5.5.2 Concrete mix M2

The SEM micrographs of the mix M2 at 7 days showed that its structure has a moderate amount of pores as illustrated in Figure (38) and that the hydrate products is connected and lapped to a number of hydrate needles.

Also, at the age of 28 days, many cracks and voids were be seen in Figures (8) which match the compressive strength results and the justification that was mentioned before.

Also, the particles to form weak clusters that were used to explain the drop in the compressive strength for this particular particle size is increased can be clearly seen in Figure (8) which justify the low strength results at 28 days age.

Also, Figure (9) showed forming the weak clogs and hydrate needles for this mixture at the age of 90 days.

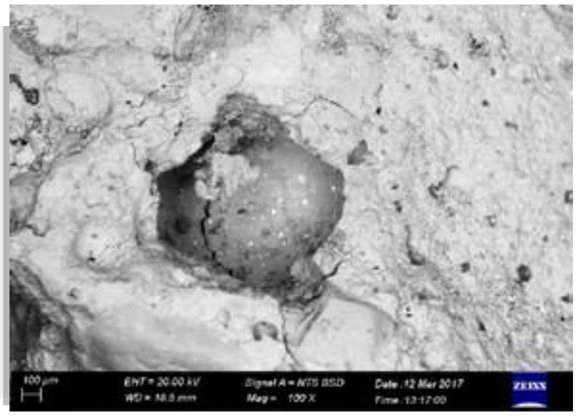


Fig.(8): SEM micrograph of the control mix M2 at 7 days of hydration.

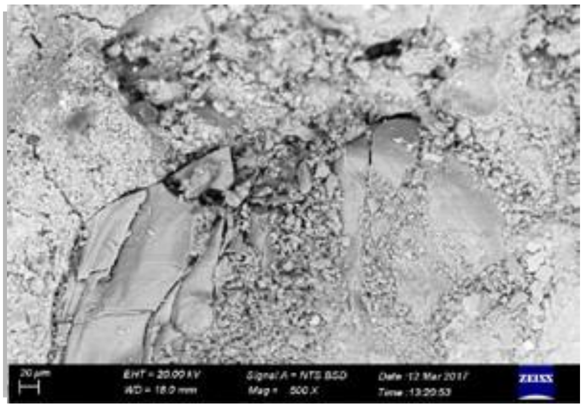


Fig.(9): SEM micrograph of the control mix M2 at 28 days of hydration.

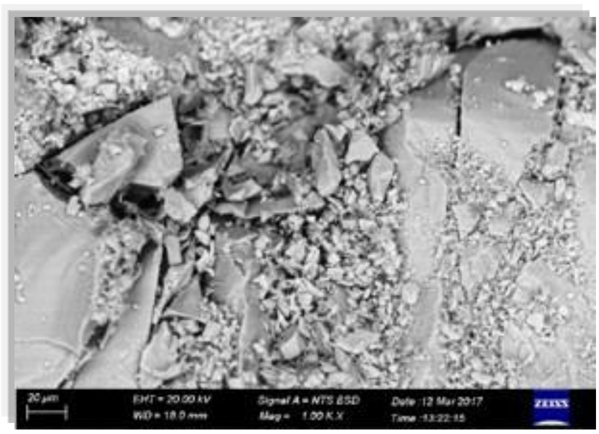


Fig.(10): SEM micrograph of the control mix M2 at 90 days of hydration.

6. CONCLUSIONS

Based on the scope, materials, techniques, procedures and other parameters associated with this work, the following conclusions can be stated:

1. The hardened concrete trials investigated possess equal compressive strength values on those of control hardened concrete trials exhibited relatively

2. The above wastes caused a great amount of environmental pollution so by reusing and recycling of these waste materials as raw materials in the manufacturing of industrial brick and other composite materials have a great contribution to the economy and to the environment by minimizing polluting effects coming from different plants.

3. Based on the results of this study, the following conclusions can be drawn; In general, the addition of wastes played significant changes in the relevant functional characteristics like decreasing the compressive strength results so the mechanical properties of bricks were affected remarkably.

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Life Cycle Assessment of Concrete Maintenance Effect on the Environment and Sustainability

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Abstract

Construction is considered one of the main consumers of resources and energy as well as the most damaging to the environment, generating one of the largest amounts of CO2. Cement, an important component of concrete, is one of the most widely used construction materials in the world, and it is solely responsible for about 7% of CO2 emissions. This highlights the importance of quality control, maintenance, and sustainability in preserving the current built stock and extending the life cycle of the standing structures, also ensuring that their impact on the environment during their utilization is kept minimal.

Maintenance is important where there are critical factors influencing the durability of buildings. Such factors include deleterious substances, sulfate and chlorides, and hot weather. For example, high temperatures greatly accelerate the effect of all these factors and, consequently, reduce the life span of the concrete if proper precaution is not taken. Building maintenance and durability have attracted the recognition of professionals and academics in this field for their ability to elongate the lifespan of the building and achieve sustainability. Recently, there has been more awareness of environmental issues and the importance of maintenance and quality control as a tool for sustainability.

This paper shed the light on the trends and advances in sustainability regarding concrete; it elaborates on the durability and deterioration of reinforced concrete structures. It emphasizes the importance of maintenance and repair of existing structures as part of the sustainability and extension of the life cycle performance and serviceability. Finally, it conducts a life cycle analysis to compare the periodic maintenance and reconstruction of buildings.

Keywords

Sustainability, Maintenance, Durability, Life Cycle Analysis, Advanced NDT

Introduction

The construction industry is one of the largest materials consumers in terms of energy and resources. Many processes are associated with this depletion, such as the energy consumption and waste generation of the production of the cementations binder and associated reinforcing steel, the mining and transport of aggregates, as well as the transportation of the mixed concrete to the job site. Most of the negative environmental impacts of construction materials, especially concrete, occur during the manufacturing of the material. The production of concrete materials, such as Portland cement, is energy intensive and causes environmental pollution [1]. It is responsible for consuming approximately 7% of the total global emission of CO2. Thus, concrete production has a great impact on both the local and global environment.

In the 1960s, the compressive strength of concrete was considered the most important parameter. However, twenty years later, durability became more important. Nowadays, serviceability and sustainability are the most interesting topics for researchers and materials scientists. Fig. 1 shows the change in interest through the years of concrete development.

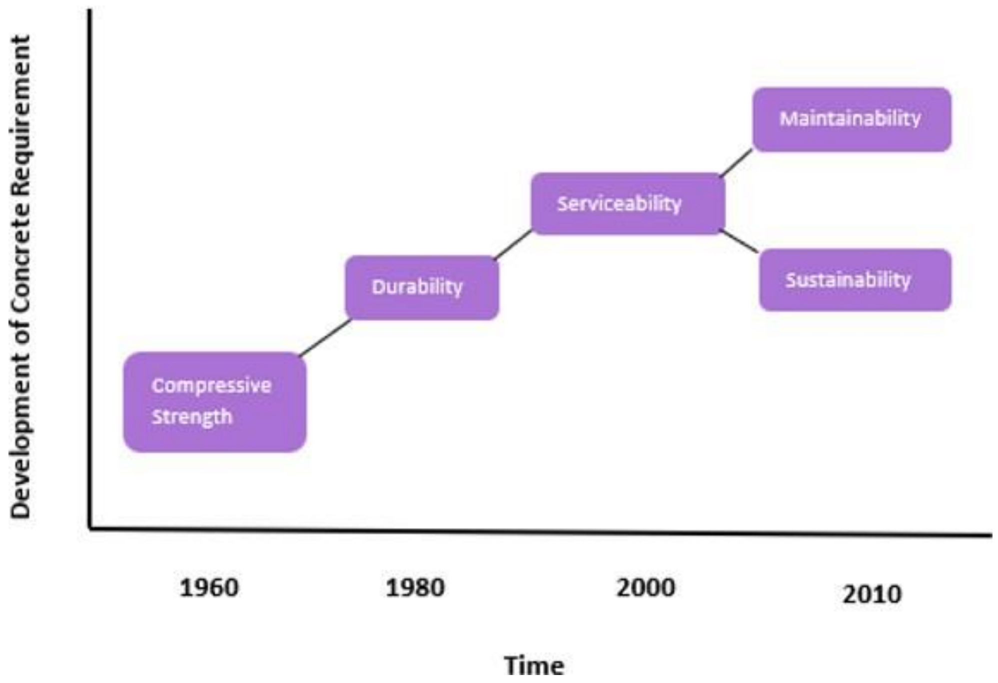

Fig. 1 Since 1960 the concrete development requirements shifted from compressive strength to maintainability and sustainability.

Concrete is generally believed to be a highly durable construction material once cured, but it is still prone to deterioration during its life cycle. Concrete is prone to several attacks, threatening its long-term durability. Physical attack, chemical attack, sulfate attack, leaching, and alkali aggregate reactions are the major factors that affect the stability and durability of concrete [2].

Deterioration of concrete structures certainly results in higher environmental harm and economic loss and more waste if the structure is beyond repair. This could lead to new construction if the function of the structure is still required.

Under such circumstances, the requirement for appropriate monitoring, maintenance, and repair strategies is particularly important to ensure that structures remain both functional and economically viable all through their design life and beyond. It is a fact that a comprehensive routine maintenance program can increase the life span of the concrete structure and thus, potentially contribute towards sustainability in the long run. A major repair is expected to cost much more than routine maintenance, and an all-out replacement can cause much more folds than a major repair. Regular maintenance and repair of concrete structures ensure that the environmental impact during their life cycles is minimal from the viewpoint of durability [3,4].

Construction Lifecycle and Sustainability

Deterioration of reinforced concrete structures has emerged as one of the most difficult challenges in the construction industry, regulatory agencies, and society. Therefore, an appropriate design for durability, regular maintenance, and repair is vital for long-term performance of concrete like environmental protection, infrastructure protection, and maintenance require the efforts and resources of the present generation.

Construction practices were always based on Cost, Time and Quality, but recently, three more factors are considered, which are, Human satisfaction, Environmental impacts as well as Materials and Energy consumption. The reason for these changes is the increasing attention given to the sustainable design. Figure 2 shows the new introduced aspects of construction.

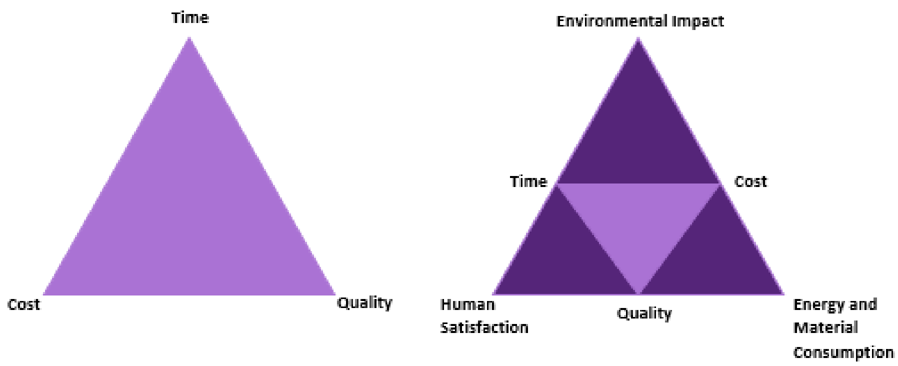

Fig. 2 Environmental impact, Energy and Material Consumption and Human Satisfaction are new aspects considered in the construction

in the construction

Sustainability is a very important pillar in the construction industry, especially in the present conditions of a rising greenhouse gas emissions, it incorporates three important dimensions which are ecological, economic, and social. It aims to meet the present-day needs for housing, working environments, and infrastructure, without compromising the ability of future generations to meet their own needs as well [5].

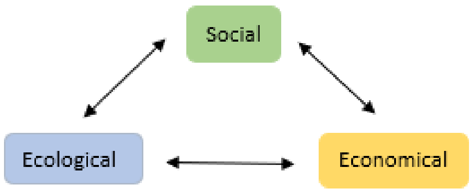

Fig. 3 Interactions between Three sustainability pillars

Ensuring sustainability entails an equal implementation of its pillars which are ecological, economic and social as shown in figure (3). The importance of the interaction between economic, social and ecological sustainability are described below:

1) Ecological and Economical: The growing economical projects and investments depend on the resources from the environment. Thus, they affect the environment in different ways by depleting resources and pollution.

2) Social and Ecological: The ecological system provides access to natural resources (food, water, air, soil, energy and so on.), well-being and working conditions and contributions to health. So if the consumption continues to grow unsustainably, it might result in negative environmental impacts, such as bad effects on health, thus, lowering the quality of life.

3) Social and Economical: The economy will provide jobs while the human factor will provide productivity based on the quantity and quality of employers.

Ecological sustainability goals are resource protection, ecosystem protection and human health protection. The Effective protection of the ecosystem can be achieved by minimizing and eliminating wastes and preventing emissions to air, water, and soil. Protection of sensitive ecosystems is achieved by maintaining good construction practices and supervision. Natural Resources such as land, material resources and fossil fuel are depleted. They can be protected by reducing energy consumption in sites, designing for whole-life costs, use of local supplies and materials with low embodied energy, use of recycled materials, as well as water and waste minimization and management [6].

Economic sustainability is the ability of an economy to indefinitely support a defined level of economic production. Its objective is to maintain high and stable levels of local economic growth and employment. In construction, the most important sector, is the Life-cycle costs, such as the costs before and after the use of the building, maintenance and repair costs and operational costs [7]. Social sustainability is concerned with social progress, which recognizes the needs of the whole community, such as employment, stability and health.

3 Maintenance as a Tool to Enhance Concrete Life-Cycle

Sustainable Construction implicates many issues in buildings design ,and management such as materials performance, construction technology and processes, energy and resource efficiency in building, operation and maintenance, robust products and technologies, long-term monitoring, adherence to ethical standards, stakeholder participation, occupational health and safety as well as working conditions, innovative financing models, improvement of existing contextual conditions, interdependencies of landscape, infrastructure, urban fabric and architecture, flexibility in usage of building, function and change, and the dissemination of academic-related, technical and social contexts.

In civil engineering, sustainability is an emerging term regarding planning, designing, maintaining, and operating concrete structures. Sustainability all about the efficient energy use, through conservative measures, such as maintenance and repair of existing structures; using renewable resources during construction; minimizing waste; reducing, recycling, and reusing of construction materials and products optimizing the resource usage. Therefore, sustainability in concrete structure can be achieved in two ways (a) using green and energy-efficient material and green technologies when constructing the structure; and (b) preserving the already constructed structures by regular maintenance and repair. Sustainable advantages in terms of durability, cost, energy and cultural responsibility can be achieved by maintenance, repair and proactive protection [7].

Sustainable buildings provide direct economic benefits to all parties involved, by having a lower annual cost. The cost of energy, maintenance, repair, water, reconfiguring space and operation. The reduced annual costs do not change the fact that sustainable building needs a higher first cost than traditional buildings, but by using integrated design and low cost of sustainable materials and equipment, the first cost of the sustainable building will be the same or even lower than the cost for the traditional one. Some features will still have a higher first cost, but the life cycle cost is usually lower than that of traditional building. Moreover, sustainable buildings provide indirect economic benefits from having a longer building life cycle, lowering the risks, reducing the expenses of dealing with claims, attracting new employees, reducing costs from air pollution damage, and lowering infrastructure costs, by avoiding wastewater treatment plants for example [8,9].

Preventative Maintenance is performed to minimize or to avoid the need for repairs [10]. In some cases, the original design includes measures to protect the building, but in most cases, these measures are not included. Regardless of the lower life cycle impact that will occur on the long term, the reason for that is to reduce the initial construction cost. For example, in the arid and semi-arid regions, where severe weather conditions occur, many structures deteriorated due to material quality or design problems. Some buildings deteriorate as they were built to carry less loads than they actually do, or due to the accelerating construction works as they go faster to reach their completion time, ignoring some design standards. We can see that preventative maintenance is very important and should be done even if it's not included in the design. Fig 4. Show how including multiple repair cycles can increase the age of the building after it is exposed to any form of chemical attack or damage [11].

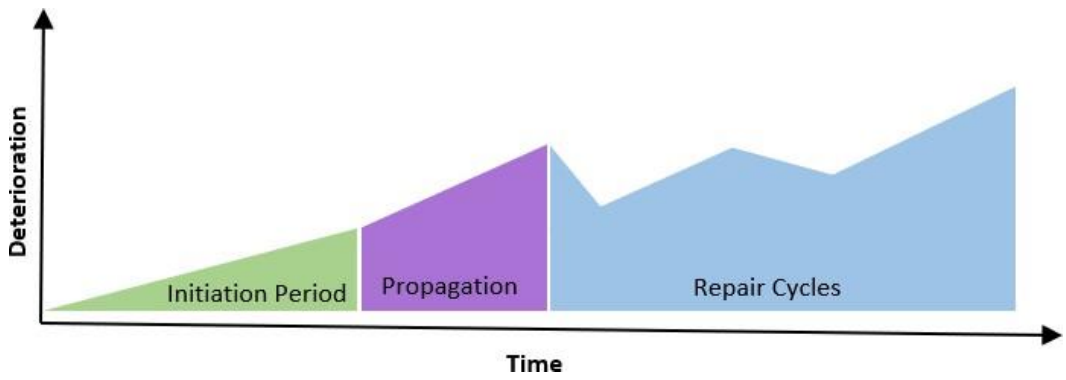

Fig. 4 Regular maintenance can lead to sustainability by increasing the age of the building

4 Non-destructive Techniques for Maintenance and Assessment of Concrete Structures

One important aspect of preventative maintenance to be considered is the periodic evaluation of the building. This can optimally be done by the use of non-destructive techniques. Maintainability of structures through non-destructive, modern monitoring techniques, especially for high-rise concrete structures, is very important. These modern monitoring technologies should be incorporated into the building design to facilitate its maintainability later on [12].

During the last years, there has been a continuous increase in the use of non-destructive testing (NDT) applied to many aspects related to the civil engineering field. This is mainly because most non-destructive methods work from a distance without direct contact with the structure. They provide a clear visualization of the object under study in terms of its structural capacity. The deterioration and condition of the reinforced concrete under the surface cannot be assessed by traditional visual and optical inspection. Alternative non-destructive methods have been developed for sub-surface inspections, including pulse propagation, magnetic, electrical, and electromagnetic as well as thermography and ground penetrating radar and infrared thermograph for the nearest sub-surface.

One of the most emerging techniques is using Unmanned Aerial Vehicle (UAV) and applications of photogrammetry. Photogrammetry is defined as “the art, science, and technology of obtaining reliable information from non-contact imaging and other sensor systems about the Earth and its-environment and other physical objects and processes through recording, measuring, analysing and representation”. It includes any type of sensors and cameras application used to obtain information. UAV is an aircraft which is is operated without an aircrew aboard and is instead controlled by a remote control or autonomously by on board computers [13]. Fig. 5 show an example of a UAV and NDT system.

Fig. 5 Example of a Drone (UAV) equipped with an NDT system [16]

Photogrammetry and UAV in civil engineering is almost unlimited. It could be used as a standalone system or jointly with other non-contact imaging data methods such as radar, LIDAR, holography and remote sensing. It could be used in architectural photogrammetry, information systems such as GIS and building information modelling (BIM) [14]. Deformation measurement and cracks opening during laboratory tests on structure and structural elements, crack measurement and monitoring, deflection beams, elongation in reinforced concrete real structure data acquisition and documentation such as bridges load testing, obtaining detailed geometries for computational structural models and visual documentation and modelling of actual symptoms (fissures, breaking, cracks or collapse) measurement of geometric and structural elements in bridge routine inspection Close range photogrammetry is employed for historic bridge documentation and routine inspection in bridge management.

5 Life Cycle Stages of Baseline Structures and Green Buildings

Every product or building process, whether a normal baseline construction or a green building system, goes through various phases or stages in its life. It starts from material acquisition, then manufacturing and/or construction, use and maintenance, and end-of-life. Material Manufacturing includes the removal of raw materials from the earth, transportation of these materials to the manufacturing location, manufacture of finished or intermediate materials, engineering Materials production and fabrication, and packaging and distribution of building products. Construction accounts for activities relating to the actual construction of a building or structure. It includes transportation of materials and products to the project site, use of power tools and equipment during construction, on-site fabrication, and energy used for site work [15].

The use and Maintenance stage refer to building operation, which includes energy consumption, water use, and environmental waste generation. It also considers the maintenance and repair of building assemblies and systems. The efficiency and planning of the phase will not only elongate the life span of structures but also will keep them functional and useful for a longer period. At the end of the service life of structures, the building demolition and disposal of materials to landfills will add to energy consumption and to the environmental waste produced. The efficient use of recycled products and their reuse will be an asset and be considered as a positive impact and an asset to sustainability.

The described life cycle applies to both the normal baseline construction and the green building structures. However, the use of energy modeling is at the heart of the LEED rating system and, as such, is becoming more widely used as a building design tool. The reduction of both the embodied and operational energy consumed by the buildings is part of the Life Cycle Assessment and an essential tool to reduce Carbon Emissions and hence Global Warming [16].

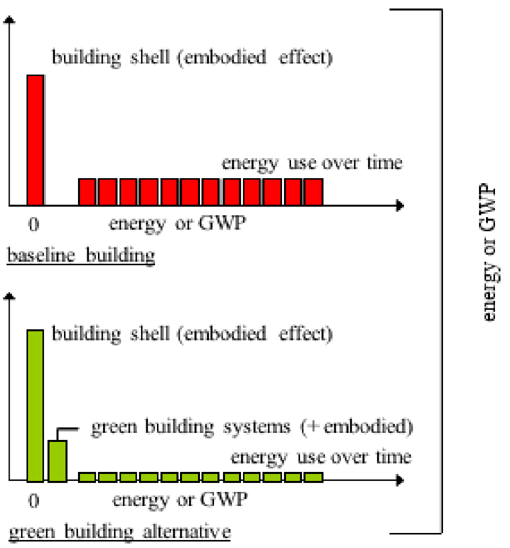

Fig. 6 Comparison of the embodied effect baseline building and green building

The embodied and operational energies of the baseline building have the smallest embodied energy but use more energy over time. The green building alternative includes additional embodied energy from systems like high-performance insulation and glazing and photovoltaics however, over time, the energy embodied in the green build systems is "paid back," and the overall impact of the green building, embodied and operational, becomes less than that of the baseline building as shown in Fig. 6.

6 Construction Life Cycle Assessment: Case Study

It is believed that periodic maintenance of concrete will lead to many advantages in terms of achieving sustainability and reducing the harmful impact on the environment. Life cycle assessment (LCA) is a versatile tool for quantifying, evaluating, comparing and improving the environmental impact any product during their life cycle, and it has been widely adopted [17,18]. A detailed Life Cycle Assessment study to evaluate the emissions and energy consumption associated with Concrete production can prove this concept. This section will present a small-scale LCA study for a G+2 building of a volume of 50000 m3. The building is assumed to have an essential purpose to the government and can't be replaced. Data were collected from multiple resources including actual cases and interviews. The inventory of the study is summarized in the following table:

Table 1 Life Cycle Inventory of both case scenarios

Type	*New Construction Expenditure*	*Maintenance Expenditure per 10 years*
Energy (Electricity and Heat)	1000 MW.h	30 MW.h
Fuels	100,000 kg	3,000
Building Material	15,000,000 kg	500,000
Water	3,000 kg	100 kg

The functional unit (FU) is having the building lasts for 50 years. A comparison between 2 cases will be evaluated. The first case is to do zero-maintenance and intend a whole new construction after 25 years. The second case is to apply overall evaluation and maintenance every 10 years to support the same building to stay for 50 years.

The system boundaries include the raw material extraction and processing, energy consumption, transportation, vehicle and equipment use and mobilization as well as construction operations. Processes like equipment manufacture and waste management were excluded from this study. Boundaries of the study doesn't include the initial construction; it will compare between the case of whole reconstruction and periodic maintenance impact.

The LCA aims to assess the potential environmental and health human impacts related to each building case. CML-IA methodology was used to evaluate the impact assessment in this study. The impact was evaluated in terms of Acidification, Eutrophication and Climate Change.

Fig 7 summarizes the environmental impact comparison between establishing a new construction and implementing periodic maintenance at 50 years. A clear advantage of reducing negative emissions is to the application of periodic maintenance.

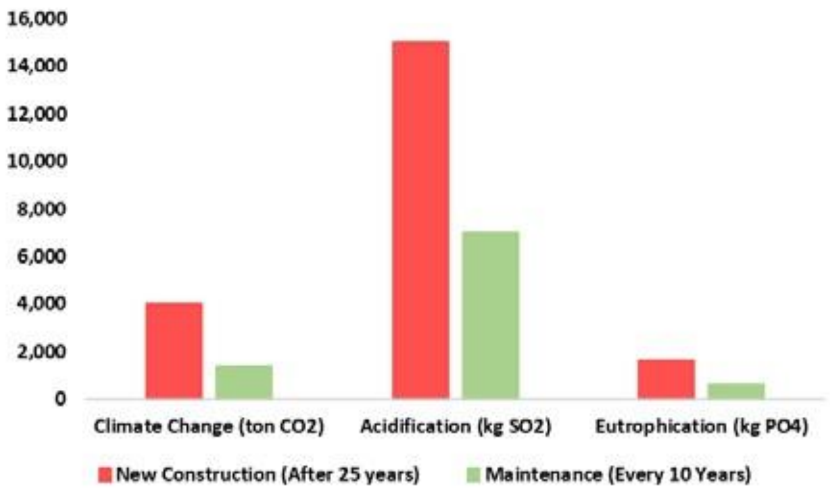

Fig 7 comparison of the environmental impact of applying periodic maintenance and reconstructing of the same building

7 Conclusions

Maintenance is defined as the process of keeping a facility in such a condition that it may be utilized safely at its original capacity and efficiency for a longer life span. This is in a way is the key to sustainability in its simplest definition of being economical, beneficial to the society and preserving the environment. Academics and professionals became more aware of the importance of maintenance and is making big strides towards implementing sustainability and green buildings. It is believed that within less than two decades there will be no market for any products and utilities that will not adhere to the bylaws and guidelines that will enforce them.

We recommend that periodic maintenance of structures must be part of the design insuring that areas which are difficult to access can be monitored and maintained easily without the need of complicated procedures as maintenance have proven to have many advantages in terms of reducing the overall cost and the negative impact on the environment. Life Cycle Analysis studies can support this claim by analysing the impact and costs of the building over its overall life cycle.

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Drones' Inspection and AI Usage for OHL Supply and Demand Stability and Reliability in NGSA by Predicting Failures

OM23 119

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Abstract

Overhead lines in National Grid SA are a major source of failures in the transmission network. Spacer damper, connectors, insulators, bolts…etc.; around 14 items configure the tower equipment. Any item failure could make many losses within the NG, causing damage to network power stability and availability. Due to the importance of failures of items in the OHL network and the difficulty in the southern NG SA network, a technical study was conducted throughout the maintenance TSD lead by Eng. Mohammad Hussain concluded the use of an unmanned aerial vehicle (UAV). This technology was new to the region in 2014, studied by different teams, and discussed with a different approach. This paper would highlight the most effective solutions for UAV use as DRONE and the sensors used, contesting for the output and the benefits of the project, and its impact on the network stability and reliability. Finally, the paper will describe the possible development in the DRONE use for maintenance inspection with an artifactual intelligence (AI) to do the analysis, recommend a proper action, and record the reading as a history of the health of a certain item. The possible future application and changes that come with it are huge, considering the next step.

KEYWORDS

DRONE, unmanned aerial vehicle (UAV), artifactual intelligence, maintenance inspection.

I. INTRODUCTION

In NG, power transmission lines link power plants and the points of consumption through substations. Most importantly, assessing damaged power lines and rusted conductors is extremely important for safety; hence, power lines & associated components must be periodically inspected to ensure the supply and identify faults & defects. To achieve these objectives, recently, Unmanned Aerial Vehicle (UAVs have been used in the southern area; in fact, DRONES provide a safe way to bring sensors close to OHL and their components without halting the equipment during inspection and reducing cost and risk. In this project, a drone, equipped with multi-modal sensors, captures images in the infrared, visible and ultraviolet domain. Finally, transmits them to the ground station. For the project it used inspection experts to analyze and highlight all expected faults (i.e., hot spots) or possible damaged components of the electrical infrastructure (i.e., damaged insulators).

II. DRONE PROJECT

The drone project was derived from the enthusiasm of implementing new technology into the maintenance inspection work done by ground and elevated inspection teams. Started by categorizing the project area into segments regarding the history of maintenance and importance for the network. Covering 4000 km circuit length by inspecting two types of drones as mentioned in table 2 in appendices. The sensing technology used is the IR thermal, Ultraviolet, and LIDAR sensors, discussed afterward.

III. SENSING TECHNOLOGY

It is tempting to say that the main subject of sensing technology covers all aspects; however, table 3 in the appendices shows the technology used to sense any failures. The four most Effective sources of sensing are discussed in the following context. Those are covering most fault items, as shown in Table 3 in the appendices. Table 1 shows different applications covered in the Drone project.

I. Optical Image Sensing

It includes methods within which a picture provided by a camera is interpreted by computer analysis to detect, spot, or identify specific conditions.

Different camera systems can provide image representations in visible, infrared, or ultraviolet spectral bands, and each of these bands has advantages for detecting different conditions or defects. Other various methods for positioning or deploying imaging cameras, with some choices more suitable for detecting certain kinds of defects. Optical imaging is an automated analog of visual inspection methods and has potential applications for a high percentage of the OHL components to be inspected. Computer analysis of images to detect specific conditions or abnormalities is widely employed in manufacturing and other structured areas where images are obtained with consistent lighting, viewpoint, magnification, and other factors. Outdoor images analysis with wide variations in illumination is more complex, but adaptive methods are available to compensate for changing conditions of shadow & sun. Statistical methods are used to minimize the effects of slowly changing artifacts such as shadows and glare spots and normalize image intensity. Computer analysis typically consists of several steps:

1. Image capture using color, monochrome, ultraviolet cameras, or infrared. If an analog camera is used, images are converted then to a digitalrepresentation in a digital camera internally or by a frame grabber.

Table 1 Summary of application covered

Application		Optical	Infrared	Ultraviolet	LIDAR
Mechanical/structural Integrity	Tower structure	ü	x	x	x
	Hardware	ü	x	x	x
	Connectors, Splices	ü	x	x	x
	Conductors	ü	x	x	x
Electrical/Operational Integrity	Connectors, Splices	x	ü	x	x
	Conductors	x	ü	x	x
	Insulators	x	ü	ü	x
	Transmission Line Surge Arrestors	x	ü	ü	x
Clearance	Trees	ü	x	x	ü
	Avian	ü	x	x	ü
	Encroachment	ü	x	x	ü
	Line Sag	ü	x	x	ü
	Galloping Conductors	ü	x	x	x
Security	Tampering (in the process)	ü	x	x	x
	Tampering (Result of)	ü	x	x	x

2. However, to remove image noise, normalize illumination, or enhance image contrast, a filtering step is usually included.

3. The image is segmented to identify regions corresponding to a physical object such as towers, insulators, conductors, or trees. Segmentation algorithms may be based on finding corners or other shapes of edges. Segmentation may also be based on differences of color or differences in image texture or other patterns.

4. By describing a set of features, each object identified in the segmented image is characterized. These feature sets include intensity, area, perimeter, shape, color, and connections to other objects.

5. To identify specific types of objects, feature sets are matched against a database. For example, while a long thin object with no connection to other objects could be classified as a conductor between towers, a large green object with a generally round shape would be classified as a tree or bush.

6. Finally, the analysis of each object is done by comparing the conditions specified in the database with specific characteristics of the observed object. In the case of a conductor condition might be the absence of a marker ball or the amount of mid-span sag, while for a tree or bush, the comparison might be related to the position in the right-of-way.

7. If certain conditions are met or not, the computer system will signal to an operator for corrective action.

The condition of transmission lines changes slowly, and there is a relatively low level of activity on and around a line. This may make the processing of images more feasible. However, many of the conditions being inspected for are hidden from clear view or require multiple lines of sight, making it difficult. Summary of Cameras specifications shown in table 4.

Table 4 Summary of Cameras specifications

Physical interface requirements	Optical methods are non-contact. To increase the stand-off distance, cameras can be equipped with telephoto lenses though this reduces the field of view. Also, to provide large scene overviews and highly magnified views of critical locations, zoom lenses can be used.
Image format	35 mm full size (35.9 mm × 24.0 mm), CMOS image sensor Effective pixel number of camera: Approx. 42 400 000 pixels
Power requirements	Battery pack: Rechargeable battery pack NP-FW5. Approx. 3.2 W
Size/weight	The Sony camera will be considered typical for this group. It is 126.9mm x 95.7mm x 60.3mm and weighs 625g.

II. Infrared Image Sensing

Infrared cameras are sensitive to longer wavelengths than conventional color cameras. The most useful infrared band for transmission line inspection is long-wave or thermal IR, from 8 to 14-micron wavelength. Early thermal infrared cameras used a single detector with a scanner to build up an image, but current systems use microbolometer arrays and quantum well devices fabricated with a typical resolution of 320 x 240 pixels. Today, many infrared camera systems are designed for operators conducting thermal surveys and include image enhancement software and an LCD viewing screen. Most are intended for use at a fairly short range, and long focal length lenses (made from germanium) are expensive. Radiometric cameras are calibrated so that accurate surface temperature can be read from the thermal image. Non-radiometric cameras indicate relative temperature but do not give an absolute temperature. The amount of infrared radiation from a source depends on the temperature of the surface and the emissivity of the source. Very smooth or shiny surfaces emit a smaller amount of radiation than rough or dull surfaces. Accurate temperature measurements require knowledge or assumptions of the surface emissivity. When the surface condition is unknown, it is still possible to spot hot spots by determining temperature differences while the absolute temperature can't be measured. IR cameras are often classified as cooled or uncooled. High-end thermal IR cameras often provide a Peltier or compressor system to cool the detector to reduce thermal noise. Uncooled cameras are typically less expensive, smaller, and have less power but are less sensitive and have more image noise. Costs for thermal infrared cameras range from $7K to $50K reckoning on the features, resolution, accuracy, and lenses included. In the OHL inspection systems, thermal IR cameras are most often wont to identify hot spots caused by leakage current dry band arcing on insulators or failing connections, e.g., splices o dead ends compression connectors. Summary of used IR Sensor specifications shown in table 5.

Physical interface requirements	As an optical method, thermal IR imaging is non-contact. Stand-off distances can range from several feet to several hundred feet if telephoto lenses are used.
Image format	Thermal Image is Uncooled VOx Microbolometer Photo Format JPEG, TIFF, R-JPEG Video Format 8 bit: MOV, MP4 14 bit:
Power requirements	22.8V from Drone M210 battery type LiPo 6S
Size/weight	Dimensions With 25 mm lens: 123.7×112.6×127.1 mm With other lenses: 118.02×111.6×125.5 mm weighs 629g.

III. Ultraviolet Image Sensing

Charge-Coupled Device (CCD) imaging arrays can be optimized to detect ultraviolet light by making the silicon substrate very thin and directing the incident radiation onto the back surface. This overcomes conventional front-illuminated CCDs' performance limits by illuminating and collecting charge through the back surface aloof from the polysilicon electrodes. Ultraviolet cameras, sensitive to wavelengths shorter than the color spectrum, are widely employed in astronomy and for inspection of silicon wafers. The first use of UV cameras in OHL inspection is to locate corona sources. one among the difficulties of detecting corona on OHL is that the large UV content of radiation is way greater than typical OHL corona sources. To spot corona outdoors within the daytime, it's necessary to filter the light to use only a narrow band of the UV spectrum (250–280 nanometers) where solar UV is absorbed by the atmosphere. Cameras using this method are termed "solar-blind." Several manufacturers supply UV cameras for use in OHL inspection. These are typically intended to be hand-held or mounted on a tripod. The operator will direct the camera at a potential corona source and observe an LCD screen to see if a UV source have presence. The cameras include controls adjusting the sensitivity & software measuring the intensity of corona by counting photon events. Cameras obtain images at both ultraviolet and visible wavelengths that can be combined in the display are available. This provides the operator with the ability to locate the UV source with scene features accurately. While this is very useful to operator inspections, it should have less value to automate systems that will probably include a separate visible camera from the UV. The Summary of the used Ultraviolet Imaging sensor specifications is shown in table 6.

Table 6 Summary of Ultraviolet Imaging sensor specifications

Physical interface requirements	Absolute – at all sunlight and all weather conditions, the target can be inspected with the sun in the field of view /Minimum Discharge Detection1pC @ 15 meters/Minimum UV Sensitivity 1.9 x 10-18 watt/cm²
Power requirements	7.5÷30 VDC, 14 Watts
Size/weight	Weight 1.4kg / Dimensions L x W x H L245 x W125 x H101 mm

IV. LIDAR

Light Detection And Ranging use the same principle as RADAR. The LIDAR is an instrument that transmits light out. It uses this light to target where a portion of the light is reflected back to the instrument. Finding the time for light photons to travel out to target and back to the LIDAR instrument, is used later to determine the range to the target. The simplest instruments are single-point LIDAR distance rangefinders. These have recently found their various consumer uses, such as distance to golf holes space, the dimensions of rooms, the dimensions space of parking lots. This consumer market has lowered cost of simple laser rangefinders. Typical laser rangefinders range up to 3000 feet and have a range accuracy of +/- 3 ft. These are typically hand-held devices without data interfaces and require modifications in an automated measurement system. More complex LIDAR systems use an optical scanner to direct the laser in fans or raster patterns, it then measures length over a line, or use two for an area. These systems are often combined with GPS/Inertial navigation technology to confirm stability. Also, to uniform measurements. LIDAR systems are also used for spotting encroachment measuring the height of objects or movements into the right of way ground. If the system is deployed on a line-crawling robot, a line scanning LIDAR, like airborne systems, it could construct a swath's elevation profile under the line. Any points that rise above reference level over a specified amount it would be spotted as encroachment. Utilities currently use LIDAR to map their right of way and determine the conductor's position. They do this infrequently and use the results to design new lines or determine whether their lines meet the NGSA conductor to ground clearance requirements. The Summary of used LIDAR sensor specifications is shown in table 7.

Table 7 Summary of LIDAR sensor specifications

Physical interface requirements	10 mm survey-grade accuracy scan speed up to 200 scans/second measurement rate up to 500,000 meals./sec (@ 550 kHz PRR & 330° FOV) operating flight altitude more than 1,000 ft field of view up to 330° for practically unrestricted data acquisition regular point pattern, perfectly parallel scan lines
Power requirements	11 - 34 V DC / typ. 60 W
Size/weight	Compact (227x180x125 mm), lightweight (3.5 kg), and rugged

IV. RESULTES AND BINIFITES

The project results are reviewed per segment and helped discover a borderline to do the necessary maintenance. Drone-based inspection of transmission assets involves two key steps drone operations and expert analysis and solution.

Drones are equipped with sensors based (e.g., visual, thermal, UV, LiDAR) on failure modes to be tested. Drone operations provider pilots conduct flights using multi-rotor or fixed-wing drones. The pilot and expert teamwork to predict faults in asset images, then faults are reported to the maintenance team for repair and recorded. The southern region was selected for drone pilot due to the following reasons:

1. Mountainous terrain with difficult to reach areas, making manual inspection either extremely slow or unfeasible
2. Old assets that had not been inspected in a long time
3. A high-security area with safety risks
4. unclear instructions and share with them investigating results.

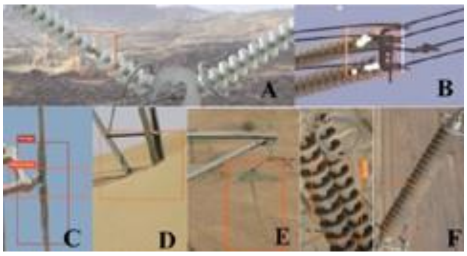
Operations for the drones pilot started in July 2018 and were completed in April 2020 (18 months). Drones pilot is planned to cover ~4,000 km of high voltage (380kV) transmission lines in the southern regions of Asir, Jizan, and Bahah. The pilot-scale and technical requirements were extensive, covering multiple drone types and sensors. The pilot led to three key tangible benefits across safety, operations, maintenance costs, and asset availability/ reliability. Table 8 shows the benefits of the drone project.

V. AI DEVELOPMENT ON DRON

Power transmission lines are the means of electricity distribution, and it is of utmost importance to confirm the continual supply of electricity and also the high performance of those lines. Constant surveillance and inspection of power lines can play a vital role in avoiding power shortages: detecting defects in power equipment at an early stage can prevent severe and costly damage and even be used to expect future anomalies. Generally, the electrical equipment undergoes a maintenance and repair process, based on their condition, termed preventive maintenance.

Table 8 Summary of DRONE project benefits

Safety	Cost Savings	Asset Availability/ Reliability
During 2019 Safety incidents were (0) during drone inspection vs. 7 incidents during the manual inspection in 2018	Inspection costs were reduced by ~25-30%. reduction in costs between drone and manual inspection 2,275 (2019) vs. 3,150 (2018) SAR/ km	improvement after drone inspection in: 1. SAIFI reducing it by 30% 2. SAIDI & ENS reducing it by 34% 3. MAIFI reducing it by 2%
		Dispatched points (DPs) affected are reduced by 34% improvement (90 vs. 140 DPs annually/ 1Klines).
	Reduction in corrective maintenance (CM) costs as a result of better inspection and preventive maintenance savings by ~ 2.0-2.5M SAR, in 2019 as a result of drone inspection	Increasing inspection speed up to ~5-6X increase in inspection speed six times vs. current manual process
	Revenue loss avoided ~0.4M SAR. After drone inspection 2019	



igure 1 A sample of common defects: (A) missing plate along the nsulator chain; (B) Corona discharge (C) damaged strand of the ductor and broken clamp; (D) sand accumulates around tower foo foundation; (E) cable joints, which are more frequently hot spot sensitive; (F) a string of insulators, polluted.

The primary damages in OHL could be broken wires, damage to insulators, conductor corrosion, and vibration damage; a number of these defects are shown in Figure 1. Several methods are employed to spot and analyze these anomalies. Some of these methods identify faults and classify their severity in power equipment using different image analysis approaches [1]. Also, different methods for classifying the level of faults in electrical equipment [2]. In the past, the two most common power equipment inspection methods were foot patrol and helicopter-assisted investigation. Inspection based on foot or patrolling is highly to be inaccurate, slow, and is simple for the surfaces of the OHLs' equipment and thus, more substantial defects can sometimes be overlooked. The pilot flies the aircraft over the power lines in helicopter-based inspection while the camera operator films the conductors, insulators, pylons, and power transmission lines. Over the recent years, manned and unmanned aerial vehicles or Drones are used for a broad spectrum of applications, supporting humans in dangerous and challenging environments, including the inspection, operations, and maintenance of power equipment. Advanced flight control techniques and image processing allow unmanned aerial vehicles (UAVs) to carry out fast inspections from some distance.

Based on GPS data of both the UAV and electric towers, the embedded algorithms can perform the automatic tracking of power lines [3–7]. The acquired data, generally a sequence of images, are analyzed to assess status of power equipment. Also, the inspection by drones allows using different sensing payloads and, hence, to comprehensively inspect both OHL and associated components using different kinds of sensors from an optimal point of view. With that in mind, Artifactual intelligent started as an idea to improve the drone inspection analytic part, where NGSA suggested implementing a software part to do the analysis. An MVP study of the global market was done in 8 weeks. The results are big potential benefits. A summary of the benefits of applying AI to the drone project data is shown in Table 9.

Table 9 Summary of DRONE project benefits

<table>
<tr><th>Safety</th><th>Cost Savings</th><th>Asset Availability/ Reliability</th></tr>
<tr><td rowspan="4">Zero incident expected during the elevated inspection using drones</td><td rowspan="2">Inspection costs were reduced by ~13M. 30% savings annually by 2024 after drones inspection</td><td>improvement after drone inspection in:
4. SAIFI reducing it by 17% (0.23 vs. 0.28)
5. SAIDI (12.2 vs. 14.9) & ENS (0.002 vs.0.003) reducing it by 19%
6. MAIFI (0.0316vs.0.032) reducing it by 1%</td></tr>
<tr><td>Dispatched points (DPs) affected are reduced by 19%
improvement (7.1 vs. 8.7 DPs annually/ 1Klines).</td></tr>
<tr><td>Reduction in (CM) costs by ~13.4M SAR
And 11% annually by 2024 after drone inspection</td><td rowspan="2">Increasing inspection speed up to ~7-8X
increase in inspection speed Eight times vs. current manual process</td></tr>
<tr><td>Revenue loss avoided ~ 0.4M SAR. after drone inspection annually by 2024.</td></tr>
</table>

Providing a pilot project model for an AI to analyze spacer damper faults out of 200 test pictures. 2250 pictures trained the models, 250 of them defected. AI solution will retrieve drone data from SEC data, run the analytics, and return the outputs back to the system (reports/ SAP PM input); the AI solution Overview is shown in figure 2.

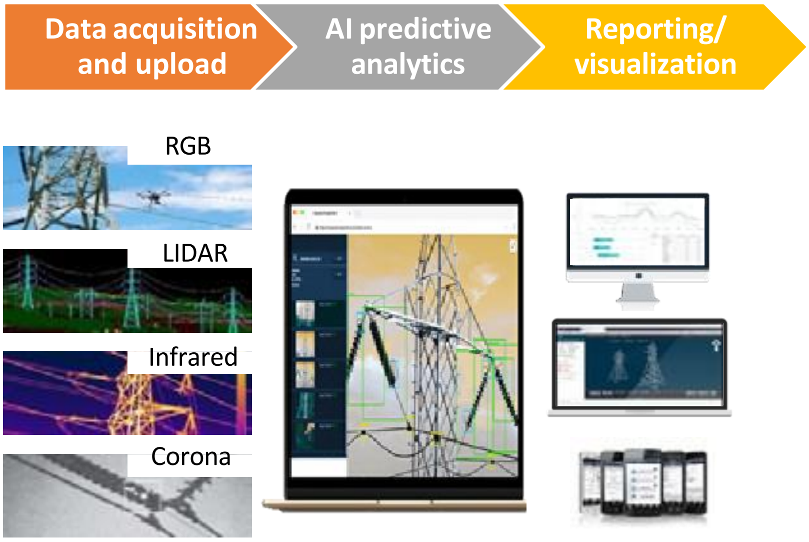


Figure 2 AI solution overview

The MVP evaluation Panel was made of:

1. Functional experts (1)
2. AI experts (3)
3. SEC experts (4)

Each of the eight panelists submitted a detailed evaluation scorecard for each provider; each provider's scores and feedback were cumulated. Two key metrics to measure model performance. Confusion matrix created to compare the expected vs. predicted results (of AI model) on faulty vs. healthy images. AI model should maximize accuracy while optimizing false positives/ negatives, which could either increase costs/ worsen asset health. e.g., False positive means that SEC sent maintenance crew to fix an actually healthy asset, while false negative means that no crew was sent to fix a faulty asset (because the model classified it as healthy). The F1 score is used to assess the latter above – i.e., how well does the model optimizes false positives/ negatives; Higher the F1 score, better the model performance/ fidelity, the F1 score is a combination of two key metrics (precision and recall). Precision (P) is calculated as TP/ (TP + FP) while recall (R) = TP/ (TP + FN). F1 is a harmonic mean of precision and recall, equal to 2*P*R/ (P+R). Therefore, keeping a record of Table 10 parameters makes it easy to evaluate and configure the Precision (P) & recall (R) and F1. There are several strong points for the top three vendors selected after evaluation of those as follow:

- Sophisticated AI modeling techniques with a clear process to re-train and enhance the models over time
- Comprehensive and mature solutions with advanced functionalities such as drone flight planning
- Simplified UI/ UX and reporting with key application integrations such as SAP, IBM Maximo, etc.
- Cloud agnostic architectures with demonstrated experience in deploying on-premise and supporting client-specific data encryption protocols
- Strong experience in utilities and providing services across the value chain (i.e., drone operations and AI/ ML)
- Open to partnering with SEC and supporting upskilling of client teams on both drone operations and AI/ ML

Table 9 Parameters to record for configuration of P, R, F1

<table>
<tr><th colspan="4">Expected results (based on manual identification)</th></tr>
<tr><th rowspan="3">Predicted results

(based on

AI model)</th><th></th><th>Faulty</th><th>Healthy</th></tr>
<tr><th>Faulty</th><td>True positive (TP)</td><td>False-positive (FP)</td></tr>
<tr><th>Healthy</th><td>False Negative (FN)</td><td>True negative (TN)</td></tr>
</table>

VI. CONCLUSION

It has been shown that the incidents Application of computer vision methods to analyze electrical faults and diagnose the condition of specific components of the infrastructure has been proved as one of the safer procedures for inspection. In the present work, we applied computer vision-based methods on visible images to perform maintenance inspection of spacer damper components. Results, with different statistical parameters, are compared to the performance of obtained output with the manual ground truth. With an average of 88.5% Accuracy index and 76.8% an average of the F1 score index, the method effectively detects power lines spacer dampers. The method achieved a state-of-the-art performance, but we also provide a classification based on their status (pointing out even the opening clamp) to allow predictive maintenance of it. The need to notice that even the comparison with previous research is biased by the differences in data used for training the model. In the use of such data most cases are made unavailable, difficult, and costly to be collected. Also, an extra value is to be implemented, is an application and an online service; to make it easier for operators to use the tool. However, on the other hand, to permit to enlarge our dataset and improve further the performances and/or increase the interpretation of the insulator status. Hence, we conclude from our results that may improve the efficiency of drone surveying of the electrical infrastructure and open the way to the development of a novel monitoring payload (to be embedded in UAV) able to provide accurate and fast detection of faults and anomalies in power lines and its accessories. Along with AI applications, Communication diagnostics systems of substations, robotics applications, and permanent surveillance systems. As data feed for the future Big Data of Power system transmission network as National Grid SA are considered to be analyzed to develop of digital substations to enable communication of digital data directly from the equipment monitoring system with less configuration layers to have real time data for applications of predictive analysis.

VII. ACKNOWLEDGMENTS

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APPENDICES

Table 2 types of Drone used in the Southern area project

Type	Dimensions (mm)	MAX SPEED	MAX ALTITUDE (ASL):	Max Flight Time	Operating temperature MIN, MAX
MATRICE 600 PRO	1668 × 1518 × 727	65 km/h	4500 m	No payload: 38 min, 5.5 kg payload: 18 min	-10° C to 40° C
M200 V2	883×886×398	81 km/h	3000 m	38 min (no payload), 24 min (takeoff weight: 6.14 kg)	-20° to 50° C
H6 Harris	1425	54 km/h	2000 m	5 hours	-20 ~ 40 °C
TRON F90 Plus	1775 x 325 x 428	65 km/h	2000 m	60 min	0 °C to 45

Table 3 fault detection, causes, probability, and sensing technology

Item application	Cause	Result	Update interval	Probability	Consequence	Sensing technology
System Tampering	Terrorism	Tower/line down	Real-time	Low	High	Optical
System Encroachment	Avian Nesting, Waste, & vegetation	Flashover, & Fire	3,6, and 12 Months	High	High	Optical, LIDAR
Shield Wire	Corrosion, & lightning	Flashover, & Outage	1-3-6 Years	Med	High	Optical, IR
Insulator (Polymer & Ceramic)	Age, Material Failure, Contamination, & Gunshot	Outage, & Flashover	Real-time- 3 Months 6-12 Years for Age, & Material Failure	For Age, & Material Failure Med for Polymer and Low for Ceramic. And Med for others.	High for Outage Med for Flashover	Optical, IR, & UV
Phase Conductor	External/ internal strands broke, and corrosion of steel core	Line down, & Fire	1 Year	Low	High	Optical, IR, & UV
Connector Splice	Workmanship, Thermal cycling, & Age	Line down, & Fire	1 Year	Med	High	IR
Hardware	Age	Line down, & Fire	6 Years	Low	High	Optical, & IR
Phase Spacer	Age, Galloping event	Line down, & Fire	6 Years	Low	Med	Optical, & UV
Aerial Marker Ball	Vibration Damage, & Age	Safety Concerns	1 Year	Low	Med	Optical, & UV
Structure (steel lattice & steel pole)	Corrosion, Age, Bent, Damaged members, & Internal Deterioration	Reliability Concerns	10 Years for Corrosion, & Age 1 Year For Bent, Damaged members, & Internal Deterioration	Med	Med	Optical, & IR
Foundation	Corrosion, & Age	Reliability Concerns	10 Years	If Foundation (Direct Embedment, Anchor, Screw-In, or Rods) it is High If Foundation (Perform) it is Med If Foundation (Anchor Bolt, Stub Angles) it is Low	High	Optical
TLSA (Transmission Line Surge Arrestor)	Lightning Strikes, & Age	Reliability, & Lightning Concerns	1 Year	Med	Med	Optical, & IR

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SUSTAINABLE INNOVATION IN UNDERGROUND INFRASTRUCTURE CONSTRUCTION AND MAINTENANCE PRACTICES

OM23
26C

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Abstract

Underground infrastructure utilities networks require continuous development, repair, and rehabilitation due to increased populations and their demands, aging networks deterioration. Networks of water, solid waste, electrical and communication cables are just an example of these essential utilities in our life. Today, decision-makers in public authorities, and engineers are facing a big challenge in finding and implanting not only the most economical construction and maintenance methods, but also, they must use the most less-disturbing and sustainable methods that have minimum impact on social and business public-life and the environment. New Innovativd technology of Trenchless construction and maintenance methods offer an opportunity as an optimum solution for installing new utilities networks and rehabilitating existing aged infrastructure networks using economical and green concepts. This paper explores this new construction technique, with its economic and environmental benefits in trenchless construction and maintenance compared with the traditional open-cut excavation. It demonstrates the merit of adopting trenchless construction technique for sustainable development of underground infrastructure, road construction and maintenance. next step.

1. INTRODUCTION

In today's modern society, the continuous availability of basic infrastructure services are essential part of daily life. No communities could be considered inhabitant without the availability of fresh water and wastewater networks, power and telecommunication. The necessity to provide these services and keep them in updated functioning condition is so crucial to the municipality in such away it make creating an emergency department and highly skilled emergency crew to repair urgent and damaged utility on the 24 hrs. basis are available. This task becomes big burden and heavy task when it comes to service and maintain old and damaged infrastructure utilities in the urban and critical locations of big cities and communities affected by. For Infrastructure new construction, and existing aged rehabilitation, and maintenance, local municipalities and Infrastructure Engineers, decision-makers and ccontractors in these dense- pedestrian and traffic are faced with challenging tasks of installing and maintaining underground infrastructure utilities in the crowded vicinities. This includes installation, inspection, repair, and replacement of underground service networks of various infrastructure utilities such as water and waste water pipelines, power, and telecommunication.

Traditionally, construction and maintenance of underground utilities involve open trenching methods are proven expensive, particularly in congested urban areas of crowded cities and critical locations (Figure 1).

Contractors have to close roads, divert traffic and create chaos and frustration for vehicles, commuters, and business in the operation vicinity, in addition, they must cautiously dig and operate carefully around other existing critical utilities to achieve the required depth and proper location, which in turn slows down the whole operation and delay the projects. Additional costs in open trenching construction are incurred by the process of restoring the existing original surfaces including pavements, sidewalks, and other disturbed facilities, as well as, landscaping. Open cut trenching operations often result in high user and social costs due to the disruption to vehicles and pedestrian traffic, as well as its adverse impact on nearby businesses [1,2,3,8], let alone the danger of possible collapse of trenches walls on the working personnel, and close by pedestrians. Furthermore, the increases in the population of crowded cities, and urgent need to rehabilitate, replace aging infrastructure utilities systems, as well as, repairing damaged utilities, together with the increased emphasis on user and social costs, have pushed municipalities and contractors to seek alternative methods for repairing and replacing underground utilities [4]. Accordingly, in many western countries, under-pressured municipalities found the solution for this problem by utilizing the Trenchless excavation technology in construction. This Trenchless construction methods are an emerging area of construction involving innovative methods, materials, and equipment used for the installation of new, and the rehabilitation, or replacement and maintenance of existing underground infrastructure with minimal or no need for open cut excavation [3].

Figure1: Traditional open-cut Trenches construction: Disturbance for Pedestrians, traffic, business and environment [8]

2. Trenchless Construction and Maintenance Tanique:

Trenchless construction (Figure 2) can be defined as "a family of methods, materials, and equipment capable of being used for the installation of new or replacement or rehabilitation of existing underground infrastructure with minimal disruption to surface traffic, business, and other activities" [1, 6,7]. Based on location, type of infrastructure utility, and soil type, different trenchless construction-techniques are available such as horizontal directional drilling, pipe jacking, micro tunneling, auger boring, and pipe bursting. Other trenchless rehabilitation techniques include lining of pipe, pipe scanning and evaluation, and robotic spot repair. Even-though, the extensive use of trenchless construction for the installation, repair, or replacement of underground infrastructure utility is a relatively recent development; yet, the idea and uses of trenchless techniques dates back to the 1860s, by Northern Pacific Railroad Company pioneer the use of pipe jacking techniques. By the 1930s, reinforced concrete pipes had been installed using this technique. Subsequently, other methods of trenchless construction began to emerge and utilized including horizontal directional drilling (1971), pipe bursting (1980). auger boring (1940), impact moling (1962), , microtunneling (1973), and [3, 6,7,10]. Thereafter many developed countries have successfully started to adopt trenchless construction technology in one form or another.

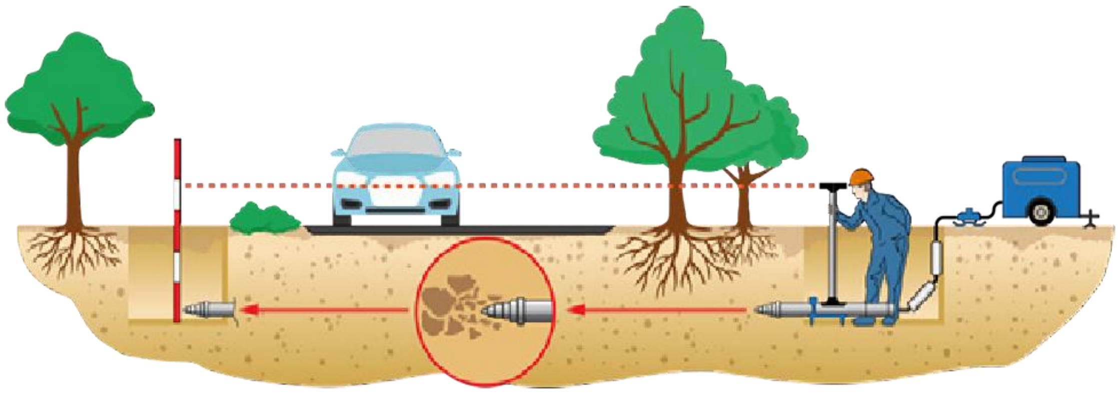

Figure 2: Sustainable Trenchless Technique: No disturbance for pedestrians, traffic, business, and environment [8]

3. Trenchless Construction methods

There are various methods of trenchless technologies that may be used (Figure 3) dependent upon utility type,

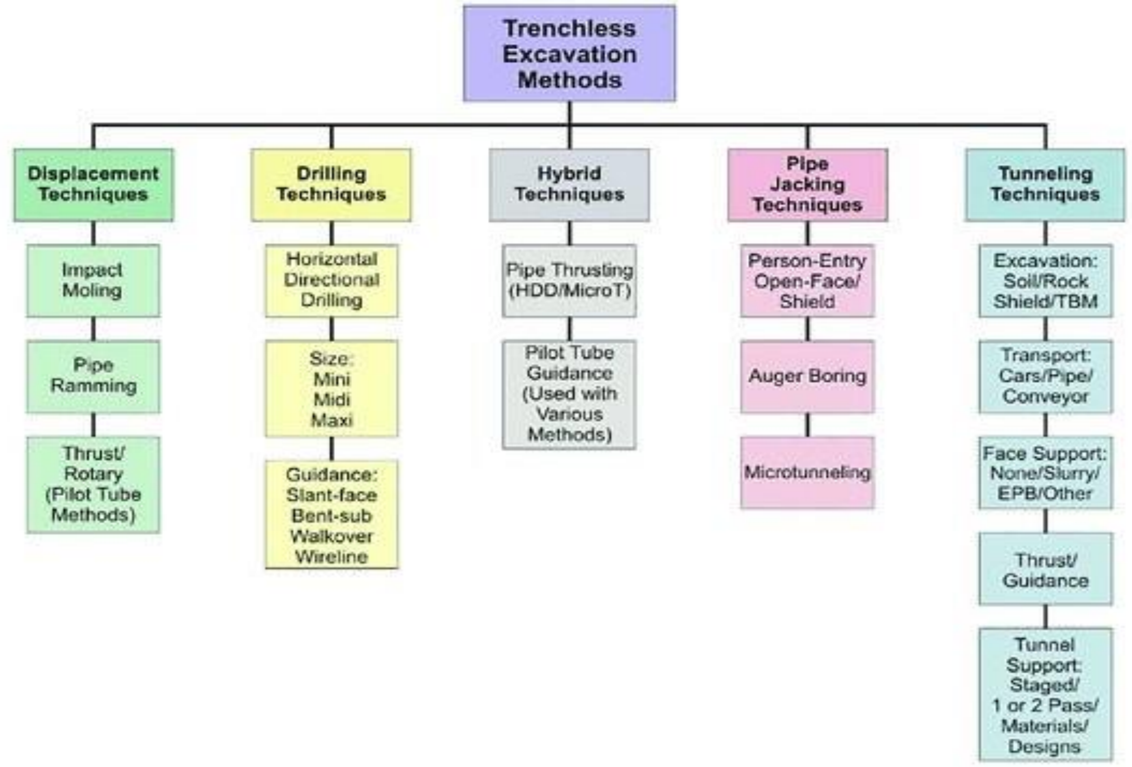

Figure 3: Trenchless Construction and Excavation Methods

location, soil condition of the ground, pipe size that needs to installed, the depth it needs to be installed to, and the overall cost of the method. Example popular methods have been outlined below (Michigan Department of Transportation 2006) [10, 11, 12].

Horizontal directional drilling: A steerable system for the installation of pipes, conduits, and cables in a shallow arc using a surface launched drilling rig. Traditionally HDD is applied to large scale crossings such as rivers in which a fluid filled pilot bore is drilled without rotating the drill string, and this is then enlarged by a wash over pipe and back reamer to the size required for the product pipe (Figure 4).

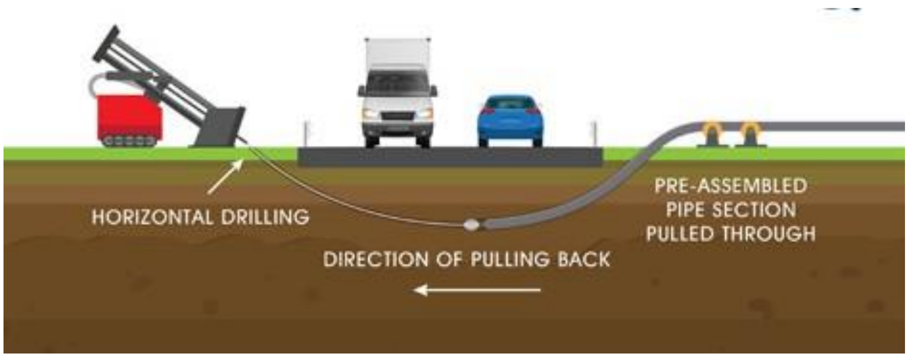

Figure 4: Horizontal Directional Drilling [10]

Pipe bursting: A technique for breaking existing pipe by brittle fracture, using force from within, applied mechanically. Pipe remains are forced into the surrounding soil. At the same time a new pipe, of the same or larger diameter, is drawn behind the bursting tool (Figure 5).

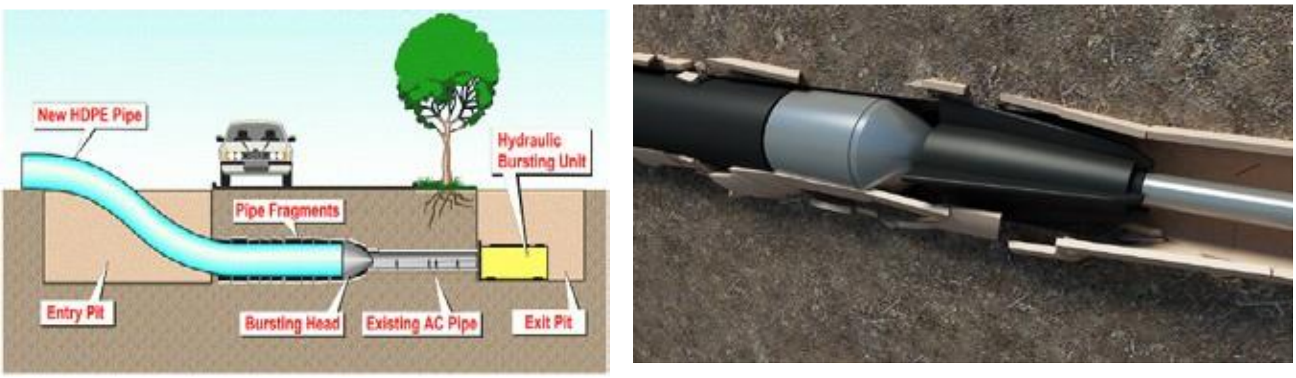

Figure 5: Pipe Bursting

Pipe ramming: A technique for installing steel casing from a drive shaft to a reception shaft utilizing the dynamic energy from a percussion hammer attached to the end of the pipe. A continuous casing support is provided and over-excavation or water is not required. This is a 2- stage process (Figure 6).

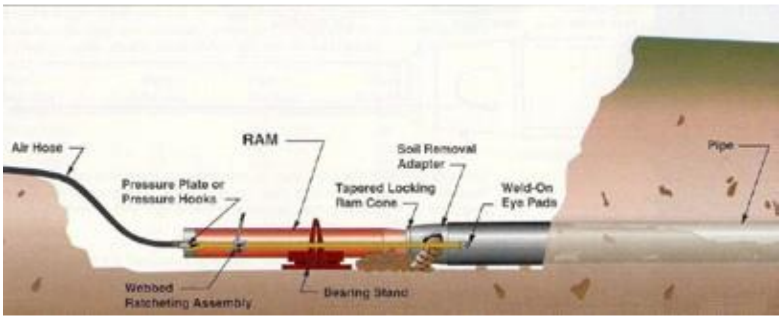

Figure 6: Pipe Ramming

Pipe jacking: A system of directly installing pipes behind a Shield Machine by hydraulic jacking from a Drive Shaft such that the pipes form a continuous string in the ground. Usually personnel are required inside the pipe to perform the excavation or spoil removal process. The excavation can be performed manually or mechanically (Figure 7).

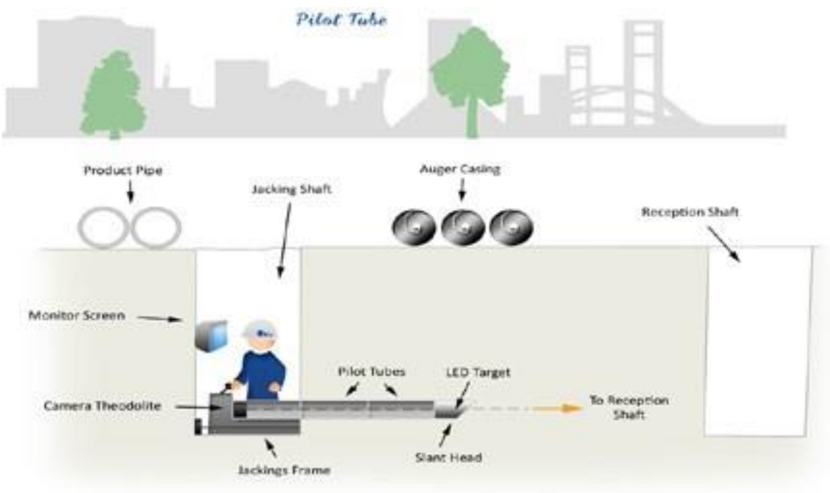

Figure 7: Pipe Jacking

Microtunneling: TT construction method for installing pipelines with the following features (Figure 8)

Remote Controlled – The Micro Tunnel Boring Machine (MTBM) is operated form a control panel, normally located on the surface. It simultaneously installs pipe as spoil being excavated and removed. The guidance system usually refers to a laser beam projected onto a target in the MTBM, capable of installing gravity sewers or other types of pipeline to the required tolerance for line and grade. It has Jacking Pipe – The process of constructing a pipeline by consecutively pushing the MTBM through the ground using a jacking system. The Face Support – Continuous pressure is provided to the face of the excavation to balance groundwater and earth pressure.

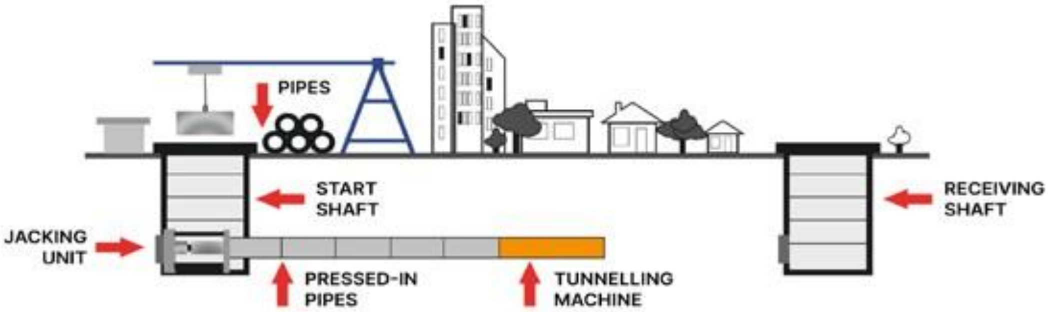

Figure 8: Microtunneling

4. Sample Successful case studies

Trenchless construction and maintenance technology for infrastructure projects (Construction, Maintenance, and Rehabilitation) in the crowded cities and critical sites are still rarely used in the Arab countries despite its successful usage and wide acceptance in western and developed countries who adopt this method of construction and maintenance, especially in the crowded cites, and critical sites. Every year, hundreds of trench less technology projects were successfully completed. Trenchless technology magazine and website list regularly stories and projects completed using this technology around the world particularly in North America and Europe. For example [17] Kezdi listed 50 projects which readers can access them through that reference.

Crossing under the River of Texas's Rio- Grande using HDD, USA

Webb County, Texas, nine-member directional drilling crews with PUMPCO Inc. have successfully crossed under the river of Rio Grande. The project involved boring and pulling back 2,200 ft of 36-in. pipe approximately 80 ft under the river's bed using Trenchless method of Horizontal Directional Drilling. It was the last leg of the 17-mile long Pipeline that has to cross the river. "Using the proper method and equipment of trenchless technology, the construction process was easy and quick" said by the project manager. On average, the crew drilled around 500 ft a day and took them around four and a half days to complete without disturbance to the river and the environment, and the project completed on time and budget [19].

Frankfurt Airport, Germany

With nearly 65 Million passengers using its services each year, Frankfurt Airport, in Germany, can't just shut down for maintenance. However, after 40 years of heavy usage, the airport's vast system of sanitation infrastructure was in danger of falling into a critical state. The system exacerbated normal wear and tear, leading to cracks, pipe offsets, corrosion and multiple un-flushable deposits. The airport authority led a charge to repair or replace the wastewater network at Frankfurt Terminal 1 and contracted Germany's ANT GmbH to manage the project. ANT sought support from Trelleborg Pipe Seals, a provider of pipe renovation systems with coverage across Europe and the United States. With a vast spiderweb of pipes lying directly beneath the terminal's buildings, this would be no simple project for either firm. Using a combination of several trenchesless technology methods, the project team had managed to successfully repair almost two and a half miles of pipes without a single trench being dug. By working at night and using compact, portable equipment, the team was able to minimize disruption to the day-to-day running of Frankfurt Airport. Crucially, the solutions that are now in place are expected to last at least 50 years, helping Frankfurt's 1970s old sanitation system to last well into the second half of the 21st century [20].

Installing Sustainable Stormwater System at Krakow Airport, Poland

In this airport, the nearby stream into which the rainwater had previously been discharged could no longer handle the growing amounts. It was therefore decided to extend the storm water sewer system by new pressure lines which should lead the water over a distance of 3 km into the Rudawa River (Table 1). 5.85 km of drainage pipes will be installed with many stretches underneath roads and Aircrafts' taxi-ways using trenchless method of Microtunneling. The works at the airport started in November 2017 and completed ahead of schedule at the beginning of 2019. The installation of this new drainage network will lay the foundation for future expansions of the airport, among others a new runway and aircraft hangars. This will allow for the number of flight operations to increase and further strengthen Krakow airport's international importance [21].

These were just a sample successful stories of sustainable Trechless technology application. more ssucessful sories are available in the literature around the world, The advantages of Trenchless technology and methods in newly installed, maintenance, and rehabilitation of underground infrastructure services are clearly noticeable in the crowded locations, busy streets, and critical locations. It eliminates public disturbance and traffic congestion, reduces construction and maintenance cost, reduces project completion time, with overall benefits to the sustainable economy and environment in the crowded vicinities.

5. Ttrenchless Construction Methods vs. Open Cut trench Method

Research and piratical experiences show the innovative methods of trenchless technology methods advantages overcome open trench methods in many important aspects such as [10, 11, 12, 14, 15]:

- Less disturbing: By open cut method disturb local properties over agricultural land or disturbing local highways. But by use of Trenchless technology come out from these problems like landscape damages.

- Less time: open cut method is time consuming method. In this method time is required for the excavation and refilling of trenches. This process also means time is taken in site restoration, spoils storage and traffic control.

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• Enhanced safety compared to steep excavations – by steep excavation Landslides can be occurs. Where the mud is likely to subside due to steep walls or water aggravation, protection needs to be taken with specialist equipment. By trenchless methods provided safety to the workers as there are no steep trenches involved in this work.

• Minimize chance of disturbing existing utilities . Trenchless technology methods comes with the ability to install new pipelines and rehabilitate existing pipelines with limited disturbance to traffic and business activities, reduce damage to existing paved surfaces.

• Problem to the public such as noise and air pollution – The indirect social costs of open cut projects consist of unhealthy, inconvenience to traffic, and noise pollution. But these problems can play a big part of local communities. These problems can be overcome with trenchless technology methods without the need for road closures, noise pollution.

• CO2 Emission: Researches shows that trenchless technology are more friendly to the environment in many ways such as its identical operation using open cut exaction will safe 80% of carbon emission to the atmosphere [6,14]. In addition less dust and no trees or green landscape areas will be disturb or removed. As shown in Figure 9

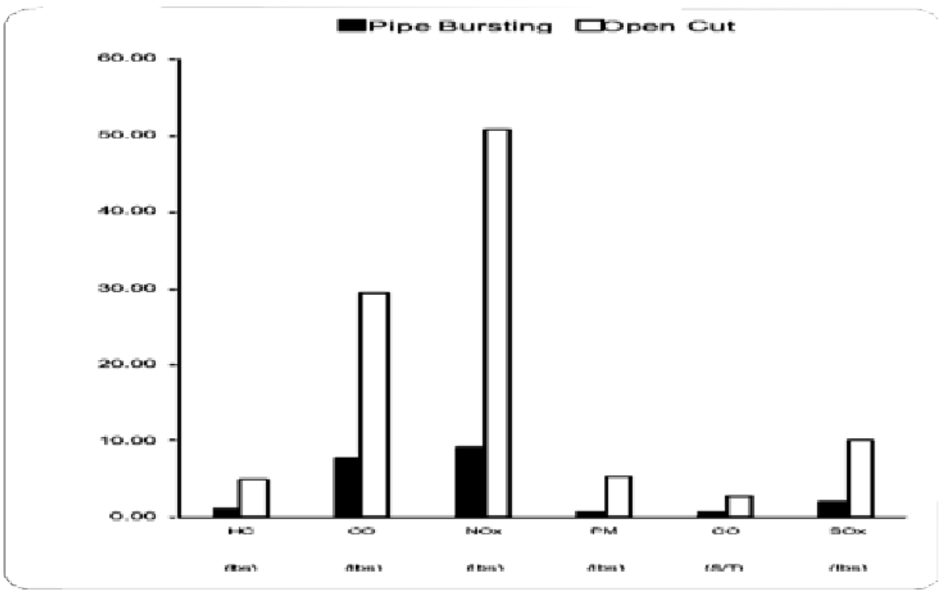

Figure 9: Comparison for reduction in gas emission between open cut and Trenchless method

• Choosing the right excavation method, trenchless technology methods could save up to ½ total cost of the similar operation [15]

• Encountering fewer unknowns in the ground – in open cut method, approximately 70% of the cost required for excavating and replacing the ground during the process. As per unknowns come in the excavation or digging cost of excavation increases. By use of Trenchless technology methods reduced this problem.

• Save time and cost related to survey and design – open cut method consists of preliminary survey, detailed survey etc. In detailed survey consist of the depth of the cut, the ground conditions where the trenches will run and also how much dewatering will need to take place, ensuring that conditions are safe to work. But in trenchless technique saved time and cost related to survey.

Despite its many advantages, yet the decision to use the trench less technology should have careful pre-planning and thoughtful investigation for the type of project, location, soil type and cost. Michigan Department of Transportation [10] recommendation for engineers and decision-makers that should recognized there are conditions where trenchless applications are not appropriate, such as emergencies, where immediate trenching of the pavement is necessary, and advanced planning simply cannot be done. In other cases, conditions such as the nature of the soils and rocks below the surface, or the presence and/or uncertain location of existing utilities preclude the use of trenchless technology methods.

Table 1 : Appropriate Technique for Trenchless New Installation [10]

TECHNIQUE	Water	Sanitry & Storm Sewers	Gas	Electricilty	TeleCumuni-cations
Horizental Auger Boring	x		x	x	x
Pipe Ramming	x	x	x	x	x
Pipe Jacking		x			
Drirectional Drilling	x	x	x	x	x
Microtunnling		x			
Pipe Bursting	x	x	x		

6. Conclusions

In today modern society, having proper underground infrastructure utilities such as, service lines of water wastewater or gas pipes, electric or telecommunication cables, becomes an essential part of the our daily life, installing new utilities and maintaining the existing old, or damaged sections are becoming costly and disturbing for the society (traffic and pedestrian delays) and environment (safe trees, landscape, less gases emission, and less pollution to water and soils). This problem is especially magnified and tedious in crowded cities. Trenchless technology methods in construction and maintenance are an innovative new technology successfully utilized in many developed countries. Yet, it is not commonly adopted by the majority of the crowded cites in the Arab countries. Many innovative methods have been developed to suit type of utility, soil condition and locations. Many benefits could be gain by introducing these sustainable technology solutions in the region such as lowering construction cost, less traffic and pedestrian congestion and headache, and many others advantages that demonstrate the merits of adopting trenchless technologies for sustainable development of underground infrastructure systems.

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Maintenance and asset management improvement based on resilience and sustainability classification systems

OM23 102

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Abstract

Maintenance and Asset Management are very important for the Architecture, Engineering, Construction and Operation (AECO) sector. The increase in associated information makes necessary to have greater control of it, with the emergence of Construction Information Classification Systems (CICS), which are fundamental in the classification of information and its use. The built environment is vulnerable to risks that are impossible to eliminate, and this prompts the need for managing and classifying the resilience and sustainability of different constructed assets.

This paper presents contributes to a discussion on the ways to measure the resilience and sustainability of built assets, namely based on rating systems composed by different dimensions, several indicators and parameters. It covers not only the building's intrinsic qualities, but also its interdependence with the community, surroundings, and users in the context.

Keywords: Maintenance; Asset Management; Classification; Resilience; Sustainability

1. Introduction

Building maintenance covers several activities (e.g., inspection, service execution, repairs, replacements) to provide functional elements to maintain their quality, so Asset Management (AM) is the set of coordinated activities that an organization uses to see its assets generate value (Raposo, 2011). Construction Information Classification Systems (CICS) emerged in the twentieth century to meet the AECO sector's needs related to organizing itself in a rational manner, to facilitating storage and retrieval of information, and to exchange information that is relevant to the sector (Lima et. al, 2021a).

The classification of the resilience of built assets is increasingly becoming a topic of the greatest importance and relevance for asset managers and building users, with the need for its operationalization through a system that is consensual and easy to implement and use (Duarte et. al, 2021).

The Strategy for the Sustainability of the Built Environment, launched by the European Commission, establishes several principles of circularity throughout the entire life cycle of buildings, highlighting the use of the LEVEL(S) sustainable classification approach. This approach aims to integrate life cycle assessment into public and non-EU procurement for sustainable financing, based on targets for reducing carbon constraints and a potential for carbon storage (Lima et. al, 2021b).

2. Conceptual framework

ISO 15686-1 defines the maintenance concept as a combination of technical and administrative actions that allow the building and its constituent elements to perform the functions for which they were designed during their useful life (International Organization for Standardization, 2000). According to BS 3811 (British Standard), maintenance is the combination of all actions taken to maintain the building or to restore it to a reasonable state, clarifying that the maintenance of a building includes tasks such as inspection, cleaning, repair and replacement of several systems or elements (British Standard Institution, 1984).

The standard series ISO 55000, state that Asset Management (AM) comprises a coordinated set of activities from an organization to obtain value through its assets, being formulated comprehensively to adapt specific asset needs, changing contexts and differences throughout the organizations. The importance of Asset Management, for the last decades, has been under discussion. AM techniques applied to buildings are complex and presents several challenges, such as the availability of numerous parameters of the AM activities to meet the life cycle needs and to reduce the costs associated with assets (without compromise the performance of other requirements). It is required a critical and holistic view of the entire life cycle. However, this task faces new challenges when applied not only to the built asset but to the entire project that encompasses it, and even more when it is simultaneously associated with the management of program or portfolio by an organization (Salvado, et. al., 2008).

The Construction Information Classification Systems (CICS) for the AECO sector emerged in the 20th century to meet some needs of the sector in organizing itself rationally, facilitating the storage and retrieval of information and for the exchange of relevant information between the sector stakeholders. In general, the classification system has the objective of finding the best possible order to, after the classification of a given element, is easier to find it within a given set. The CICS is configured in a set of interdependent elements that form an organized whole. Such systems can be developed according to the needs of each country, region or even a company, to meet their longing to organize themselves, as well as to follow international classification standards (Nunes, 2016). Although there is no absolute way to classify, the most correct would be for all business partners of the sector to use a common language. With a CICS, the objects are grouped into classes, relating them according to the particularities of their properties. There are several types of classification that can be described and that are associated according to the objectives, scope, and particularities of the system (Pereira, 2013).

The urban resilience of built assets can be seen as the ability of these physical assets to withstand severe damage within acceptable degradation parameters and to recover in reasonable time intervals. No definition for this has been unified yet, but strength, absorption, and recovery characteristics are generally recognized as the basis for resilience assessment systems (Rezvani et. al, 2022). The striking advantages of increased resilience have increasingly attracted the attention of managers and engineers to use it in various aspects related to risk reduction and prioritizing the budget allocated to assets, especially national built assets that need to be preserved for future generations (Vugrin 2010; Rahi, 2019; Burroughs, 2017). In Portugal, there were some attempts to develop a resilience classification system, in line with European Standards and Community Policies, already published and to be complied with in the 21st century (Falcão Silva et. al, 2022).

The LEVEL(S) approach allows for simplified reporting assessment and a defined effect of comparable data, which helps in performance management activities. With this approach, the European Commission intends to: i) Encourage users to think about the entire life cycle of buildings, deepening a basis for understanding, analyzing and studying the life cycle; ii) Address a number of aspects of helping circularity, extending life and indicators that can harness the future utility of their use (in terms of utility and potential for reuse and recycling of their materials); iii) Allow performance comparison through cumulative reporting portfolio, including asset properties; iv) Provide a development framework that can be incorporated into service assessment and support schemes and circular economy policy initiatives at European, national and local levels (Lima et. al., 2022).

3. Resilience classification system – Case study 1

The proposed resilience classification model for built assets seeks to be based on the ISO/TR 22845 standard with a focus on natural disasters, whose national exposure is high or medium, adapted from: earthquakes, floods (urban, rivers, seas), fires, and tsunamis. The proposed model has a hierarchical structure with three (3) layers (Dimensions, Indicators and Parameters) and follows the following principles: i) Minimize performance reduction; ii) Minimize recovery time after an event; and iii) Maximize recovery capacity. The classification model, which is semi-quantitative, is based on existing resilience classification systems and sustainability classification systems that are reasonably mature. The scale adopted meets the recommendations of ISO 11863, as it considers five (5) different levels expressed in single-digit integers on a scale of 1, 3, 5, 7 and 9, where one (1) corresponds to the worst performance and nine (9) for the best. For a clearer interpretation of the final score, the numerical score can be transposed into resilience classes from F to A++ allowing the differentiation of resilience levels to be understood and intuitive (Duarte, et. al., 2021a; Almeida et al, 2021).

The definition of indicators and parameters aims to assess resilience and facilitate communication and consultation procedures. The parameters subdivide the indicators, and, in turn, each set of indicators expresses in more detail each of the dimensions. The evaluation criteria defined for each parameter were initially established based on the limits of different metrics. The process of reviewing and calibrating indicators, parameters, and evaluation criteria, for improvement, is expected to be iterative. The process must be monitored for the influence of judgments or opinions, lack of data and difficulty of quantification (Falcão Silva et. al., 2022). The resilience rating system proposed (Garcia, 2022) was developed to better suit the intended objective for assets maintenance and management and comprises five (5) dimensions, eighteen (18) indicators and ninety-five (95) parameters (Table 1).

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Table 1 – Resilience classification system proposal, adapted from (Garcia, 2022)

D1 - ENVIRONMENTAL
I1 - Earthquake
- Seismic zoning - type 1 EC8
- Seismic zoning - type 2 EC8
- Seismic vulnerability of PDM soils
- Terrain slope
- EC8 soil type (1)
- Distance to cliffs
- Distance to geological faults
- Population density
I2 - Tsunami and tidal effect
- Land altitude
0 - Distance to the coast
1 - Distance to the river
2 - Natural barriers in the surroundings
3 - Man-made barriers in the surroundings
4 - Moving objects
5 - Rows built between the coast and the building
6 - Susceptibility to the direct tidal effect PDM
7 - Relative location
I3 - Flood
8 - Distance to the river
9 - Natural barriers in the surroundings
0 - Man-made barriers in the surroundings
1 - Vulnerability to PDM Floods
2 - Distance to vegetation
I4 - Fire
3 - Density of vegetation
4 - Vegetation maintenance status
5 - Type of vegetation
6 - Adjacent buildings
7 - Proximity to the industrial zone
I5 - Landslides
8 - Terrain slope
9 - Precipitation
0 - Groundwater level position
D2 - ECONOMIC-FINANCIAL
I6 - Insurance
1 - Insurance against natural disasters
I7 - Financial and strategic implications
2 - Financial plan
3 - Economic assessment of downtime
4 - Existence of disaster funds
5 - Access to External/Internal credit
6 - Access to titles
D3 ORGANIZATIONAL
I8 - Internal organization
7 - Business continuity plan
8 - Risk analysis and management
9 - Post disaster recovery plan
0 - Routine
1 - Simulacra
2 - Learning and updating
3 - Destructive event data
4 - Responsible
I9 - External organization
5 - Compliance with the existing regulatory scenario
6 - External standards for resilient construction
7 - Responsible entity
8 - Relationship between the community and stakeholders

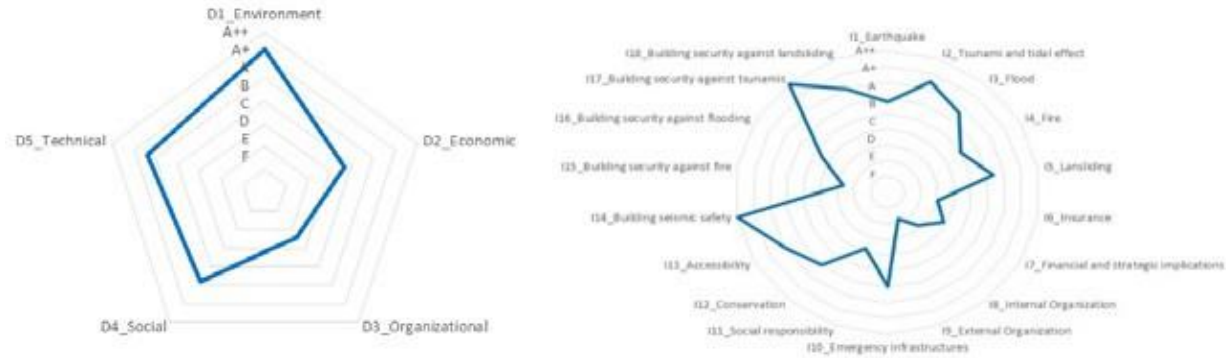
D4 - SOCIAL
I10 - Emergency infrastructure parameter
P50 - Access to police stations
P51 - Access to fire stations
P52 - Access to shelters
P53 - Access to hospitals and health centers
I11 - Social responsibility
P54 - Occupants
P55 - Disclosure
P56 - Social vulnerability
P57 - Existence of mutual help programs with neighbors
P58 - No. of social defense organizations
D5 - TECHNICAL
I12 - Conservation
P59 - Year of construction
P60 - Structural system
P61 - State of conservation
P62 - Maintenance, faults, and updates history
I13 Accessibility
P63 - Building density (1)
P64 - Alternate routes (*)
P65 - Street characteristics
I14 - Seismic safety of the building
P66 - Plant irregularity
P67 - Irregularity in height
P68 - Interaction with adjacent buildings
P69 - Slabs unevenness
P70 - Expansion joint
I15 - Building fire safety
P71 - State of conservation of electrical installations (2)
P72 - Gas installations
P73 - Distance between overlapping spans
P74 - Existence of fire compartmentalization (*2)
P75 - Fire detection and alarm (*)
P76 - Existence of emergency signs and lighting (2)
P77 - Existence of security team (2)
P78 - Escape paths
P79 - Existence of smoke control and evacuation systems (*2)
P80 - Existence of intrinsic means of combat (*2)
P81 - Existence of fire extinguishers (**2)
P82 - Existence of external hydrants (2)
I16 - Building flood safety
P83 - Existence of barriers (2)
P84 - Existence of pumping systems against flooding (*2)
P85 - Vulnerability and exposure of facades (2)
P86 - Number of floors
P87 - Street characteristics
P88 - Vulnerability of underground floors
P89 - Waterproofing solutions (basements)
P90 - Wastewater drainage systems
I17 - Building safety against tsunamis
P91 - Number of floors
P92 - Guidance
P93 - Ground floor hydrodynamics (*)
I18 - Building safety against landslides
P94 - Degree of Waterproofing (soils)
P95 - Slope stability

To validate the proposed resilience classification system, four (4) public collective use buildings, located in the city center of Lisbon, were used. Characterized by a sober monumentalism, the E1 building was built during the 50's of the 20th century [1], with three bodies standing out at the back and perpendicular to the main body, two at the ends and one at the central part. It has: i) Reinforced concrete structure; ii) Exterior and interior walls of simple filling of the brick masonry structural mesh; iii) Facades mostly covered with marble – a technique characteristic of the construction period [3], incorporating elements of limestone ashlar in the basements, sills and windowsills (this same material was also used in the access stairs to the building); iv) Roof structure in reinforced concrete / metal structure; v) Covering the roof with concrete slabs / fiber cement tile / metal sheets; vi) Wall and ceiling finishes in sand and lime plaster / stucco and paint / false ceilings; vii) Wooden / metallic window frames; viii) Wooden / metal doors; and ix) ceramic tile / stone / parquet / carpet floors. Regarding the building E2, it is dated from the 1960´s of the 20th century and comprises: i) Exposed concrete structure; ii) Roof structure in reinforced concrete / metal structure; iii) Covering the roof with concrete slabs / fiber cement tile / metal sheets; iv) Wall and ceiling finishes in sand and lime plaster / stucco and paint / false ceilings; v) Exterior cladding of the facades in glazed brick (natural and cream tone); vi) Wooden / metal frames, wooden / metal doors; and vii) ceramic / stone / parquet / carpet floors. The E3 building, opened in 1972, has the following elements: i) Reinforced concrete structure; ii) Exterior and interior walls of simple filling of the brick masonry structural mesh; iii) Roof structure in reinforced concrete / metal structure; iv) Covering the roof with concrete slabs / fiber cement tile / metal sheets; v) Wall and ceiling finishes in sand and lime plaster / stucco and paint / false ceilings; vi) Exterior cladding of the facades in ceramic elements; and vii) Wooden / metal frames. Finally, the E4 building, already built and inaugurated during the 1990's, also consists of a reinforced concrete structure and walls (inside and outside) in brick masonry, presenting great rigidity considering its functions. In addition to the above mentioned, other elements are: i) Structure of the roof in reinforced concrete / metallic structure; ii) Covering the roof with concrete slabs / metal sheets; iii) Wall and ceiling finishes in sand and lime plaster / stucco and paint / false ceilings; iv) Exterior cladding of glass / ceramic facades; v) Metallic window frames; vi) Metallic doors; and vii) Ceramic tiled / parquet floors.

In Figure 1 to Figure 4 we can observe the graphic representation of the classification obtained for the four (4) Collective Use Buildings (CUB) analyzed for the different dimensions and indicators, using the ninety-five (95) parameters from the resilience classification system.

a) b)

Figure 1 – E1 Resilience scoring: a) Dimensions; b) Indicators

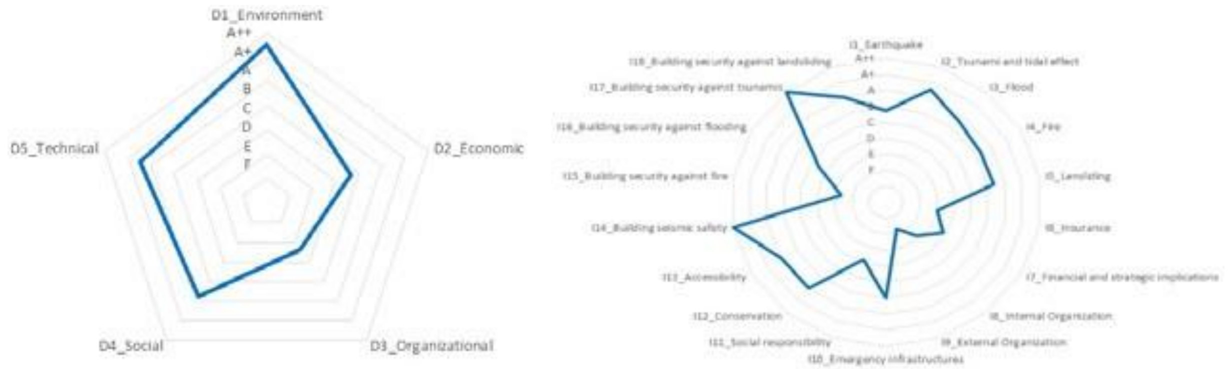


a) b)

Figure 2 – E2 Resilience scoring: a) Dimensions; b) Indicators

a) b)

Figure 3 – E3 Resilience scoring: a) Dimensions; b) Indicators



a) b)

Figure 4 – E4 Resilience scoring: a) Dimensions; b) Indicators

Considering the results, and in what refers to the different Dimensions, it was obtained good rating for all studied buildings, considering D1 (Environment) and D5 (Technical). Furthermore, for D2 (Economic) and D4 (Social), the results achieved correspond to low to medium rating, respectively. For D3 (Organizational), and for all buildings studied, belonging to the same asset manager, it was obtained very low rating. While the better Indicator for all buildings corresponds to I14 (Building seismic safety), the worst Indicator for all buildings corresponds to I15 (Building security against fire). All analyzed buildings present similar behavior for I10 (Emergency infrastructures). Most of the similarities seem to appear since all buildings belong to the same organization, having the same type of maintenance and asset management, as previously referred to organizational dimension.

4. Sustainability classification system – Case study 2

LEVEL(S) uses a set of sustainability indicators to measure carbon, materials, water, health, comfort, life cycle costs and climate change impacts, evaluated from the design phase to the use phase of the buildings. Their common structure is organized into three (3) levels that represent the increasing complexity of the construction project phases / stages. Each LEVEL has associated indicative stages, and it may be useful to understand how and when different activities, in each of these stages, contribute to the application of the LEVEL(S) to the project. LEVEL 1 (Concept for the construction project) represents the simplest level, as it involves a qualitative assessment in the initial phase. LEVEL 2 (Detailed design and construction performance) represents an intermediate level, as it involves quantitative assessment of the performance of what is designed and the construction monitoring, according to standardized units and methods. Finally, LEVEL 3 (Reality after completion and including delivery to customer) represents the most advanced level, as it involves monitoring activity at the construction site and the building and first occupants (Lima et. al, 2021b).

The LEVEL(S) structure indicators are divided into three (3) different Areas: i) Resource use and environmental performance during the life cycle of a building; ii) Health and comfort; and iii) Cost, value, and risk. Each area is subdivided into Macro-objectives, that describe the strategic priorities, for the contribution of buildings, to the European Union’s and Member States’ policy objectives, in the field of energy, use of materials and waste, water, and indoor air quality. For each macro-objective, performance Indicators are defined. The LEVEL(S) approach suggests sixteen (16) performance indicators for buildings. It uses basic sustainability indicators, tested with and by the construction sector, to measure carbon, materials, water, health and comfort, and the impacts of climate change. They consider life cycle costs and value estimates (Table 2) (Lima et. al., 2022).

Table 2 – LEVEL(S) sustainability classification system

AREAS	MACRO-OBJECTIVE	INDICATOR
Use of resources and environmental performance	1. Greenhouse gas and air pollutant emissions along a buildings life cycle	1.1 Use stage energy performance
		1.2 Life cycle Global Warming Potential
	2. Resource efficient and circular material life cycles	2.1 Bill of quantities, materials, and lifespans
		2.2 Construction & demolition waste and materials
		2.3 3 Design for adaptability and renovation
		2.4 Design for deconstruction, reuse, and recycling
	3. Efficient use of water resources	3.1 Use stage water consumption
Health and comfort	4. Healthy and comfortable spaces	4.1 Indoor air quality
		4.2 Time outside of thermal comfort range
		4.3 Lighting and visual comfort
		4.4 Acoustics and protection against noise

Cost, value and risk	5. Adaptation and resilience to climate change	5.1 Protection of occupier health and thermal comfort
		5.2 Increased risk of extreme weather event
		5.3 Increased risk of flood events
	6. Optimised life cycle cost and value	6.1 Life cycle costs
		6.2 Value creation and risk exposure

After analysing the LEVEL(S) approach and comparing it with its objectives, an application example of some classifications made, based on Macro-objective 2 (Life cycles of circular and resource-efficient materials) and Indicator 2.2. (Construction and demolition materials and waste), is presented. The decision is based on this macro-objective to contain the indicators most related to the reuse and recycling of materials, to the waste generated by the construction and deconstruction processes, with a focus on the lists of quantities of important materials, for the Life Cycle Analysis (LCA) and the adaptability of dismantling buildings, a topic of greatest relevance today.

Indicator 2.2. (Construction and demolition materials and waste) aims to identify the types of construction and demolition waste and materials. These classifications can be important in the decision process of reuse for these products, as well as determining the degradation state witch they are, to support actions capable of making them return to the life cycle and, consequently, extending the useful life of the materials. This indicator also estimates and measures the total amount of waste generated by construction, renovation, and demolition activities (in kg) which, when broken down into the main types of CDW (Construction and Demolition Waste), according to the entries in the European Waste List, results in a mapping for a better destination of these (e.g., recycling, landfill, etc.). The suggested classifications consider the Type, Constitution, and possible Destination of the waste, as described (see Table 3).

Table 3 – Possible classes and properties for Construction and Demolition Waste (CDW)

PARAMETERS TO BE CLASSIFIED		PARAMETERS DESCRIPTION
LEVEL 1	LEVEL 2	
Waste type	Inert Dangerous Not dangerous	Waste classification to be generated according to the type of material that is present
Waste constitution	Concrete Tile Roof tiles Ceramics Wood Glass Plastics Bituminous mixtures Copper / bronze / brass Aluminium Iron Steel Other metals Cables Soil and stones Drainage spoil Track ballast Insulation materials Asbestos-containing materials Gypsum-based materials Door elements Window elements	Waste type classification to be generated based on its composition according to the European Waste List (LER Code), the same classification used in the Excel spreadsheet: Estimation of amounts of waste from Indicator 2.2 of the LEVEL(s) approach.
Waste material destination	Residual material for reuse Residual material for recycle Residual material for recovery Residual material for disposal	Classification indicating the destination of the material that can support the measurement of how much construction or demolition is associated with recycling, reuse, and waste of materials.

The classifications proposed in Table 4 are necessary for better information management and standardization of these properties and characteristics. With these codes, the language used by the different agents of the project is standardized, thus avoiding divergences in the communication among them. Once the information is classified, it can be introduced in the LEVELS(S) calculator (available at: https://ec.europa.eu/buildings-performance-calculator/screen/ home) or in the Excel format template (available at: https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/ 412/documents) to obtain the results, according to the methodology. Another function of the standardization and codification of these classifications is the possibility of being used as parameters in the BIM methodology. This makes it possible to generate graphically informative models about how the elements may be intended with respect to their nature or even what type of material is being applied in the construction, with the possibility of extracting the information directly from a BIM model, through proprietary routines.

The validation of the LEVEL(S) classification system was carried out by applying it to an unfamiliar house located in the North of Portugal, for all three (3) levels and life-cycle phases, which, although not completely representative of a diversified sample, either in terms of quantity or in terms of distinguishing between the characteristics of each one of them, will allow for the expeditious validation of the system.

Table 4 – Proposed classification for Construction and Demolition Waste (CDW)

NUMBER	DESCRIPTION	TABLE LEVEL
Table PC	**Properties and Characteristics**	**1**
PC_10	**Construction and demolition waste and materials**	**2**
PC_10_01	Element Properties	3
PC_10_02	Nature of waste	3
PC_10_02_01	Inert	4
PC_10_02_02	Dangerous	4
PC_10_02_03	Not dangerous	4
PC_10_03	Waste destination	3
PC_10_04	Constitution of the residue	3
PC_10_04_01	Concrete	4
PC_10_04_02	Bricks	4
PC_10_04_03	Roof tiles	4
PC_10_04_04	Ceramics / tiles	4
PC_10_04_05	Wood	4
PC_10_04_06	Glass	4
PC_10_04_07	Plastic	4
PC_10_04_08	Bituminous mixtures	4
PC_10_04_09	Copper / bronze / brass	4
PC_10_04_10	Aluminum	4
PC_10_04_11	Iron Steel	4
PC_10_04_12	Other metals	4
PC_10_04_13	Cables	4
PC_10_04_14	Soil and stones	4
PC_10_04_15	Drainage garbage	4
PC_10_04_16	Runway ballast	4
PC_10_04_17	Insulation material	4
PC_10_04_18	Material containing asbestos	4
PC_10_04_19	Gypsum based material	4
PC_10_04_20	Door element	4
PC_10_04_21	Window element	4

5. Conclusions

The results of the calibrations of the resilience classification system proposed, for four (4) Collective Use Buildings

(CUB) located in the municipality of Lisbon are presented, however, it is still necessary to develop complementary work to implement the proposed assessment, in a representative number and diversity of the constructed assets types, as well as to extend the scope of the proposed multivariable classification system about other types of risks (e.g., human-induced hazards) and the identification of countermeasures and their classification. Different buildings with different functions and uses can, and should, be used as empirical case studies to show how technical performance and risk engineering can be programmed defensively to improve resilience and reliability in a more sustainable environment for future generations. The expansion of the approaches presented, in the future, include: i) An online platform GIS based with the objective of rapid and wide dissemination of research results, developments and applications; ii) A roadmap to increase the reach and extended impact of project results, for public and private organizations that manage construction assets, such as government agencies, banks, insurance companies, design and construction companies and various professionals in the AECO sector.

The LEVEL(S) approach proposed by the EU also appears as a starting point for the development of a classification component with a sustainable aspect, supporting users in “greener” decisions. Divided into six (6) macro-objectives, the proposed classification focused on the life cycles of circular and resource-efficient materials. Through the parameters suggested in four (4) indicators, classifications are defined that aim to describe; materials and their life cycles (2.1); the classification of construction and demolition waste (2.2); the adaptability of buildings to promote greater life cycle (2.3); and criteria that facilitate the disassembly, reuse, and recycling of materials (2.4). The results of classifications for indicator 2.2 already have been defined and are in the evolution phase for application and dissemination in building projects.

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ANALYZING THE RELATIONSHIP BETWEEN SUSTAINABILITY AND MAINTENANCE IN THE FACILITIES SECTOR

OM23 68

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Abstract

The research is related to analyzing the relationship between sustainability and maintenance in the facility sector. A lot of attention has been given to sustainability in the past. In the facility sector, maintenance is the key strategy for achieving sustainability as it helps in maintaining the quality of the product and makes the production cost low (BenoitIung & Levrat, 2014). Maintenance helps in making the product efficient and also fulfills the demand of the environment. Using new technology to integrate sustainability goals into traditional maintenance management is a creative management approach to sustainability (Franciosi, Voisin, Miranda, Riemma, & BenoitIung, 2020). According to the research conducted in the past, maintenance impacts production volume, expense, machine performance, equipment availability, and final product quality (Sinaga, Suharyono, Musadieq, & Iqbal, 2022). The aim is to find out the impact of maintenance in the facility sector. This research has utilized a systematic review to fulfill the gap in the research and to formulate the results. According to the result, digital technology is the key strategy that is helping the utility and facility sector to achieve sustainability by maintaining it in a positive manner (Sabatin, M.Frangopo, & Dong, 2015). Therefore, it is recommended that facility companies may use digital technology to create a significant impact, unlock new efficiencies, reduce material consumption, and maintain quality for achieving a climate-positive future.

1. Introduction

In industrial settings, maintenance is performed on a variety of assets to keep them operating or to restore them to their original condition (Franciosi, BenoitIung, Miranda, & Riemma, 2018). This strategy is often applied to large machines and equipment to ensure their optimal functioning. Cleaning bearings, replacing filters, pumping tyres, and repairing conveyor belts, reactors, and pumps are just a few of the things that are accomplished using this method (BenoitIung & Levrat, 2014). Controlling airflow and air quality, replacing filters, maintaining tyres, and fixing conveyor belts, reactors, and pumps are just a few of the things that are included in this category. The strategy keeps many of these operations running efficiently and supports “the triple bottom line of sustainability: people, the planet, and profits” (Franciosi, Voisin, Miranda, Riemma, & BenoitIung, 2020).

A lot of attention has been given to sustainable manufacturing in facilities as a new technique in the last decade, thereby prompting facility companies to meet sustainability targets (Sabatin, M.Frangopo, & Dong, 2015).

Maintenance is very important for a facility industry as it allows the organization to make its production system efficient by maintaining quality in every aspect (Hojjati, Jefferson, & Metje, 2018). It has the potential to increase the volume and lower the cost, as well as maintenance, can perform asset performance and make the equipment available all the time. Maintenance in the facility also helps to maintain the workers' health and safety and also to make the national environment sustainable (Ahmad, et al., 2021).

The demand for higher product quality and economic instability have made life difficult for facility manufacturing companies, which must also deal with physical resource depletion, higher laws and regulations, and frequent economic downturns. Many firms have used sustainable manufacturing as an innovative manufacturing strategy to cope with these issues and gain an edge in today's competitive market (Sabatin, M.Frangopo, & Dong, 2015).

Customers' demands, government and regulation, the environment's concerns, the shortage of natural resources, and rising energy costs are the key factors driving sustainability, and manufacturing processes that are sustainable are those that reduce adverse environmental impacts, conserve energy, and save natural resources and are also safe for workers, communities, and consumers (Sabatin, M.Frangopo, & Dong, 2015). It is the process through which the organization produces goods by using a series of procedures that alternately minimize the negative impact on the environment and also contribute towards conserving energy. It preserves natural resources and also it is safe for the workers and society as a whole. Sustainable production requires indicators to evaluate an organization's journey toward it. There are three aspects of economic environmental and social impact that should be evaluated by such a measurement (Vlasov, Shakhnov, Sergey, & Krivoshein, 2019). In other words, maintenance functions to preserve the operation of a company's manufacturing system in good shape and deliver high-quality merchandise. Maintenance has the potential to significantly influence other firms' procedures, making it a good candidate for sustainable manufacturing (BenoitIung & Levrat, 2014).

From an innovative management perspective, integrating sustainability goals into traditional maintenance management, as well as using new technologies and methods, are just a few of the strategies that maintenance can use to promote sustainability (Byrne & Taminiau, 2015). More research and real-world experience have contributed to highlighting the importance of maintenance's role in sustainable operations (Sinaga, Suharyono, Musadieq, & Iqbal, 2022).

Maintenance impacts reproduction volume expenses and also the performance of the machine and equipment. And all this ultimately creates a positive impact on the final product category and quality. Maintenance has a variety of consequences, including people's health and safety, the environment around them, and social welfare. Maintenance has numerous ramifications on sustainability issues, including the production process and final product quality because of their competence or inefficiency (Sinaga, Suharyono, Musadieq, & Iqbal, 2022). A proper, sustainable maintenance management strategy can minimize and control these effects (Sabatin, M.Frangopo, & Dong, 2015).

The maintenance activities of an asset or equipment must ensure the production process, product quality, and environmental sustainability in addition to minimizing economic, societal, and environmental impacts. In contrast, a sustainable business function must be maintained in order to minimize the flows and impacts produced by maintenance activities (Nezami & Yildirim, 2013).

The modern world relies on electricity, an essential part of the infrastructure and an important part of daily life (Nezami & Yildirim, 2013). Electricity has played a critical role in productivity, wages, and employment around the world, as well as the lifeblood of what is being called the new global economy. Around the world, electricity-based innovation is helping to build increasingly sophisticated global, real-time networks (Vlasov, Shakhnov, Sergey, & Krivoshein, 2019). Because of electricity, the business will be spurred in a variety of industries, from lasers to microprocessors that will make future industrial efficiency improvements (Franciosi, Voisin, Miranda, Riemma, & BenoitIung, 2020).

In the near future (two to three decades), wind, solar, and biogas are becoming more and more popular electricity alternatives (i.e., they will increase in popularity in the future), but coal, nuclear, large hydroelectric, and gas will continue to be the bulk electricity fuels of the future (i.e., for the next twenty to thirty years). Each of them has a distinct sustainability problem. To keep nuclear as a future energy source, spent fuel or high-radioactive waste must be stored for a long period of time. The development of clean coal technologies and carbon sequestration strategies might be crucial for the continued use of coal (Sabatin, M.Frangopo, & Dong, 2015). Flooding of ecosystems and the relocation of populations might be prevented by developing clean coal technologies and carbon sequestration strategies (Byrne & Taminiau, 2015). The development of clean coal would be critical to the continued utilization of coal. The availability and expense of gas, despite its being a cleaner fuel than coal, would have to be addressed in the future. None of these generation options is without long-term environmental implications (CISCO, 2022).

Sustainable development techniques pose significant obstacles for the electric facility industry, not only those associated with introducing these techniques into business, but also doing so at a time when the industry is experiencing radical changes in the business environment (Franciosi, BenoitIung, Miranda, & Riemma, 2018). Electric facilities are faced with a variety of uncertainties regarding government regulations, the market's reorganization, client demands, and technological change (Franciosi, Voisin, Miranda, Riemma, & BenoitIung, 2020).

Future approaches to environmental and social issues may also be altered. Growing demand for transparency and stakeholder participation, in addition to a globalized and interconnected world, requires a more inclusive approach to future dialogue (Ahmad, et al., 2021). These stakeholders, including customers, regulators, governments, electricity sector regulators, environmental NGOs, and academics and scientists, have a significant influence on decision-makers, and because governments are considering future energy directions and individual facilities are seeking changes to their operating licenses, these stakeholders will play a key role in discussions about future energy alternatives (Byrne & Taminiau, 2015).

The environmental and social pressures facing electric facilities are complicated, and companies must invest substantial dollars in response to them (Franciosi, Voisin, Miranda, Riemma, & BenoitIung, 2020). The most promising avenues for great strides towards sustainable energy futures lie in collaborating with other companies in research and development, sharing information on innovative practices, and partnering (Franciosi, Voisin, Miranda, Riemma, & BenoitIung, 2020).

Goals and objectives

The core objective of this paper is to analyze the studies that have been conducted in the past related to the impact of maintenance on the facility and utility sector and also identify the sustainable indicators. The research has been carried out using a systematic literature review to fulfill the gap in the research and to formulate a result. There are a number of studies conducted in the past but still, there is a lack of a comprehensive framework of maintenance impact on the sustainability of the facility industries. Maintenance is key to sustainability in a building factor which means that we must broaden our perspective by starting from the perspective of sustainability rather than focusing on maintenance (Hojjati, Jefferson, & Metje, 2018). To achieve this goal, the first step is to define sustainability and its impact on maintenance procedures. In addition, the research must identify indicators to gauge these impacts. We will therefore be able to obtain a comprehensive understanding of the impact of maintenance activities on sustainability through this research. The purpose is to provide a valuable contribution to solve the research challenge and to meet the research objectives in a comprehensive manner that could help the facility sector to become more sustainable in the future.

The research objectives are summarized below

- “To examine the connection between maintenance and sustainability concerns.”
- “To investigate the maintenance impacts on the sustainability of facility industries.”
- “To find out the indicators used for measuring sustainability impacts.”

2. Research methodology

In this study, we carried out a structured review following a clearly defined objective to minimize subjectivity and to obtain a detailed picture of maintenance impacts on industrial sustainability. It is not based on the author’s knowledge perspective but rather on a clear objective. First of all, we searched for and reviewed papers that examined the impacts of maintenance on facility manufacturing industries’ sustainability. Next, we measured the impacts of maintenance on sustainability by collecting sustainability-related indicators.

Thereafter, we evaluated research gaps and challenges. Academics and industrialists should better understand the no negligible implications of maintenance processes on industrial sustainability, as well as the need to monitor those impacts in order to safeguard the three pillars of industrial sustainability.

This study has been undertaken as a systematic literature review based on the research questions designed.

“RQ1. What is the relationship between maintenance and sustainability issues?”

“RQ2. What is the maintenance impact on the sustainability of the facility industry?”

“RQ3. What are the indicators that are used for assessing such impacts?”

The methodological steps involved in conducting the review are listed below.

2.1. Identification of research databases and keywords definition

This research was conducted using a systematic literature review and the research papers were acquired from Scopus and Web of Science, which are considered to be the biggest scientific and technological literature databases. Keywords were chosen to target the review, ensuring they were selected carefully in order to achieve the review’s objectives and goals. The first set of keywords includes ‘maintenance,’ the second set includes ‘sustainability,’ and the final set includes ‘sustainable,’ ‘facility,’ ‘industrial’, and ‘facilities’.’

2.2. Inclusion and exclusion criteria

A search was performed on all English-language scientific journals, conference proceedings or books that met the criteria to retrieve all papers published in the last year. Only papers that had been published in peer-reviewed journals, conference proceedings or books and contained the keywords were considered. All papers were imported into the software Mendeley after being identified through the search, eliminating any duplicates.

In the first step, we examined the abstract and the title of the articles to determine whether or not they met the scope. In the second step, we examined the conference proceedings to separate the articles that were not about maintenance and sustainability issues from those that were.

In order to provide a final assessment of the papers selected at the initial screening phase, the second step consists of reading the full text of all of them. During this step, irrelevant papers that don't specifically address the research questions are eliminated, while papers focusing on sustainability indicators or addressing sustainability issues on three core pillars are deemed to be included.

In the final step, the papers selected at step two are evaluated for citation relevance. Therefore, the citations were investigated to see if additional papers might be included.

2.2. Analysis process and information extraction strategy

In investigating the papers, we located the main information and used it to group them based on the type of publication whether be it a journal article conference paper or book chapter. The year of publication was carefully examined while extracting the research paper and also the objectives of the study reviewed. Those articles were extracted that were based on the research questions related to sustainability in the facility sector. Extraction criteria was carefully examined in order to carry out the analysis in a smooth manner and to have a holistic view of the investigation.

2.3. Review results

From the 3144 papers included in the databases searching for the keywords, 2489 yielded after removing the duplicates. After excluding the duplicates, 99 papers were identified for analysis. Of these, 99 papers were read in full, whereas the others were discarded during the first screening process in accordance to the two exclusion rules. After reviewing the 35 papers selected, 11 more papers were discovered through reference checking, for a total of 46 papers that were considered relevant.

2.4. Content analysis

The 29 articles included in this paper pertain to the research questions posed in the section. Therefore, the second subsection looks at the 17 studies that examine the links between maintenance and sustainability in the three dimensions of economic, environmental, and social sustainability.

3. Results

The facility industry is shifting to more sustainable practices, causing local, national, and global GHG emissions (Byrne & Taminiau, 2015). These forces will contribute to these targets:

The growing demand for green energy sources provided by facility companies could boost the demand for those energy sources, due to the expansion of wind turbines, solar arrays, and other renewable installations (Nezami & Yildirim, 2013). Consumers may elect to power their facilities using Eco investment power or traditional investment power, since more Eco-invested firms are purchasing green energy (CISCO, 2022). As more individuals purchase green power, it has a higher demand for renewable sources. The ongoing operating costs of renewable energy installations have fallen lower than traditional power plants

(Vlasov, Shakhnov, Sergey, & Krivoshein, 2019). The cost to operate a renewable energy installation is lower than with traditional hydrocarbon sources once the initial investment is paid off. The cost of raw materials such as sunlight, wind, and water is essentially free to produce power once the raw materials are used to produce the power (Byrne & Taminiau, 2015).

As renewable energy becomes cheaper to generate, facility companies will increasingly choose it as their source. It addresses all three of the driving forces listed above: it meets government regulations, consumer demand, and the cost of doing business (CISCO, 2022).

Process optimization and operational efficiency

Facility companies can monitor the use of sensors throughout the distribution network to determine real-time power consumption data (Sabatin, M.Frangopo, & Dong, 2015). By utilizing this data, companies can regulate power production, network configuration, and switching load, among other things. In case of outages, sensors on the grid may alert operators to damage, allowing them to turn off power to dangerous lines, and preventing electrocution, wildfires, and other accidents. Digitalization can help the power sector extend the lifetime of power plants and networks through condition-based constant preventive maintenance (Sabatin, M.Frangopo, & Dong, 2015).

Energy monitoring and efficiency

Facilities and customers can monitor their energy consumption and usage patterns via advanced data analytics and visualizations (Sabatin, M.Frangopo, & Dong, 2015). They can use this information to derive insights and create better energy efficiencies and optimize usage behaviors to reduce emissions and facility bills.

Smart meters and smart thermostats are two of the most popular applications of IoT in the energy sector besides being utilized for advanced analytics. By using IoT coupled with advanced analytics systems, power generators can forecast the generation capacity of renewable energy sources such as solar and wind as well as adjust their operations in the case of an emergency (BenoitIung & Levrat, 2014).

Audit/reporting and analytics

Block chain and smart contracts may allow you to trace the source of materials and energy through the supply chain. They can help reduce material and energy consumption and optimization by offering many new possibilities which can contribute to achieve sustainability. Users can now verify that the electricity they use is eco- or green-labeled, and they can ask for eco-/green-labelled energy (Franciosi, BenoitIung, Miranda, & Riemma, 2018). They're more aware of their own energy consumption and ecological footprint and make environmentally conscious decisions in their day-to-day lives. Facility managers can now track energy use, consumption patterns, and carbon footprint in real time through the use of energy audit, analytics, and reporting tools. They are able to select energy providers in a more efficient manner because of the available digital energy auditing, analytics, and reporting tools (Hojjati, Jefferson, & Metje, 2018).

4. Discussion

On the one hand, the effects of maintenance processes on sustainability in an organization as a whole have not been systematically investigated, and on the other hand, the link between maintenance processes and sustainability indicators has to be formalized and established (Nezami & Yildirim, 2013). Stakeholders should be encouraged to consider and monitor the impacts of maintenance processes in order to help reach sustainability targets (Nezami & Yildirim, 2013). However, the research examined in this paper demonstrates that, on the one hand, maintenance processes have not been systematically investigated and, on the other hand, the link between maintenance processes and sustainability indicators has to be formalized and established (Franciosi, Voisin, Miranda, Riemma, & BenoitIung, 2020).

It examines all three dimensions of sustainability as well as the consequences of maintenance on various parts of the organization, from the customer's viewpoint (Byrne & Taminiau, 2015).

The presented framework covers all sustainability indicators relevant to the maintenance system regardless of their nature (i.e. whether they are connected with the production system or the manufactured product), their specificity (i.e. whether they are very precise for a particular industrial case study or very general), or their nature (i.e. whether they are connected with maintenance activities or the production system).

This is due to the different viewpoint adopted compared with previous research. The majority of existing literature on this topic begins with a maintenance perspective rather than a sustainability approach and the whole business enterprise. We start with an original idea: the discovery of consolidated frameworks in the literature involving general sustainability indicators at business enterprise level.

In order to identify the indicators that can be used to evaluate the efficiency of maintenance processes and hence, the impact on organizational performance, the authors proposed a method. This method uses indicators from both the maintenance perspective and the organizational perspective, in order to find indicators that may be used to judge performance.

With regard to the first point, a general framework may be created by examining all aspects of maintenance impact from both a sustainability perspective and from a business perspective. In other words, maintenance may have both positive and negative impacts across a variety of areas and business sectors. In addition, performance indicators may be used to quantify the impacts to identify where gaps might exist and to direct effort and resources to the areas where they are most needed (Hojjati, Jefferson, & Metje, 2018).

In the United States, electricity generation is responsible for 25% of greenhouse gas emissions. It makes sense that coal and natural gas account for 60% of electrical supply, because these fuels are involved in a significant amount of electricity generation (CISCO, 2022). What may surprise you is that facilities are leading the way in sustainable practices. Facility companies are anticipated to commit in 2022, as environmental, social, and governance (ESG) aims, as well as value creation possibilities, are driving forces. The growing popularity of clean energy, evolving state clean energy mandates, and the chance of federal legislation are all factors driving the trend. (Vlasov, Shakhnov, Sergey, & Krivoshein, 2019)

The three key forces driving sustainability in the facilities industry are: 1) government regulations are expanding, 2) consumer and shareholder demands for eco-friendly corporate conduct are growing, and 3) the cost of renewable energy is falling as a result of expanding technology markets.

Recommendations

Global warming is getting worse, and countries and international organizations are drafting and announcing ambitious climate action plans in response. At the COP 26 summit, more than 100 world leaders promised to end deforestation by 2030, and more than 35 world leaders have promised to speed the deployment of clean technologies. Many of the promises evoked a mixed response from environmentalists and the public since there were no solid execution plans to back them in most cases. Greenwashing, in order to soothe people's concerns, may have been involved. Around 200 organizations have pledged net zero emissions by 2040, but very few have specified how they will reach that goal.

Countries and organizations must set lofty sustainability goals and put standard procedures and tools to monitor progress towards those goals in order to ensure the urgency of the matter is addressed. There is currently no visibility, data, or standardized monitoring tools that can assist organizations in tracking the progress of their climate action plans. Digital technologies like data analytics, blockchain, and machine learning can help organizations mine data and track the progress of their climate action plans.

Digital technologies are not just about providing a monitoring and reporting framework based on empirical data but also provide the foundation for exigent data that paves the way for improved efficiencies in many industries, helping them reduce their emissions and footprint through rampant digitalization. These technologies have the greatest scope in the industries traditionally considered hard to decarbonize and account for up to 80% of current global carbon emissions. These sectors are critically important in the economy and society and include power, transportation, industrial manufacturing, and construction.

According to a 2019 United States Environmental Protection Agency report, up to twenty-five percent of the global greenhouse gas emissions come from the power and electric facility sectors alone. In light of the current discussion, we plan to look at how digital technologies can help power companies reach and monitor the climate action targets without jeopardizing sustainable growth and the interests of all concerned parties, as specified by the abovementioned report. Facility companies may use digital technologies to create significant impact, unlock new efficiencies, and reduce material consumption and energy usage across the value chain for a climate-positive future.

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