Green Business Strategy Simulator: A Decision-Support System for Energy, ROI and Sustainability Analytics

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Abstract-

With the pressure of sustainability needs growing in the world, corporations are under increasing pressure to balance profitability and environmental responsibility. However, most organizations, especially the small and medium-sized enterprises (SMEs) do not have available tools to measure the financial and environmental implications of embracing green practice before committing capital. This paper introduces a web-based decision support system (DSS), which is the Green Business Strategy Simulator and allows the user to model sustainable business configurations and calculate energy consumption, as well as, the analysis of return on investment (ROI) and important sustainability indicators. The parameters are set usefully by the users such as operational area, equipment inventory and energy sources. The system calculates Key Performance Indicators (KPIs) which include monthly energy usage, Green Score, total investment cost, estimate savings and payback period. Simulated financial analytics module gathers past simulation data to produce business intelligence comprising of average ROI, sustainability trend projections and twelve-month ROI projections. A smart intelligence dashboard also uses simulation logs to create actionable advice to improve energy efficiency and sustainability. The suggested platform is placed as a decision support tool to students, researchers and SMEs in order to strictly evaluate green strategies prior to the full deployment.

Keywords- Green Business Simulator, Sustainable Business Planning, Financial Analytics, Sustainability Metrics, Decision Support System, Environmental Impact Assessment.

I. INTRODUCTION

n the modern business environment, companies in every industry experience the growing pressure to implement environmentally friendly methods of functioning and at the same time remain economically viable. This two-fold imperative is instigated by a combination of forces such as soaring energy prices, more rigorous government controls, changing expectations of investors and a growing understanding of climate change by society. It is a matter of urgency; however, a significant percentage of small to medium size enterprises (SMEs) still find it very difficult to estimate the potential returns of making transition to the environmentally responsible practices prior to investing financial resources into such transitions.

The traditional approaches to the sustainability assessment are largely based on manual computerization or generic estimation software that

cannot capture the true state of operations with enough accuracy. Such methods will not provide the decision-makers with the granular and actionable data on the return on investment (ROI), energy consumption trends, or economic benefits in the long-term. This causes a serious obstacle to be informed green decision-making by resulting in the presence of information asymmetry. In addition, there is no cohesive platform currently available, which incorporates holistic economic analysis and multiple-dimensional sustainability measures in one, conveniently accessible platform.

To cure this deficiency in the system, this paper presents Green Business Strategy Simulator web-based application that has been designed with an idea of empowering organizations to simulate a business configuration that is environmentally friendly and thoroughly evaluate their financial and environmental performance before physical implementation. The simulator will provide the user the ability to model various parameters which include the size of the area of operation and the inventory of different components. In addition to the ability to simulate, the system takes into consideration an AI-based intelligence layer that examines historical simulation data to discover patterns of performance and provide evidence-based suggestions related to the operation configuration in the future.

This intelligence capability helps users to draw conclusions based on monthly ROI trend, energy used pattern and sustainability growth indicator which turns raw simulation data into strategic decision support intelligence. The system also has a strong user authentication and advanced reporting features. Connecting the current gap between the sustainability desire and the financial viability analysis, the Green Business Strategy Simulator is a rich, interactive and user-friendly tool that makes the sophisticated green business analysis more democratic.

II. LITERATURE REVIEW

Sustainable business strategy has developed as a fringe idea of corporate responsibility to a known competitive necessity. The notorious concept of shared value was created by Porter and Kramer [1] who showed that both competitive positioning and the bettering of social and environmental conditions were possible at the same time in the business. The given theoretical framework is the basis of the two-fold purpose of the suggested simulator: high ROI and improved sustainability performance. To add to the same view, Elkington [2] developed the Triple Bottom Line (TBL) model that includes People, Planet and Profit that created the need to assess environmental and social performance alongside the usual financial measures. The philosophy of the multi-dimensional performance evaluation which is inherent in the TBL is reflected directly in the Green Score metric of the proposed system.

Decision Support Systems (DSS) are critical in supporting the process of making decisions in organizations that are data driven. Turban et al. [3] give a detailed model on how to incorporate analytics and business intelligence in the decision-making processes within organizations. Mohammed and Salleh [14] also report the growing use of DSS tools in sustainable businesses, which brings architectural precedence to the system described in the present case. In the macro level, Global e-Sustainability Initiative (GeSI) [4] has highlighted the revolutionary input of information and communications technology to sustainability transitions, showing how simulation and analytics tools can be used to respond to environmental issues on a massive scale. Khosravi et al. [12] explicitly examine the energy analytics methodologies and confirm their ability to enhance energy efficiency and sustainability performances.

Any sustainable assessment platform must have the basic requirement of being able to estimate the energy usage accurately. The International Energy Agency (IEA) [5] provides empirical standards of energy efficiency trends globally, which serves as an informational backdrop of the realistic calculational logic of the simulator energy calculations. The simulator uses the area-based energy modeling technique that corresponds with the reviewed methodology of the simulator presented by Rajpathak and Patil [9], the authors that consider building energy simulation models that can be used in a commercial environment. In terms of sustainability performance measurements, the research done by De Giovanni et al. [6] with extensive research on the subject of green supply chain management and structured KPI frameworks and the research done by Alam et al. [13] on the topic of green computing measurements and sustainability standards give reasons as to why the systematic approach of sustainability scoring used in this research.

The economic aspect of green investments is discussed by Peiro-Signes et al. [10], who empirically prove the effectiveness of energy conservation strategies and adopting renewable energy sources in enhancing the environment and economy performance of SMEs.

Mahmoud et al. [8] also confirms the application of composite ROI and sustainability measures as composite performance measures in sustainable engineering systems. The increase in the use of artificial intelligence in the sustainable energy systems gives further incentive to the intelligence layer that is presented in the proposed simulator. The advanced energy prediction methodologies are considered by Lo and Yeung [7] and the review of the AI-based optimization methodology and predictive analytics is conducted by He et al. [15] and it is shown that the inclusion of an intelligence layer with the ability to predict trends and smart recommendations is supported by the whole energy systems. Lastly, the sustainability presented by Fernandez et al. [11] as a source of innovation and competitive advantage adds weight to the strategic importance of integrating sustainability analytics in business decision support systems. All the literature reviewed confirm the necessity to have the integrated systems that would combine financial analytics with energy models, sustainability metrics and intelligent decision support a combination which the Green Business Strategy Simulator strives to achieve.

III. PROBLEM STATEMENT

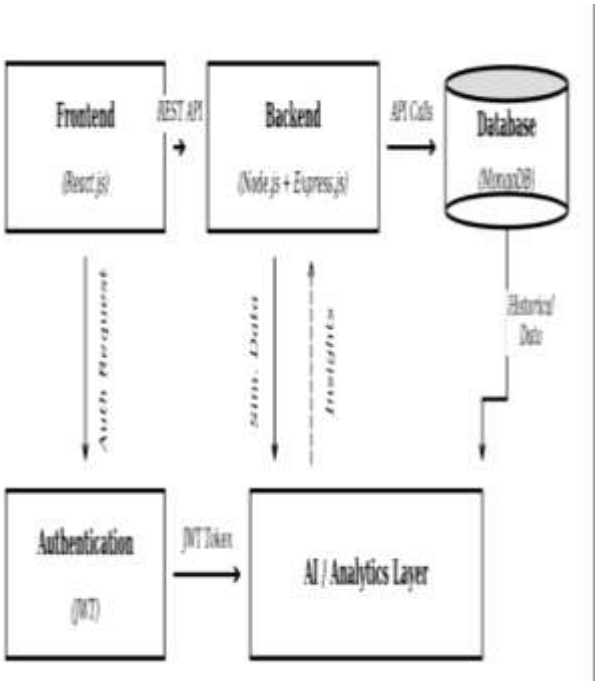
Modern business organizations are confronted with an ever-growing dilemma as to how sustainable business operations can be balanced with long-term requirements of profitability. Particularly the small to medium-sized enterprises lacks the practical, cost effective methodologies to assess the financial feasibility of green investments such as adoption of renewable energy and energy efficient deployment of infrastructure as well as long term resource allocation strategies. The current models in sustainability assessment are often typified by too much complexity, too costly or the lack of being properly integrated with the basic business decision processes [3] [8].

There is an empirical gap to a complete, open-source solution that enables businesses to: model a variety of operation schemata; perform sound financial payoff analysis; assess environmental resultant performance and create intelligence-driven actionable information. Without this platform, organizations are facing a great challenge in ensuring that they strike a perfect balance between the responsible practices towards the environment and sustainable economic growth paths [1] [10].

IV. OBJECTIVES OF THE PROJECT

The main goals that will be used to design and develop the Green Business Strategy Simulator include:

A. To create and develop a web based platform that provides reasonable simulation of business energy consumption and operational configurations as



input parameters vary.

B. To analyze the different business decisions in terms of their financial performance using rigorous ROI, investments cost and savings estimates.

C. To calculate multi-dimensional sustainability indicators, such as Green Score and energy consumption distribution, following the frameworks of sustainability, developed [2] [6].

D. To give intelligent, data-driven insights and practical recommendations based on AI-based analytics [7] [15].

E. To have the ability of visualizing performance trends with the use of interactive dashboards to improve strategic decision-making capabilities.

F. To produce downloadable, professionally formatted analytical reports that can be used in both business and in academic purposes.

G. To have a strong user authentication and longitudinal data storage.

V. SYSTEM ARCHITECTURE

The proposed system follows the client-server architecture that is structured in terms of modular separation of concerns and aligned with the current principles of web application designs [9]. The front-end is designed in React.js and the application layer of the back end is developed with Node.js together with Express.js that offers the performance and scalability features inherent to event-driven, non-blocking I/O models. MongoDB is used as the long-term storage of the user credentials, simulation inputs, outputs and longitudinal analytics information. Authentication is done by using the JSON Web Token (JWT) systems. The intelligence layer, which is AI-centered, performs the analysis of the results of the simulation in the past to come up with the trend analysis, the prediction of the performance values and the contextually based recommendations.

The system consists of four logical distinct layers:

5.1 Presentation Layer (User Interface)

All user interactions are handled by the web-based user interface, which is created in React.js and it oversees the data visualization, interactive dashboard rendering and creation of reports. Its interface is such that it can reduce the cognitive load and on the other hand, maximize data accessibility.

5.2 Application Layer (Business Logic & APIs)

This layer is implemented with the help of Node.js and Express.js and contains all business logic, simulation processing algorithms, ROI calculation engines and RESTful API endpoint processing. It is the heart processing unit of the system.

5.3 Intelligence Layer (Analytics & AI)

The analytics-based module uses the past-accumulated data of simulation to produce trend analysis, predictive growth models and intelligent sustainability advice that is in line with the principles of AI-based decision support recorded in the literature [7] [15].

5.4 Data Layer

MongoDB database offers persistent storage of all data in the system such as user's credentials, input using simulation, output, record of historical analytics and other data. The layered architecture is structured such that it provides scalability of the system, maintainability and smooth inter-layer data flow.

VI. SYSTEM DESIGN AND DIAGRAMS

6.1 Use Case Diagram

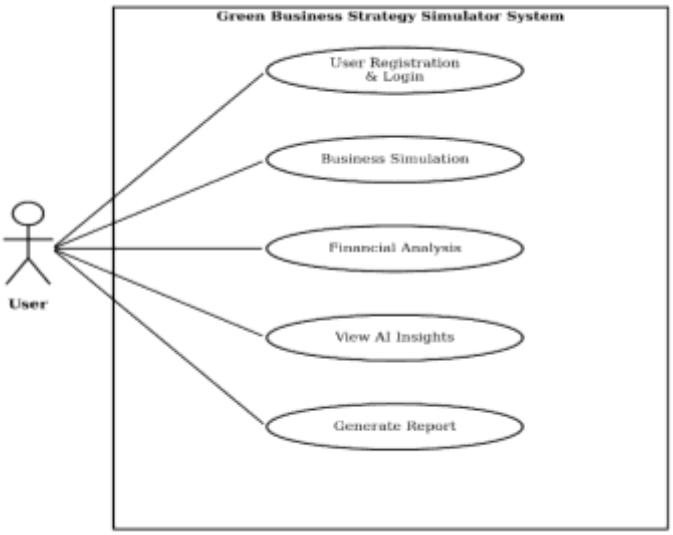


Fig. 2. Use Case Diagram

The use case diagram has been presented in Fig. 2 Illustrating the transactions of the system actors with the functional use cases. The key participant is a Registered User and the system is a secondary participant. Some of the major use cases are User Registration and Authentication, Business Simulation Execution, Financial Analysis, AI Insights Viewing and Report Generation.

6.2 Data Flow Diagram (DFD)

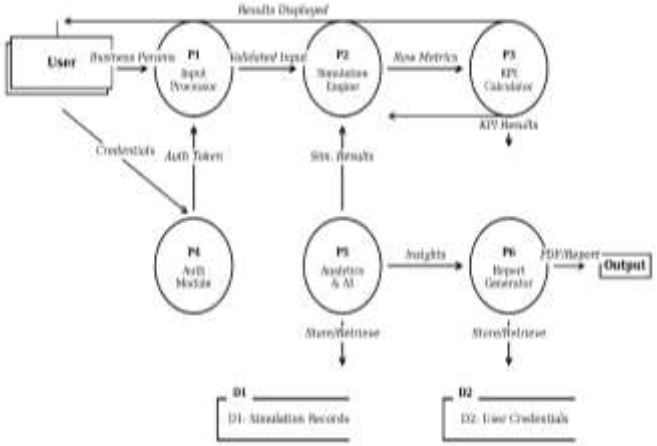


Fig. 3. Data Flow Diagram

All the data flow across the system because of user input and processed output. The major data flows are: (1) user input of business parameters; (2) simulation engine processing, (3) analytics and AI module insight generation and (4) result storage and visualization. The sequence diagram in Fig. 4 shows the chronology of events that occurred during execution of the simulation and the sequence of message passing that occurred

between the user interface, application server, intelligence layer and database components.

6.3 Sequence Flow Diagram

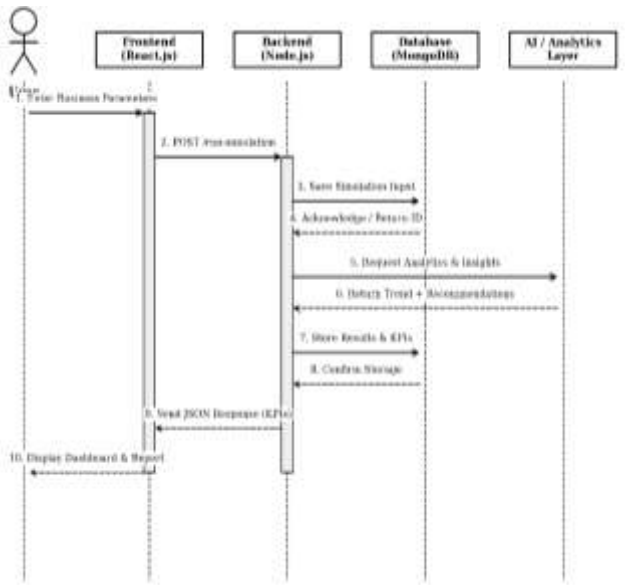


Fig. 4. Flow of Simulation Execution Sequence Flow Diagram

The sequence diagram in Figure 4 shows the order of events that happen during the simulation. It explains how the messages are sent between user interface, application server, intelligence layer, and the database.

VII. METHODOLOGY

7.1 Area-Based Component Recommended Logic

The simulator uses the business operational area, measures in square feet, to automatically suggest an initial selection of electrical components. This method is based on standard building energy simulation techniques [9].

Table 1: Area-Based Component Recommended Formulas

COMPONENT	FORMULA USED
PCs	[Area / 50]
LED Lights	[Area / 25]
Air Conditioners	[Area / 400]
Solar Panels	[Area / 800]

7.2 Energy Consumption Calculation

The calculation of the monthly energy usage is done by the multiplication of power and time. The calculation is done in conformity with the IEA standards [5].

Energy Consumption (kWh/month) = Σ (Wattage × Hours/day × Quantity) × 30 / 1000

7.3 Financial Computation

A. Financial results are measured using the standard ROI formula, which has been confirmed in research on sustainable engineering [8].

ROI (%) = [(Savings - Investment) / Investment] × 100

B. Payback Period- The investment recovery period is calculated as follows:

Payback Period = Investment / Total Annual Savings

7.4 Sustainability Metrics

The Green Score is used mainly to measure how sustainable something is. It is found by taking the count of renewable parts, dividing it by the total number of parts, and then multiplying the result by 100. It is found by taking the number of renewable parts, dividing it by the total number of parts, and then multiplying the result by 100.This shows how much of the system comes from renewable sources, which relates to the environmental aspect of the Triple Bottom Line framework [2] [6]. The Green Score is calculated by dividing the number of renewable parts by the total number of parts and then multiplying the result by 100.

Green Score = (Renewable Components/ Total Components) * 100

Table 2: Summary of Core KPI Formulas and Purposes.

Metric	Formula	Purpose
Monthly Energy (kWh)	Σ (Watt × Hours × Qty) × 30 / 1000	Monthly consumption
ROI (%)	(Savings – Investment) / Investment × 100	Profitability index
Green Score	(Renewable Comp. / Total Comp.) × 100	Sustainability index
Payback Period	Investment / Annual Savings	Recovery duration

7.5 Intelligence and Analytics Module

The simulation data of the past is strategically processed to produce actionable intelligence products [7] [15] in the form of:

(A) ROI performance trend and visualisations;

(B) specific energy optimization recommendations and (C) sustainability improvement recommendations that are adjusted to the user operating profile.

VIII. RESULTS

The Simulator of Green Business Strategy has been designed successfully and deployed successfully and functionally tested. The system correctly takes user-specified inputs such as business operation area, hours of daily work, inventory and power source configuration of devices and generates a full set of output; monthly energy consumption estimations, overall investment cost estimations, monthly savings estimates, ROI estimate, payback period and Green Score. The calculated values prove to be in line with empirically determined energy efficiency levels [5] and financial modeling standards [8].

The system also stores the simulation records on the persistent database layer and produces longer-term ROI trend analysis to allow comparative analysis of green business strategies among the numerous simulations runs. The outcomes of validation prove that the system can help the users to compare the available green alternatives and to draw decisions based on the combined financial and environmental factors. The AI-based recommendations engine can find optimization points among user settings and it gives specific and context-related advice in line with intelligent DSS concepts [3] [14].

IX. CONCLUSION

The paper has introduced the Green Business Strategy Simulator, as a web-based decision support system that combines both the lack of sustainability desire and financial viability analysis. The simulator solves a detailed algorithm that calculates a performance portfolio that includes the energy used, investment price, estimated savings, ROI, payback period and Green Score, further supported by longitudinal trend analysis. The architecture of the system incorporates simulation, financial analytics, sustainability indicators in accordance with the Triple Bottom Line model [2] and AI-enhanced decision intelligence [7] [15] in a single and easily available platform.

The Green Business Strategy Simulator shows that a systematic combination of financial analytics, energy modeling, sustainability metrics and intelligent decision support as put forward by the literature review is technically feasible, but also useful in practical terms to SMEs, students and researchers. The platform allows organizations to make evidence-based decisions that are grounded in rigorous pre-implementation appraisal of the green strategies, thus balancing the economic performance and environmental responsibility of the organization, thus making a meaningful contribution to the overall objective of sustainable development.

The future work is aimed at the integration of real-time data on energy pricing, the enhancement of the AI recommendation engine with the reinforcement learning features and the use of blockchain-based sustainability verification systems [19] to make the system even more analytical and credible.

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