

Building Services Equipment and Effective Maintenance Culture: The Experts Standpoint

B. B. Okon and V. E. Okon

Department of Mechanical Engineering, Sustainable Infrastructure Services Group, Akwa Ibom State University, PMB 1167, Uyo, Nigeria

Abstract: Effective management and maintenance of building equipment can yield more sustainable delivery of building services systems with buildings/facilities. Buildings generally provide habitation, security, comfort and indeed habitat for social and recreational activities. All over the world, buildings/facilities play very vital role in the economic development of any nation. Building equipment is classified as refrigerator, pump, lift and escalator systems, HVAC (heat ventilation and air-conditioning) systems, extractor fans as well as water and firefighting equipment among others. In this paper, the roles of maintenance culture within building equipment were examined in pursuit of achieving effective services delivery. More often than not, maintenance of building equipment option is sometimes played down but with emphasis on achieving optimum performance without recourse to striking a balance between the above indices. The paper also examines immediate and remote causes associated with maintenance management practices within building infrastructure systems (equipment) in this investigation. Experts' opinions were sought for their understanding, barriers and commitment of sustainability agenda in pursuit of building equipment maintenance ethics and the way forward. The achievable outcomes from this study demonstrate that optimum services delivery of building equipment relied on efficient management and maintenance culture options as best practices.

Key words: Building equipment, infrastructure, maintenance culture, management, sustainability.

1. Introduction

Buildings equipment and top quality maintenance management culture are two separable phenomena in the quest for effective services delivery in sustainable buildings. It is a common fact that without buildings, man, some animals, equipment, goods and other housing activities cannot exist comfortably due to harsh weather and the general environmental conditions. Buildings universally have played vital economic and social role within the built environment and the importance attached to buildings development cannot be overstressed. Arguably, sustainable buildings are not stand-alone without workable equipment for the overall comfort and functionality of the end users. Since the functionality of sustainable buildings relied on the efficiency of buildings

equipment, then, proactive maintenance management culture is desirable for the attainment of optimum service delivery.

In many respects, maintenance culture has become a determining factor for effective performance of both mechanical and other equipment in buildings. With the current economic trends, that is, in the procurement of buildings equipment, it is no longer a question of applying the technique of maintain-as-we-go philosophy but a trio (predictive, preventive and corrective) maintenance culture [2, 17]. This ethos of maintenance management culture associated with sustainable buildings, is viewed in the context of achieving sustainable development goals.

Concerns over environmental degradation (carbon emission, acid rain, wind storm, waste pollution and indeed climate change) as well as increasing population [18] have identified that these factors contribute more pressure on buildings equipment. This pressure overtime has negative impact on the

Corresponding author: B. B. Okon, PhD, senior lecturer, research fields: sustainable infrastructure services, and energy management. emails: engrvik@gmail.com, engrvik@yahoo.com.

buildings equipment to include HVAC, fire hydrants, sprinklers, combine heat and power system, water pump and chillers to mention but a few and their maintenance account for increased investment in building development.

Research conducted [13, 2] has presented that in order to attain the set goals of integrating sustainability into building services management, various stakeholders within the building industry are expected to simulate environmental sustainability agenda and just-in-time (JIT) maintenance management culture in their activities. Against this background, Lazarus [11] study has revealed the most significant environmental impact emanated from building services infrastructure activities. Buildings undertakings from schools, shopping malls, hospitals, factories, airports, railway stations, homes among other places constitute sources of environmental impact [5].

The above highlighted activities could be overcome through appropriate design of maintenance management scheme with integration of sustainability agenda as core management strategy.

These options are desirable since building services equipment is often prone to malfunction without sound and strategic management approach. More often than not, maintainability of building services equipment is regarded as a *de facto* in the management practice in this context without recourse to achieving sustainability which should also be a prime objective.

Issues relating to maintenance management ethics on building services equipment with the integration of sustainability in the 21st Century are increasingly gaining prominence within the interdisciplinary engineering applications. Some researchers have also proposed the regulation of maintenance management standards in building services engineering activities through the integration of the sustainability agenda within corporate business strategies as a means of achieving sustainable development goals [3]. This

points to the fact that maintenance management practice on building services equipment could be vigorously pursued with the integration of sustainability programme. In this pursuit, the three major maintenance management practices earlier mentioned were: predictive, preventive and the corrective mode could be best achieved with the incorporation of sustainability as an index for measuring the total performance of building services equipment.

Experts [2] have opined that inadequate and poor maintenance management culture without integration of sustainability agenda can lead to the depletion [18] of resources, dearth, shut-down and sometimes malfunctioning of building services equipment generally [3, 5]. The contributions of building services profession to the nation building are very enormous ranging from provision of comfort, employment generation, skill development to the gross domestic product (GDP) index. From the highlighted benefits of building services profession, then government efforts should be directed towards the training of manpower to cope with the building services equipment challenges [16, 17].

Building services equipment performance from the cradle-to-grave rests on sound maintenance management culture. One of the major challenges in achieving strategic and effective maintenance management culture in building services equipment performance is lack of resources to cope with the regular or timely schedule of maintenance activities. With the pressing challenges in this regard, the impacts of building services equipment have to be addressed across building services stakeholders (public and private) within the built environment. The public and private sectors of economy in this case [2] posit are grossly affected by the syndrome of poor maintenance cultural standard. Current drive in this perspective is far beyond achieving good quality maintenance management practice on infrastructure systems but the attainment of sustainable maintenance

management standard is the state-of-the-art option.

There is no doubt that the overall impression in this study is centred on the actualisation of the sustainable development goals. Sustainable development involves processes and frameworks for redefining social progress and redirecting economies to enable all people meet their basic needs for improved quality of life, while ensuring that the natural systems, resources and diversity upon which they depend are suitably maintained and enhanced for their benefit and that of future generations [4].

Inadequate or poor maintenance management culture in building services equipment [2] most often led to the shut-down of equipment and/or malfunctioning of the entire infrastructure systems. The performance of building services equipment from the cradle-to-grave rests on sound maintenance management culture.

2. Challenges in Building Services Management

Challenges associated with building services equipment and maintenance management culture include lack of implementable frameworks, paucity of experts with inclination to sustainability agenda especially at the design and construction/installation stages of building infrastructure. Also in this list is lack of regulatory policies formulations as well as inadequate research and development (R & D) tailored in the context of building services performance. These challenges are major setback in equipment sustainability.

(a) Implementable Frameworks

Researchers have proposed various implementable frameworks to assist in the evaluation of building services equipment and maintenance management [1, 8, 15, 17, 18] studies contain these facts.

Implementable frameworks guide in the design process via construction/(installation), operation and maintenance (O & M) till the end-of-life stages of sustainable building services equipment activities.

With the adoption of good quality implementable frameworks, then, operation and maintenance management is easily achievable.

The merits of adopting implementable frameworks in building services equipment and maintenance management are enormous ranging from equipment appreciation, longevity and resources utilisation to efficiency increase in output. A typical schematic representation of building services equipment from the cradle-to-grave is shown in Fig. 1.

From the above presentation in Fig. 1, the relationship between building services equipment O & M management are expressed from design and construction to the end-of-life stages. It should be noted that the building services equipment activities at the points marked (σ) and (∞) are not considered in this analysis. Emphases should be put on the construction (*SIc*) and operation (*SIo*) stages of the building equipment study.

The considered boundary conditions are:

Initial equipment lifespan (t) boundary condition, ($t = 0$), and Temporal (final) equipment lifespan boundary condition ($t = \alpha$).

Where, α expresses the infinity status within the investigated equipment and the building services equipment activities during construction phase (*E*). Also, the activities of the building services equipment during operation and maintenance are denoted by (*IU*) and sustainability index is represented by (*SI*) in this analysis. It is also noted that all parameters in this analysis are normalized values [6, 7, 14]. Therefore,

$$SI(t) = IP(t) + E.IU \quad (1)$$

Let μ = building equipment capacity (variables) factors, then,

$$[0 \leq \mu \leq 1] \quad (2)$$

But,

α = building equipment usage (variables) factors.

Therefore,

$$[0 \leq \alpha \leq 1] \quad (3)$$

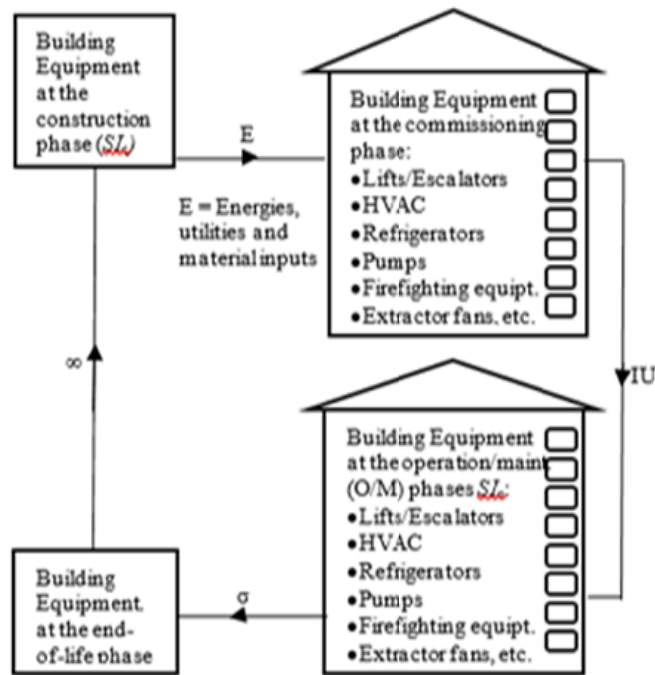


Fig. 1 Schematic representation of the building services equipment lifecycle.

For the sustainability index analysis within the investigated building equipment at the initial construction (c) time, before operations (o) or use:

$$[0 \leq SI_o \leq 1] \quad (4)$$

Recalling Eq. (1),

$$SI = IP(t) + \alpha\mu \frac{dSIc(t)}{dt} \quad (5)$$

Then,

$$SI = IP(t) + \alpha\mu \frac{dIPc(t)}{dt} \quad (6)$$

But,

$$SI = SIc(t) + \alpha\mu \frac{dSIc(t)}{dt} \quad (7)$$

$$\frac{dt}{\mu x} = \frac{dSIc(t)}{SI - SIc(t)} \quad (8)$$

In any case,

$$\int \frac{dt}{\alpha\mu} = \int \frac{dSIc(t)}{[SI - SIc(t)]dx} \quad (9)$$

$$\frac{t}{\alpha\mu} = \ln[SI - SIc(t)] + k \quad (10)$$

At t = 0,

$$SIc(t) = 0 \quad (11)$$

Also,

$$\frac{0}{\alpha x} = -\ln SI + k \quad (12)$$

$$k = \ln SI_o \quad (13)$$

$$\frac{t}{\alpha\mu} = \ln[SI_o - SIc(t)] + \ln SI \quad (14)$$

Hence, for building infrastructure in construction state, the following equations apply:

$$SIc(t) = SI_o(1 - e^{-t/\alpha\mu}) \quad (15)$$

The post-construction (operations) state function is an exponential decay relationship given by:

$$SIc(t) = SI_o(e^{-t/\alpha\mu}) \quad (16)$$

$$\left(\frac{-t}{\alpha\mu}\right) = \left(\frac{[SI_o - SIc(t)]}{SI_o}\right) \quad (17)$$

Hence,

$$\left(\frac{-t}{\alpha\mu}\right) = \frac{[SI_o - SIc(t)]}{SI_o} \quad (18)$$

$$SI \ell^{-\frac{t}{\alpha\mu}} = SI - SIc(t) \quad (19)$$

$$SIc(t) = SI_o - SI_o \ell^{-\frac{t}{\alpha\mu}} \quad (20)$$

$$SIc(t) = SI_o \left(1 - \ell^{-\frac{t}{\alpha\mu}}\right) \quad (21)$$

Therefore, the final mathematical analysis yields:

$$SI_{oc}^1(t) = SI_o \ell^{-t/\alpha\mu} \quad (22)$$

The critical SI level of the building services equipment occurs when $t = \alpha\mu$ and yields 37% of original (as-built) SI value in Eq. (23).

Also, if $t = \alpha\mu \rightarrow$ critical SI level of building infrastructure use, then,

$$\begin{aligned} SI_c^1(t) &= SI_o (\ell^{-1}) \\ &= SI_o \times 0.367879 \quad (23) \\ &\approx 0.367879 SI_o \end{aligned}$$

$SI_o \approx 0.37$.

Eq. (22) is then applied for the analysis.

Then, commercial buildings (operations and maintenance) evaluation ($SI = 0.54$):

$$\begin{aligned} SI_o^1(t) &= 0.54 \ell^{-t/\alpha\mu} \\ &= 0.37 \times 0.54 \\ SI &\approx 0.20 \end{aligned}$$

(b) Policy Formulation and Legislation

Awareness creation regarding the use of building services equipment is of necessity based on the current economic trends. Therefore, management agencies, government arms; legislature, ministries, parastatals, departments and corporate organisations should be actively involved in the promotion of sustainability agenda concerning sustainable buildings and equipment services. Policies formulation and conscious practical implementation should be exercised regarding the sustainability agenda in view of achieving best practices towards building services equipment and maintenance management.

(c) Research and Development

This basically involves training of building services personnel. Training of building services experts should incorporate the use of cleaner technologies for eco-services design. It also becomes expedient to

adopt economic efficiency strategies in the design and implementation of building services management. This is with a view to minimising the use of resources without compromise to the standard of services delivery at all times. Building services and facilities management experts, engineers, architects, estates managers and other players with interest in sustainability agenda needs adequate training and re-training to contend with the current challenges in this context.

Beyond this, no meaningful advancement could be made in managing building services equipment without the integration of innovative technologies (cleaner energy) through flexible design of systems, energy, water harvesting/recycling and eco-efficient blueprint. The implementation of the highlighted strategies concerning building services management will encourage the best practices and add value to maintenance managers in getting data from nine multi-purpose commercial buildings in Akwa Ibom State, Nigeria. Kumar and Maxwell [9, 12] methods were applied in this study.

3. Data Collection

In this study, three sets of data were collected from commercial buildings. The obtained data from the following buildings services equipment: pumps, refrigerator systems, HVAC, lifts, wind turbine infrastructure, CHP (combined heat and power) and others, and their maintenance management practices were analysed and compared. Further information on this study is subsequently presented in the results and discussion sections.

4. Results and Discussion

Achievable results from the investigated buildings services equipment from the commercial buildings are presented in Table 1. In this study, measured field data were obtained from the listed equipment through the equipment monitoring and maintenance management departments of the investigated buildings and their

average performances from buildings A, B and C respectively are shown in Table 1. The building services engineers and other experts in each of the three considered buildings: banks, warehouses and shopping malls provided measured data concerning their equipment performance and the related routine maintenance management procedure for effective operation.

It is also revealed in this study that less emphasis is given to the maintenance of hose reel, sprinkler and lift in bank buildings as shown in Table 1. This finding indicates that the highlighted equipment is seldom put into use thereby not requiring periodic maintenance. Lifts service specifically is restricted to some members of staff and customers with special cases (disable) and movement of heavy equipment and other goods within the banking floors and other equipment statistics are presented.

Bank buildings are generally performing well in terms of maintenance of equipment as presented in Fig. 2. Available information further indicates that bank buildings have achieved 70% correlation as the maintenance performance index in the overall assessment.

This result also established that more attention is given to the maintenance of building equipment to include CHP, HVAC, and pumps among others adopting the current technological and innovative models in managing water, energy and the

maintenance management practices within the bank buildings.

Warehouse activities in terms of building services equipment and maintenance management practices have recorded very high performance rating as shown in Table 1. The achievable results show that HVAC, pumps and CHP are the top marked equipment with high performance indices, other building equipment in this case are slightly below this level of performance. It is also observed that sprinkler and hose reel are with bottom grades.

These outcomes are true reflection of what is obtained in the bank buildings. In the performance index result, in Fig. 2, it is evident that 67% correlation of the equipment performance yields a good degree of concordance on the general maintenance management practice regarding warehouse building equipment.

The shopping malls information in this research is very interesting with four building equipment (pump, HVAC, lifts and CHP) having substantial rating as indicated in Table 1. This study also revealed that only hose reel achieved the least performance index demonstrating a strong correlation with the other investigated buildings. In Fig. 2, shopping malls have 71% performance index in the group data curve signifying very strong relationship among the building equipment and their maintenance management culture. Findings generally points to the fact that effective

Table 1 Results of building services equipment performance in commercial buildings.

S/n	Equipment performance	Commercial buildings											
		Banks				Warehouses (W/H)				Shopping malls (S/M)			
		A	B	C	Av.	A	B	C	Av.	A	B	C	Av.
1	Pumps	0.86	0.68	0.79	0.78	0.75	0.66	0.87	0.76	0.69	0.95	0.85	0.83
2	Wind turbine	0.85	0.79	0.60	0.75	0.68	0.73	0.65	0.69	0.82	0.50	0.67	0.66
3	HVAC	0.78	0.81	0.76	0.78	0.74	0.67	0.89	0.77	0.67	0.92	0.74	0.78
4	Lift	0.56	0.48	0.86	0.63	0.47	0.92	0.58	0.66	0.53	0.89	0.72	0.71
5	Refrigerators	0.69	0.58	0.80	0.69	0.63	0.57	0.87	0.69	0.85	0.68	0.51	0.68
6	CHP	0.72	0.68	0.80	0.73	0.86	0.59	0.72	0.72	0.71	0.83	0.60	0.71
7	Solar system	0.78	0.56	0.68	0.67	0.61	0.84	0.46	0.64	0.50	0.64	0.72	0.62
8	Sprinklers	0.53	0.62	0.51	0.55	0.44	0.39	0.70	0.51	0.74	0.47	0.63	0.61
9	Hose reel	0.48	0.41	0.54	0.44	0.55	0.65	0.46	0.55	0.48	0.59	0.49	0.52

* Authors' compilation (Feb.-Sept. 2017).

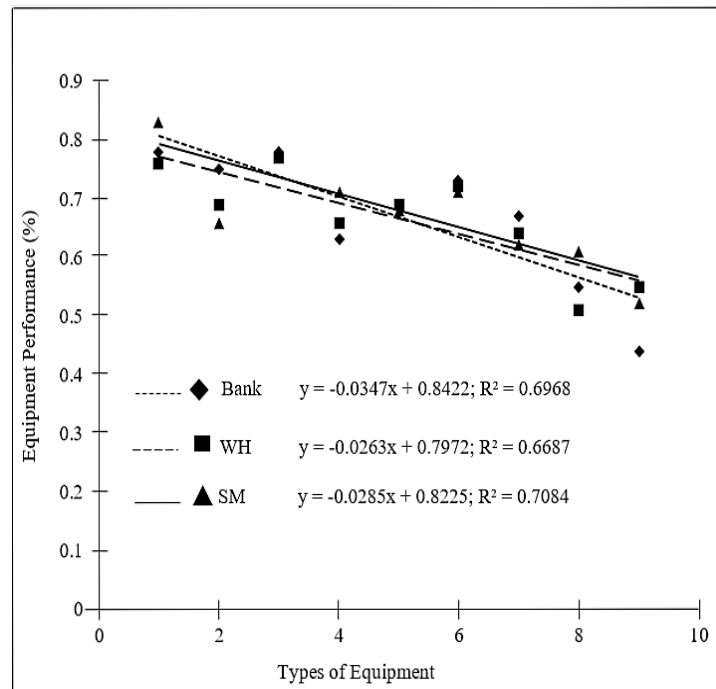


Fig. 2 Relationship between types of equipment and their performance indices.

maintenance management procedure with the integration of sustainability agenda in this context can deliver resources gains and equipment longevity.

Given the challenges related to building services equipment and maintenance management; it is desirable for the building services experts to be trained and re-trained in the design and appraisal of the building services equipment for sustainability pursuit.

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