Optimized Mathematical Model for Energy Efficient Construction Management in Smart Cities Using Building Information Modeling

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Abstract

Nowadays, a Smart city design brings smart buildings and structures and environmental using BIM. The performance and evaluation of the model are experimentally sustainability. Building Information Modeling (BIM) performance describes how to measure a construction project or entity's capability and maturity in terms of development, utilization, and assessment. Energy fluctuation remains a barrier in such development and utilization. In this paper, an Optimized Mathematical Model for Energy Management (OMMEM) has been proposed to assess energy utilization in the construction management of smart cities analyzed by determining building information and distribution systems to the OMMEM performance analysis model. A collection of parameters and variables important for planning and prediction concerning the energy management of construction is acquired to model a smart infrastructure in a smart city. The findings revealed that the mathematical model provides a new method of evaluating the potential of the BIM

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application towards energy management in smart building construction of smart cities with high accuracy, performance with low delay and error rate.

Keywords: Construction management, smart city, building information modeling, optimized mathematical model, energy management.

1 Introduction to Energy Efficient Construction in Smart Cities

A smart city is a developed and effective urban platform that offers a high-quality life to the people through optimal maintenance of all available resources [1]. A smart city primarily accepts or reduces a factor to give a high-quality lifestyle with resource optimization [2, 3]. Smart cities' energy demands are more complex and in enormous need, and energy resource management models are the most common need. Its absence is a significant negative factor in smart city development, which affects the considerable role of energy systems [4]. Smart cities have to develop and implement coordinated strategies and solutions optimally [5]. An integrated energy-optimized model that can be used for all energy needed, like transport, households, etc., makes maintenance easier than separate management systems. Resources, forecasting, and wind power are investigated, as well as ideal microgrid management and scheduling, optimal investment in electricity growth and sloped earth with an embedded pipeline, and the battery deployment strategy [6, 7].

Many simulations have been done to develop energy management of building construction in smart cities to minimize the dynamic nature of energy resources and their impacts [8–10]. BIM provides a better optimal result without subsequent analysis effectiveness related to design panning [11]. The BIM improves the modification analysis to achieve the energy management performance criteria [12, 13]. BIM provides the whole data for the measurement and performance analysis in the energy-efficient structure of the initial design [14–16], which helps to various research and assessments [17, 18] regarding performance in an optimal manner [19, 20].

This research introduces an optimization approach for smart infrastructure by considering the distribution grid system, and it benefits energy management and its optimization modelling. The contribution of this paper is to develop an optimized mathematical model for energy management, which is necessary for multiple energy handling control of numerous systems in connection with a smart distribution system based on the need and demand on a large scale. The OMMEM model's overall error rate can be reduced by examining smart infrastructure with BIM and energy resource management security. It has a lower rate of inaccuracy than the preceding models. The graph demonstrates that the OMMEM analysis technique has considerably reduced the total error rate. For smart city study, OMMEM has a very low rate of errors compared to other models.

The rest of the paper is organized as follows. Section 2 presents Various related research works. Section 3 describes the mathematical model for optimizing energy management in the smart buildings of smart cities using building information modelling. Section 4 elaborates on the results and discussion of the concerned research. The conclusions and future perspectives of this research are discussed in Section 5.

2 Related Research Works

Raffaele Carli et al. [21] introduced a bi-Level Programming decision-making model (BPDM) for the energy management of smart cities. It is a combined, formulated, and open access model for energy management. A case study was conducted in Italy using the proposed idea of decision making in energy management, and the main limitation underlies the payoff and cost of implementation.

Yi Liu et al. [22] presented an IoT –based Energy Management with Edge Computing (IoT-EMEC). A deep reinforcement software learning for energy management In smart cities has been described. Along with an energy scheduling scheme based on the same was proposed. A time delay has been noted based on the experiments conducted.

Ayesha Anjum Butt et al. [23] described a Three-Layer Architecture (TLA) with cloud, consumer, and fog layers for energy management in smart cities. Using the research, an algorithm based on a virtual machine for controlling resource usage was implemented, reducing the computational cost. The major drawback of the study relies on the bin packing issue.

YujieLu et al. [24] presented a Green BIM Triangle Taxonomy (GTT-BIM) for supporting the design, construction, operation, fitting of smart infrastructures. The analysis cleared out the negative impacts of the parameters mentioned above, and the lack of interoperability limits the merits of the research.

PremjeetSingh et al. [25] elaborated on the critical Variables Contributing to Energy Efficiency (CVCEE) based on the building infrastructures. The orientation of the infrastructure and the surrounding circumstance changed for the energy management assessment in a multi-component view. The absence of the mathematical background of the analysis delimits the proposed research.

Li, Y. W et al. [26] model urban buildings and infrastructure with BIM, various digital technologies are employed. The integrity and accuracy of information data interchange are ensured and maintained by the efficiency of information exchange is intelligence construction. Data and information are objective, applicable, transferable, and shareable. Geographic data is a computerized representation of diverse geographical characteristics and occurrences and their relationships.

AlSaggaf et al. [27] Applications use both classical and learning-based algorithms to identify victims and tailor the courses they take. Resources, deployment, defining a trajectory for the UAVs and protecting content are the most important issues for UAV communication networks (UAVCN). The planning of a UAV path is hindered by the difficulty to achieve robustness and resilience in the path optimization process.

To overcome the issues from various works of literature, an Optimized Mathematical Model for Energy Management (OMMEM) has been proposed to assess energy utilization in the construction management of smart cities using BIM. The performance and evaluation of the model are analyzed by giving building information and distribution systems as input to the OMMEM performance analysis model. A collection of parameters and variables important for planning and prediction concerning the energy management of construction is acquired to model a smart infrastructure in a smart city. With BIM, architects and other project stakeholders may communicate more effectively with one other as well as with their clients, contractors, and other stakeholders. One source of truth ensures that all relevant data—including models and estimations—is accessible at any time and in any location. Because of the usage of BIM in the design and building process, clients may perceive an increase in build quality. Using BIM, the precision and detail of calculations and models can be improved, resulting in a better-quality building. It has been proposed by OMMEM to strengthen the distribution system in order to fulfil the needs of smart city applications and set the standards for these applications in the future.

Optimized Mathematical Model for Energy Management (OMMEM)

The general energy management research has undergone an analysis of primary categories like building, grid, and distribution, as shown in Figure 1.

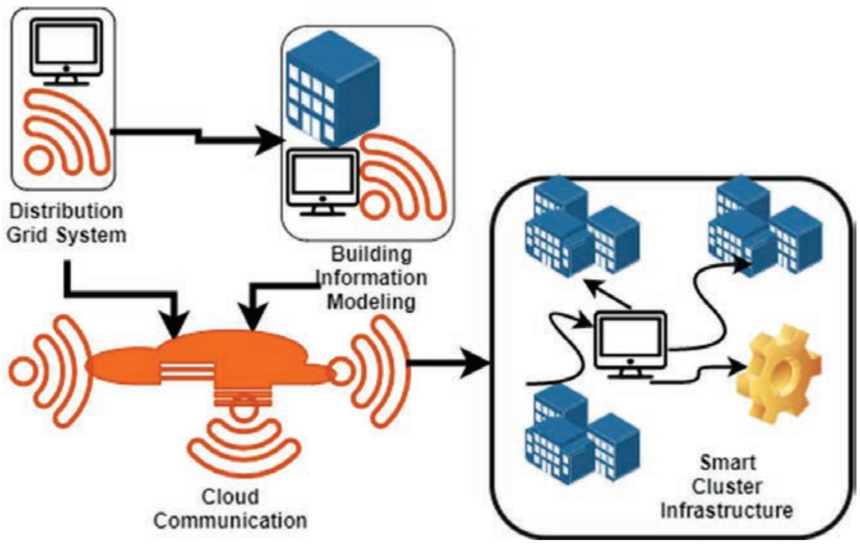

Figure 1 Building grid cloud communication.

It is a unidirectional pathway of communication. Various parameters like power, flow, load, etc., have to be noted for optimized control over resource management in the smart city.

Inefficient BIM data prevents the analysis of the energy flow in the construction sectors, which is why the distribution grid remains stagnant. The suggested OMMEM model may be used to analyse both the distribution grid and the smart structures simultaneously. As a result, construction management analysis develops a core model-based structure. Grid computing utilizes several computers, which are generally geographically dispersed yet connected by networks, to achieve joint activities. It is usually conducted on a "data grid," a collection of computers that communicate with one another to coordinate tasks. There are many different parts to grid computing, but they all work together to provide a seamless user experience.

Figure 2 depicts how energy resources received and lost from smart infrastructures are analysed using the energy management factor. The Model-based procedure is used to ensure that smart operations are developed based on this energy resource that was collected through BIM. Maximizing applicability, accuracy, successful high-end performance, and minimising time delay are the primary goals of the research described in the proposal. Figure 2: Smart infrastructure and resource analysis communicate over the internet.

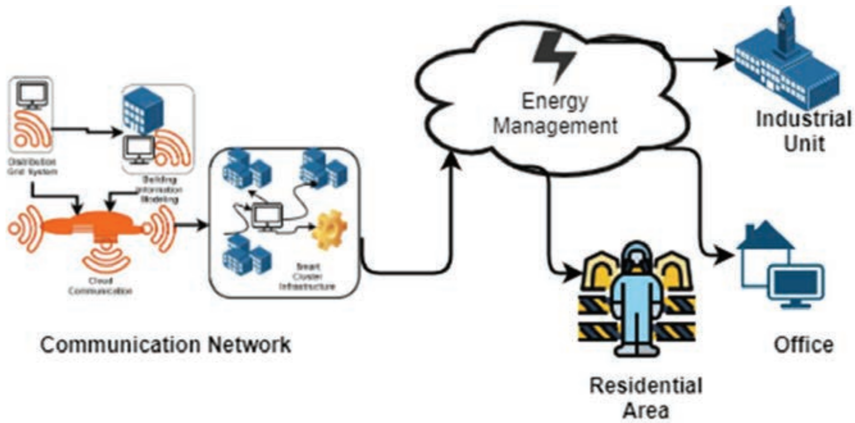

Figure 2 Energy sharing communication between smart infrastructures.

2.1 OMMEM Model

The energy management is done on the smart infrastructure by introducing OMMEM mathematical model. The initial step is to split the energy, represented in the following Equation (1).

$$\boldsymbol{H_i^j} = \mathbf{1}/\boldsymbol{C_{ij}}\left(\sum_{\boldsymbol{i=n}} \mathbf{1}\boldsymbol{H_i^j} * \mathbf{2}\boldsymbol{H_i^j} * \ldots \frac{\boldsymbol{nH_i^j}}{\boldsymbol{\omega n^i}}\boldsymbol{\mu}, \boldsymbol{\rho}\cdot\boldsymbol{\sigma}\right) \tag{1}$$

Equation (1) above aims to improve the resource H i (j) Based on the highest energy and least density, electrical, and temperature that can be acquired. In this $(\mathrm{nH_i^j})/(\omega \mathrm{n^i})$ is used to extract the energy from the smart infrastructures at the fixed 1/C ij. The BIM data is analysed in order to make the most efficient use of resources. As part of the inquiry, two-way communication between infrastructures and timely sharing of resources and utilisation are acquired. To determine if the job has to be halted, the sharing is prioritised by an automated system. Using OMMEM, the following Equation (2) determines the average amount of sharing.

$$\boldsymbol{H_i^j} = \mathbf{1}/\boldsymbol{C_{ij}}\left(\sum_{\boldsymbol{i=n}} \mathbf{1}\boldsymbol{H_i^j} * \mathbf{2}\boldsymbol{H_i^j} * \ldots \frac{\boldsymbol{nH_i^j}}{\boldsymbol{\omega n^i}}\boldsymbol{\mu},\ \boldsymbol{\rho}\cdot\boldsymbol{\sigma}\right)\frac{\mathbf{1}}{\boldsymbol{Avg_{p-T_s-Td_{+1}}}} \tag{2}$$

The sharing process $\sum_{\boldsymbol{i=n}}(\mathbf{1}\boldsymbol{H_i^j} * \mathbf{2}\boldsymbol{H_i^j} * \ldots)$ is analyzed in the above Equation (2), where it is used to attain the energy necessary for controlling power generation and loss operations. Thus, the average $\boldsymbol{Avg_{p-T_s-Td_{+1}}}$. Used to analyze the energy necessary to compute the average of Equation (3).

$$\boldsymbol{D}\,(\boldsymbol{s}) = \boldsymbol{f}(\boldsymbol{S_{in}} + \boldsymbol{S_{out}} + \boldsymbol{S_{mid}} + \boldsymbol{S_{inter}}) \tag{3}$$

Input and output for D (s) Equivalently, the Equation (3) above is computed in both on and off sharing communication states where f denotes previously shared data. An evaluation of energy sharing in a smart infrastructure is made by adding together (S in+S out+S mid+S inter).

$$\boldsymbol{D_{BIM}} = \frac{\boldsymbol{n_s n}}{\boldsymbol{a(t) * u(t) * g(t) * l(t)}} \tag{4}$$

After the distribution is evaluated, the conditions are equated as $\frac{\boldsymbol{n_s n}}{\boldsymbol{a(t)*u(t)*g(t)*l(t)}}$ in which it obtained the previous condition $\boldsymbol{n_s n}$. It is used to examine the resource shared with the previous progressive condition. By doing this, the attenuated energy $\boldsymbol{a(t)}$, utilized energy $u(t)$, gained energy $\boldsymbol{g(t)}$, and input energy $\boldsymbol{i(t)}$ is improved in analysis for the smart structure. The above Equation (4) is used to evaluate capacity and deficiency

$$\boldsymbol{d_{k+q}} = \boldsymbol{X_{uk}} + \boldsymbol{Y_{uk}} + \boldsymbol{Z_{uk}} \tag{5}$$

There are various situations where the BIM d (k+q) Having least energy indicates that energy resource management has been optimised. Thermal and electrical energy resources are automatically surveyed by the structure. Intuitive energies that go by the names of X, Y and Z It is necessary for construction management to improve the shortfall estimation, which reveals structural imbalances via Equation (5).

$$\boldsymbol{E_u} = \frac{\sum_{b=0}^{in} \boldsymbol{E_i} + \boldsymbol{T_s}}{\boldsymbol{A_{pc}}} \tag{6}$$

The split sharing in Equation (6) is evaluated as BIM distributed the energy. Thus $\boldsymbol{E_u}$, the utilized energy resource is observed in the working by using this prediction. By determining the active power $\boldsymbol{A_{pc}}$, the induced energy $\boldsymbol{E_i}$ and time $\boldsymbol{T_s}$. It is satisfied by observing the timely energy required for the structure. In Figure 3, the role-based operation is illustrated.

As in Figure 4, the benefits of OMMEM are done in three aspects, such as initial, intermittent, and output calculations, as in Equations (7) to (9). The term $\boldsymbol{A_t^s m(it) g_i^t w_{pair}}$, $\boldsymbol{Bm(it) g_i^t w_{pair}}$, $\boldsymbol{C_t^s m(it) g_i^t w_{pair}}$. Recommendations are made to maximise optimization by utilising this tool. Outcomes

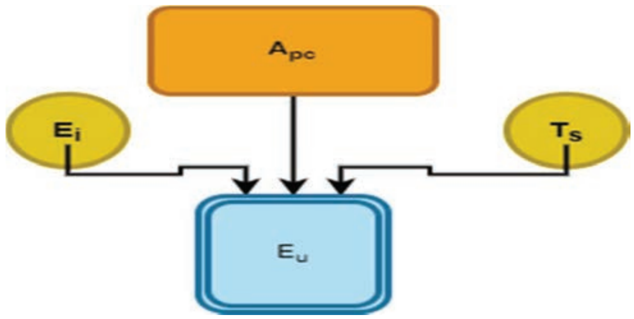

Figure 3 Energy utilization.

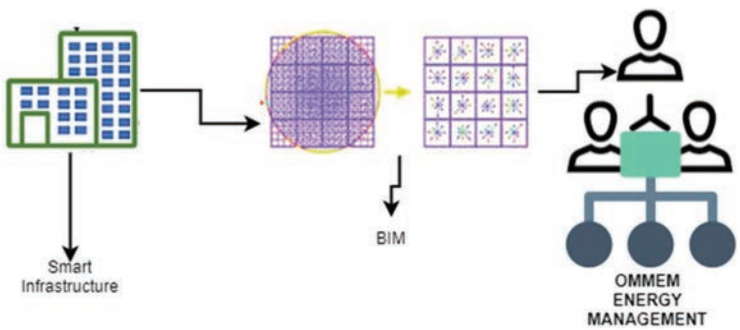

Figure 4 Energy splitting based on the Parameters of OMMEM.

from input and output S in and S out. An active condition of completion can arise at any moment or end of the procedure.

$$X(Ap_h,\ Ap_c,\ Ap_t) = A_t^s m(it) g_i^t w_{pair}(S_{in} + S_{out}) \tag{7}$$

$$Y(Ap_h,\ Ap_c,\ Ap_t) = B_t^s m(it) g_i^t w_{pair}(S_{in} + S_{out}) \tag{8}$$

$$Z(Ap_h,\ Ap_c,\ Ap_t) = C_t^s m(it) g_i^t w_{pair}(S_{in} + S_{out}) \tag{9}$$

For the purposes of this figure, it is critical to get all of the information from the extracted analysis. The dividing action is obtained with the usage of 4.

An energy management optimization equation is used to determine how much loss and generation there is in the system once a unit's resource sharing has been completed (10)

$$S(x + \dddot{y} + z) = g_i^t w_{pair}(S_{in} + S_{out}) \tag{10}$$

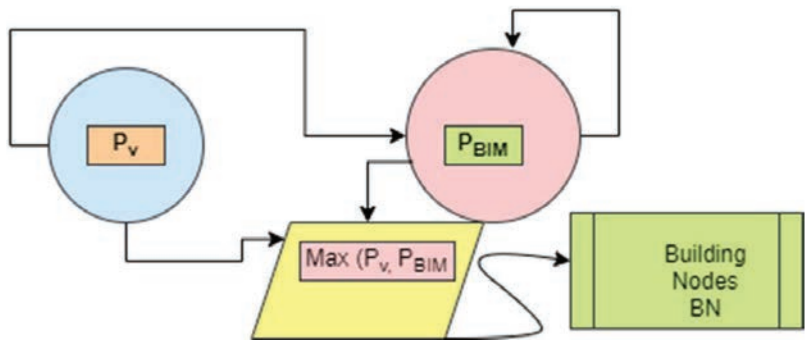

Figure 5 Backup energy based on prediction.

In the above Equation (10), the acquired energy $\boldsymbol{S}(\boldsymbol{x}+\boldsymbol{y}+\boldsymbol{z})$. Is observed with maximum capacity. Thus, the analysis is done for the successive energy required. By computing $\boldsymbol{w_{pair}}(\boldsymbol{S_{in+}}\boldsymbol{S_{out}})$. The maximum power is based on its action. Thus, the required energy concerning the direction is achieved by formulating an Equations (11)–(13).

$$\boldsymbol{\omega x_{is}} = \boldsymbol{Ax^{it}} * \boldsymbol{Bx^{it}}/\boldsymbol{Cx^{it}} \tag{11}$$

$$\boldsymbol{\omega y_{is}} = \boldsymbol{Bx^{it}} * \boldsymbol{Ax^{it}}/\boldsymbol{Cx^{it}} \tag{12}$$

$$\boldsymbol{\omega z_{is}} = \boldsymbol{Cx^{it}} * \boldsymbol{Bx^{it}}/\boldsymbol{Ax^{it}} \tag{13}$$

You can see an example of this mechanism in action in the equations that follow. With respect to infrastructure integrated by scheduling and by deriving the x,y,z direction of energy detection in this x is,y is,z is represents $\boldsymbol{x^{it}} * \boldsymbol{Bx^{it}}/\boldsymbol{Cx^{it}}$, $\boldsymbol{Bx^{it}} * \boldsymbol{Ax^{it}}/\ \boldsymbol{Cx^{it}}$, $\boldsymbol{Cx^{it}} * \boldsymbol{Bx^{it}}/\boldsymbol{Ax^{it}}$, it computes the power observation of energy acquired.

In the beginning, the energy is backed up depending on the forecasting process A previous state calculation-based BIM BN node is used to extract the surrounding energy, as shown in Figure 5. The cost of integrating renewable energy into a power grid grows as the percentage of renewable energy in the grid increases. Energy storage units, for example, are needed to deal with the fluctuation in generation output. The system's flexibility can be increased by using resources that can be quickly reconfigured. Flexible resources electricity generation costs, on the other hand, are often expensive. Renewable energy policies are being adopted globally, so short-term changes in renewable energy outputs must be evaluated to develop a cost-effective long-term plan.

$$\boldsymbol{Max(p_v, P_{BIM}) = P_v > P_{BIM} > Building\,nodes_{BN}} \quad (14)$$

$$\boldsymbol{max\left\{\sum P_v \sum P_{BIM}\right\} \sum_{0}^{ij} Building\,nodes_{BN}} \quad (15)$$

Observing the above Equations (14), (15) decides to schedule the energy resources for the smart structure in a smart city from the surroundings. It is done by taking Equations (7) and (8) and rewritten as above. Here operating maximization $\boldsymbol{Max(p_v, P_{BIM})}$ are done based on the learning rate $\boldsymbol{P_v > P_{BIM} > Building\,nodes_{BN}}$. To obtain better energy management optimization.

3 Results and Discussions

In this part, the OMMEM energy management technique has been tested using simulations. Table 1 lists the simulation validation settings that have been set to their default values:

Parameters	Values
Grid length	20 m
count Limit of the internal structure	60 units
No. of Nodes	50
No. of mediums	10
No. of gateway	6

It has been discovered that a number of models have been reworked and expanded. Dispersed in an area of a smart city's network of smart infrastructure. First, the OMMEM's design is explained. Static analysis of the suggested mathematical model of energy resource management would be enforced as a result of this. The quality of service (QoS) limit is met by the following criteria. The research viability of the QoS for managing strategy outcomes is contrasted to the usual energy consumption, delays, and configurations.

3.1 Accuracy

Analyzing the efficiency of BIM-based energy resource management using OMMEM is illustrated in Figure 6, which shows a parametric experimental

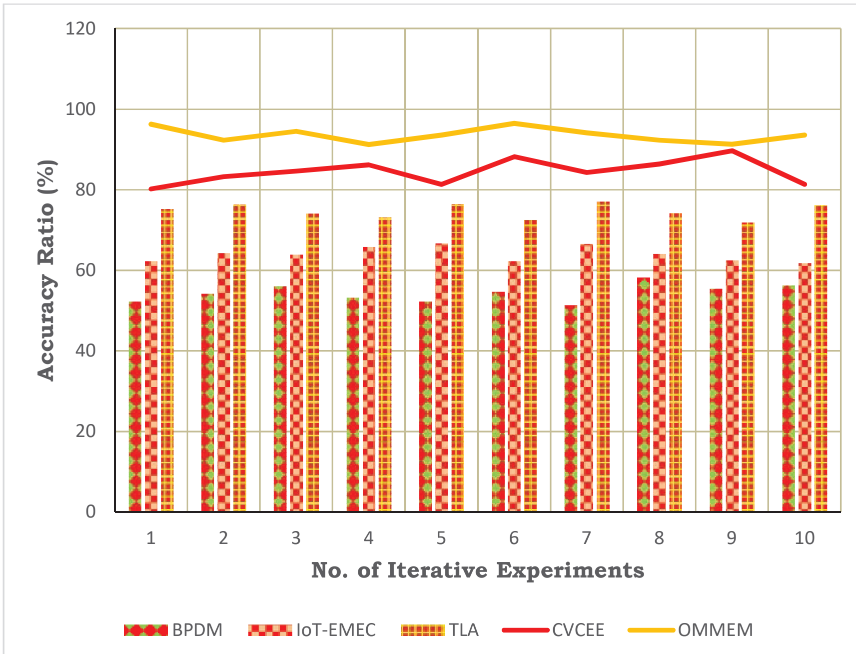

Figure 6 Accuracy of OMMEM.

setup. In the end, it was found that the proposed method is ideal for controlling smart city energy resources for smart infrastructures. This innovative approach can be viewed as an intelligent power grid system that utilizes dispersed energy. Managing and coordinating the operation and control of many dispersed energy supplies, energy storages, loads, and a set of users is a major task. Reduced energy costs, less strain on the electric grid, and increased energy efficiency are all advantages of a well-managed smart grid. Conventional tactics and models are unable to match the method's efficiency. OMMEM, on the other hand, continues to hold the top spot and is a developing analysis method for new smart building resource management applications. Figure 6 illustrates the OMMEM's superior precision.

3.2 Performance Ratio

Figure 7 illustrates the OMMEM model's performance ratio. High-efficiency design and resource management are achieved. Analytical evaluation of the model is conducted to determine the best configuration for intermittent

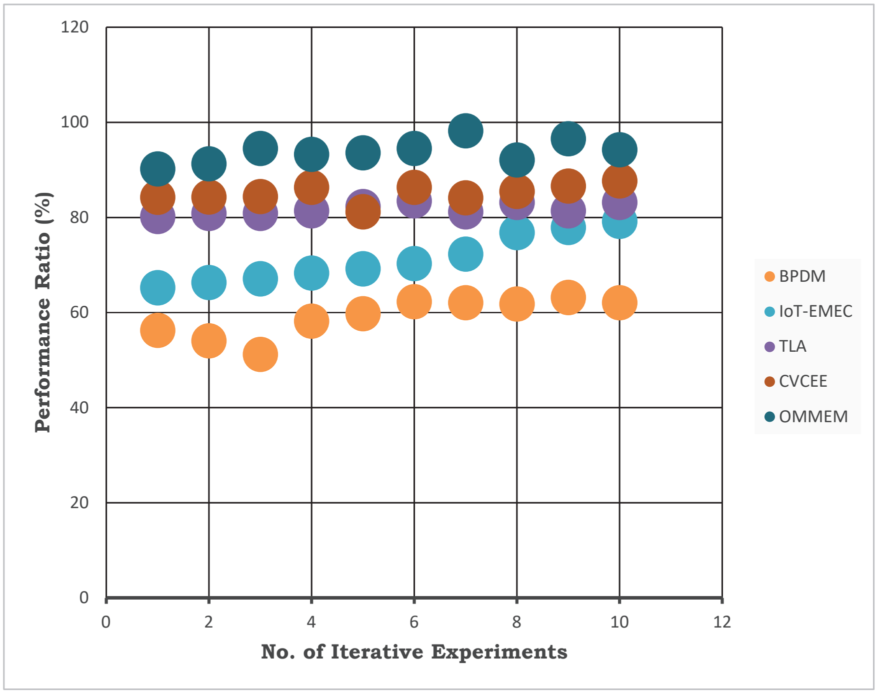

Figure 7 Performance Ratio of OMMEM.

resource sharing. Compared to the pre-existing standard mathematical technique, this one yields obvious results. Since it is an evolving growth area, the smart city considerably evolved with a high-performance ratio.

3.3 Error Rate

Figure 8 demonstrates the overall error rate of the OMMEM model in smart infrastructure analysis utilising the BIM application with security energy resource management. Compared to the current models, it has a lower rate of inaccuracy. The plot clearly shows that the OMMEM analysis has a drastically reduced overall error rate. According to the proposed OMMEM model, the conventional model of smart city analysis suffers from a relatively low error rate. But the quality of BIM models impacts the accuracy of the quantities derived. It is possible to find inconsistencies in the results due to various factors. BIM model changes can be avoided owing to this technology, which provides correct material quantities.

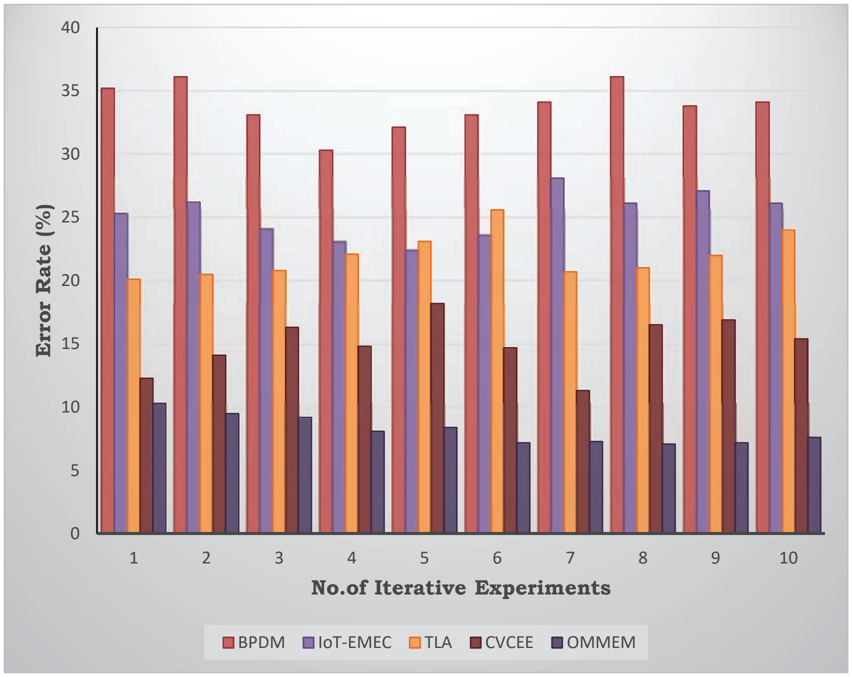

Figure 8 Error rate of OMMEM.

3.4 Delay Rate

Figure 9 depicts the OMMEM model's Delay rate for the mathematical analysis procedure. An extremely short delay time is also achieved using the model. Delay is reduced more quickly as the decay rate slows.

It is immediately compared to the conventional ways. In comparison to the current approaches, the suggested OMMEM has a very low time delay.

3.5 Energy Consumption Rate

Energy usage in the distribution system is reduced by the current OMMEM model. OMMEM is conceived and implemented through experimental analysis in an effort to reduce the amount of resources that are misused. Figure 10, based on research investigations, suggests that the OMMEM reduces energy access. Generally speaking. The number of applications has led to a rise in the amount of energy available. The proposed method has a lower energy resource consumption ratio than the existing methods in order to reduce the amount of unwanted resource access that smart city applications generate.

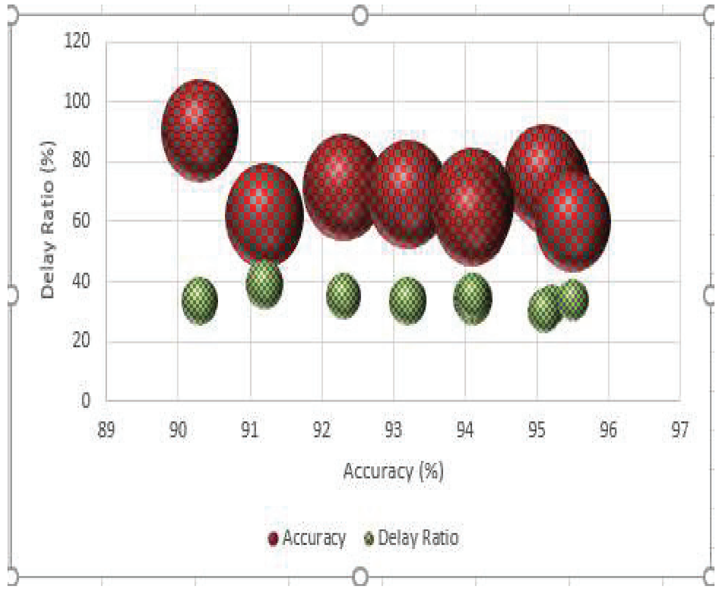

Figure 9 Delay rate of OMMEM.

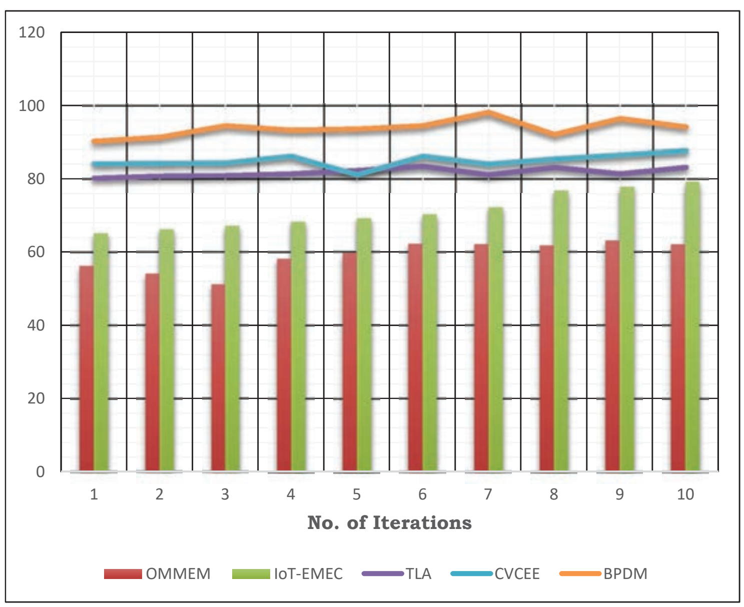

Figure 10 Energy consumption rate.

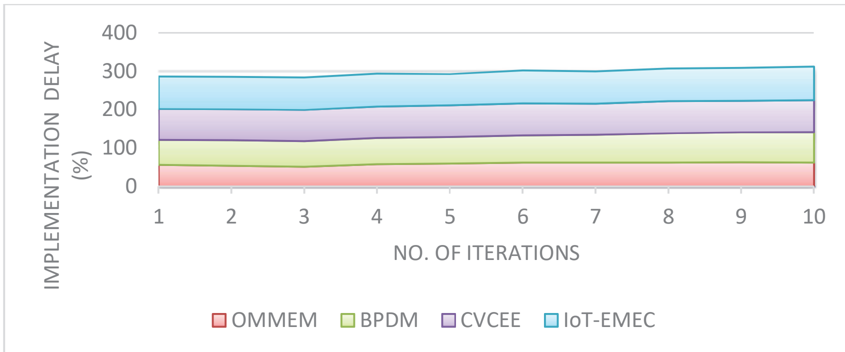

Figure 11 Implementation delay.

3.6 Implementation Delay

Figure 11 shows that the implementation time has been reduced. After implementing the OMMEM mathematical model, there is no discernible delay in energy management, as seen in the graph. Current methods are contrasted to those used in the past in an effort to demonstrate their effectiveness.

4 Conclusion

BIM's intelligent infrastructure is undergoing a transformation as more and more smart city technologies with reduced energy resource requirements are being used. An efficient model is needed to deal with a challenge in energy management with minimum delay, high dependability and productivity. the advantages of OMMEM can help satisfy the demand for outstanding smart city implementation results. Demand response programs among residential customers can be implemented using a smart grid's domestic energy management system, a critical component of the smart grid ecosystem. An energy management model is provided here that considers both the generating and consumption aspects of the process. Additionally, models for various thermal and electrical equipment, such as air conditioning units, water heaters, and vacuum cleaners. To decrease the electricity costs in a smart home, have designed an accurate solution approach to detect the operating modes of distinct loads and organize them across the considered production systems. The solution to the problem of prolonged simulation time horizon is also presented, and it is based on a math-heuristic optimization technique based on mixed integer linear programming formulation. It has been proposed that a system of energy resource management in intelligent infrastructures overrides dynamically and potentially efficiency standards. To begin with, OMMEM has proposed enhancing the distribution system in order to meet the needs and criteria of smart city applications. The results of the experiment show that the new OMMEM model is a good fit for the static system in terms of energy conservation and pathfinding reduction.

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