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A System Engineering Approach to Sustainability Decision Support System Based on SDGs

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Abstract

This study aims to develop a Sustainability Decision Support System (SDSS) based on the Sustainable Development Goals (SDGs) using a System Engineering approach at the Institut Teknolgi Bisnis dan Bahasa 'Dian Cipta Cendikia' (ITBA DCC). The main issues faced are a lack of a structured system to integrate environmental, social, economic, and governance aspects into policy campus. The methodology study covers six phases: Main, which includes Requirements Analysis, System Design, Implementation, Testing, Deployment, and Maintenance. This system merges Multi-Criteria Decision Making (MCDM) techniques, modeling system dynamics, and data analytics to visualize SDGs progress, prioritize programs, and provide recommendation strategies. Research results show that SDSS is capable of increasing transparency, accountability, and effectiveness in data-driven decision-making. The novelty of the study lies in its multidisciplinary and contextual approach to college-level vocational education in Indonesia. This system also has the potential to be replicated in other institutions as an innovative model for management sustainability.

Keywords: Sustainability Decision Support System (SDSS), Sustainable Development Goals (SDGs), System Engineering, Multi Criteria Decision Making (MCDM)

1. Introduction

Current global developments demand institutional education. They focus on academic aspects but also contribute actively to sustainable development. Institut Teknolgi Bisnis dan Bahasa 'Dian Cipta Cendikia' (ITBA DCC), as one of the colleges in Indonesia, does not have sufficient answers for integrating Sustainable Development Goals (SDGs) into its policies, curriculum, and campus operations. However, efforts to achieve sustainability are often hindered by a lack of structured, data-driven decision-making.

The application of System Engineering in designing a Sustainability Decision Support System (SDSS) can provide a solution for optimizing planning, monitoring, and evaluation of SDGs based programs. This approach enables multidisciplinary integration, beginning with the analysis of stakeholder interests, modeling the system, and culminating in the development of tools based on technological information. Thus, ITBA DCC can identify SDGs priorities, efficiently allocate source Power, and objectively measure the sustainability of impact.

Additionally, challenges such as limitations in source power, dynamic policies, and the complexity of SDGs indicators require adaptive and scalable solutions. Through SDSS-based System Engineering, institutions can enhance the transparency, accountability, and effectiveness of their sustainability programs while also serving as a model for other colleges in Indonesia. Therefore, this research aims to design a system that supports holistic decision-making to strengthen ITBA DCC commitment to achieving the 2030 SDGs targets.

Several studies have developed innovative frameworks to support sustainable decision-making across various sectors. Modified Prospect Theory to optimize system energy [1], while utilized a Bayesian Belief Network to design product sustainability [2]. Developed a PM-SDGs algorithm to evaluate the harmony project about the SDGs [3], while created a deep learning model for system food [4]. Each focused on optimizing CCUS locations and routes for micro-mobility using a geospatial approach [5] and [6]. Research emphasizes the integration of technical, environmental, and social aspects, as well as the use of a hybrid method to overcome data uncertainty and multi-stakeholder preferences.

In the sector, criticized inequality in the system's supporter decision-making farm [7], while optimized the chain supply waste-to-energy system [8]. Assessed the system energy port [9], and introduced a complex fuzzy method for the development of urban areas [10]. Evaluated the sustainability of material burn cruises [11], designed a sustainable diet [12], and assessed sustainable transportation technology [13]. Focus on building sustainability [14] and [15], while developed a system For watershed management [16]. All of them offer solutions with comprehensive data -based an approach to reach objective sustainability.

Study Next, develop a method to evaluate sustainability in various sectors. Combined MIVES and BIM for use in assessing DfMA in construction [17], while applied ELECTRE to analyze conformity inland agriculture [18]. Utilized AHP combined with FIS for sustainable supplier selection in elections [19] and [20]. In contrast, proposed a fuzzy inference model for production planning [21]. Integrated MBSE, AHP, and fuzzy logic to evaluate system handling [22], while developed a web-based UVA for evaluation projects [23]. In the education sector, identified challenges in tool evaluation sustainability (TES) and proposed THSus for campuses in China [24] and [25], while emphasized the need for standardization of global ESD indicators [26]. Highlighted the gap between theory and practice in business strategy sustainability [27]. Overall, the research emphasizes the importance of a multi-criteria approach, the integration of qualitative and quantitative data, and adaptation to a local context for sustainable decision-making.

This study was done for a number of fundamental reasons. First, ITBA DCC requires structured tools to measure and monitor its contribution towards the SDGs. Second, a systems engineering approach is needed to connect aspects of environmental, social, and governance in a coherent work framework. Third, there is currently no study type that develops SDG-based DSS for institutional business and language in Indonesia, especially in Bandar Lampung. Therefore, this study provides novelty in its context. Fourth, research in harmony with national policy encourages colleges to contribute to the SDGs through the use of innovative technology. Research like this can serve as a model for similar institutions.

Study This covers three aspect main. First, how to design a Sustainable Decision Support System (SDSS) with a systems engineering approach at ITBA DCC. Second, factors that affect the effectiveness of the Decision Support System (DSS) in supporting decisions sustainability. Third, how to measure the impact of implementing SDSS on achieving the Sustainable Development Goals (SDGs) in the campus environment. Thus, the research aims to develop an integrated DSS model based on SDGs using a system engineering approach. This involves analyzing the dynamic connection between SDG indicators and policies on campus through modeling, as well as Evaluating SDSS performance in increasing transparency and accountability sustainability at ITBA DCC. A new study involves the integration of system dynamics, multi-criteria decision analysis (MCDA), and data analytics in SDSS for high schools, with the potential for replication of this model in other high schools in Indonesia.

2. Research Methods

Engineering process methodology system For developing a Sustainability Decision Support System, including phases such as Requirements Analysis, System Design, Implementation, Testing, Deployment, and Maintenance, equipped with with relevant visual elements with technology and health and can seen in the picture following This. Following are explanations of stages in the Engineering Process Methodology System [28], for developing the Sustainability Decision Support System (SDSS):

1. Requirements Analysis
   Requirements Analysis aims to collect, analyze, and document the needs of users and systems in a comprehensive manner. In the context of SDSS based on SDGs. Phase Requirements Analysis: This becomes the foundation for the next stage, such as designing a responsive system to address the complexity of the SDGs. Approaching participation by involving multiple stakeholders is crucial to ensure the system can support making inclusive and data-driven decisions.

2. System Design
   System Design aims to design an architecture system based on defined needs. Phase: This encompasses design data structure, user interface, module functionality, and integration with SDG indicators, enabling the system to support decision-making based on sustainability.

3. Implementation
   Stage Implementation becomes critical in realizing a code-functional design system. Phase involving the development of current component systems, SDG data integration, and implementation of analytical algorithms

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for support in decision-making for sustainable development. Effective implementation ensures that the system fulfills both functional and non-functional requirements that have been defined previously.

4. Testing
   Phase Testing is a critical stage in SDSS development, ensuring the system functions as needed, is error-free, and can accurately support decision-making based on the SDGs. Stage This involves a series of systematic, which includes aspect functional, non-functional, and validation of SDG indicators.

5. Deployment
   Phase Deployment is a crucial stage where the SDSS system, which has been tested and is ready to operate in a production environment, is supported in taking decisions based on SDGs. The stage involves a series of activities, including planning, installation, configuration, and transition, all structured to ensure the user's successful implementation of the system.

6. Maintenance
   Phase Maintenance is a stage-critical post-deployment that ensures the sustainability of the operational system and its relevance to the development of SDG indicators. Stage This encompasses activities such as maintenance, corrective, adaptive, perfective, and preventive activities. To ensure the system continues to operate and provides optimal value for stakeholders' interests. Unlike conventional systems, SDSS requires a special approach because the dynamics of SDG data continue to grow and evolve.

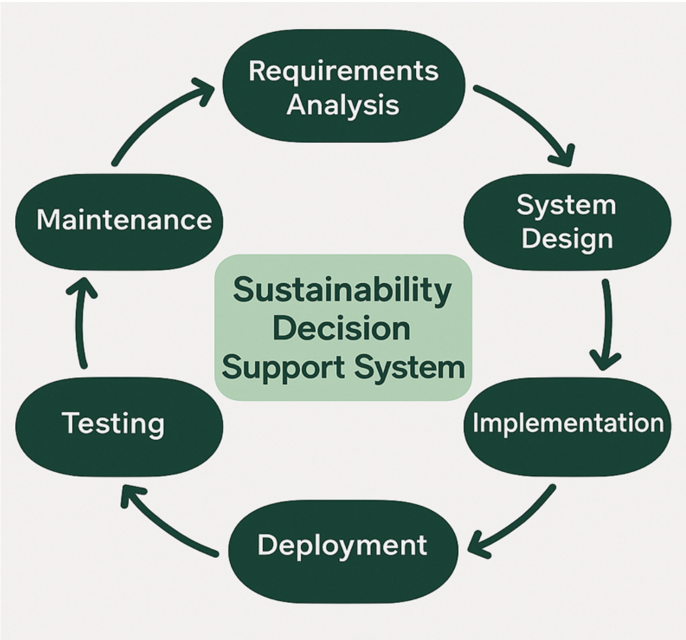

Figure 1. Engineering process methodology system For developing a Sustainability Decision Support System

3. Results and Discussions

This process began with data collection from three primary sources: the Vice-Chancellor's Academic and Student Affairs, Vice Chancellor's Finance, HR, and Cooperation, as well as campus operators on duty, who entered data into the system. Data includes aspects of academics, finance, HR, and cooperation, both internal and external external. The accuracy of data input is critical to ensure the validity of the analysis.

After the data is collected, it undergoes processing and analysis using the Sustainable Development Goals (SDGs) and Multi-Criteria Decision Making (MCDM). SDGs assess sustainability across dimensions of social, economic, environmental, and governance, while MCDM helps prioritize aspects that require more attention with various criteria. Analysis results are then visualized in the form of interactive graphs, charts, or dashboards to make it easier for stakeholders, including rectors, to understand. Visualization helps identify areas of performance That Need Improvement or what is necessary for repair.

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Next, the report evaluation is arranged to summarize the findings, including an assessment of sustainability, achievements, challenges, and strategic recommendations. Recommendations include improving the quality of academic covers, enhancing financial efficiency, developing human resources, and fostering cooperation. The report was delivered to the rector and followed up on through policy strategy. The evaluation results also serve as the basis for planning term length and allocation budget use, supporting the sustainability of ITBA-DCC. This process ensures taking data-driven decisions to reach an optimal sustainable campus. Here is a picture of the stages of *the Sustainability Decision Support System (SDSS)* process at ITBA DCC, which utilizes the *Sustainable Development Goals* (SDGs).

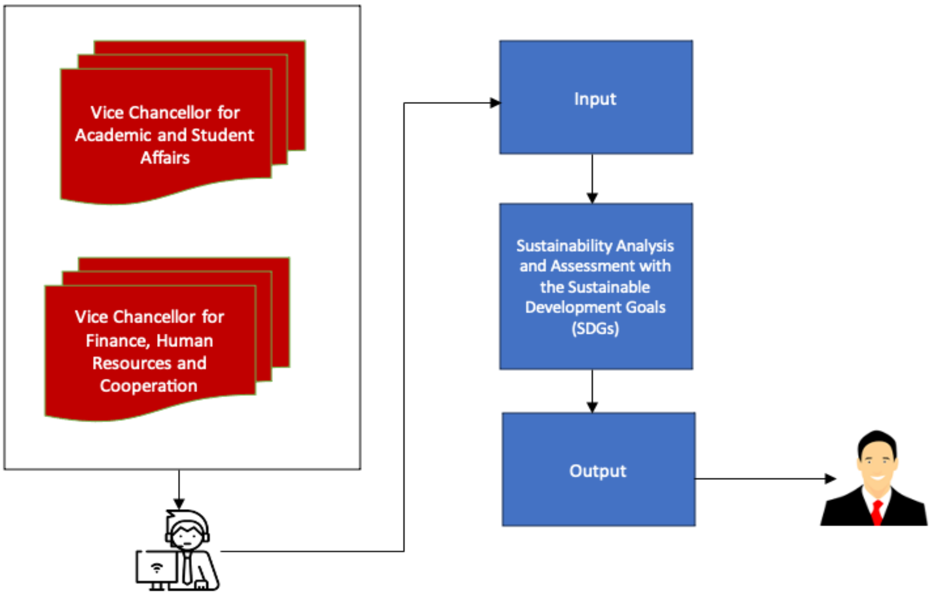

Figure 2. Sustainability Decision Support System (SDSS) at ITBA DCC uses Sustainable Development Goals (SDGs).

Based on the matter, the required tool help that utilizes a system based on a computer that is a medium that can help power medical in do work in the field that makes Sustainability Decision Support System (SDSS) at ITBA DCC uses Sustainable Development Goals (SDGs) combined with Multi-Criteria Decision Making (MCDM) technique with methodology System Engineering Process (SEP) that requires design comprehensive. The System Engineering Process (SEP) is a systematic approach to the development, operation, and maintenance of complex systems. The System Engineering Process (SEP) is a methodology that focuses on in-depth analysis, modeling, and testing in a development system cycle, which aims to ensure the system fulfills the needs of users and functions optimally. The System Engineering Process (SEP) is well-suited for projects that require coordination between elements, ensuring the system is both technically and operationally sound. Methodology involves a number of stages that focus on understanding, designing, testing, and maintaining a system.

1. Requirements Analysis
   Phase Requirements Analysis involves **:**
   a. Identification of Stakeholders and Needs Users
      Stakeholders include governments, non-governmental organizations, researchers, and interested industries with sustainable development. Collection techniques such as interviews, surveys, and workshops are used To understand relevant SDG priorities.
   b. Analysis Need Functional
      Need functional cover features, such as monitoring SDG indicators, simulating policies, and data visualization. For example, the system must be capable of integrating environmental, social, and economic data To evaluate SDG progress.
   c. Analysis Non- Functional Requirements
      Including aspect performance, data security, scalability, and compatibility with other platforms. The system must fulfill standard interoperability For integration with global databases such as the UNSDG Knowledge Platform.
   d. Mapping with SDGs Indicators

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Every need must be associated with specific SDG targets and indicators. For example, if the system supports SDG 13 (Climate Action), the required module analysis includes steps related to carbon footprint.

e. Validation and Verification Need
It needs to be validated through prototyping or use-case modeling to ensure conformity with user expectations.

2. System Design
Phase System Design involves **:**
   a. Architecture System
   Architecture designed To support scalability and interoperability, considering the complexity of multidimensional SDG data. The microservices or layered architecture approach is often used For separate components such as data processing, analytics, and visualization. Integration with external platforms (e.g., the UNSDG Database) requires an API-based design to ensure data consistency.
   b. Database Design
   The database must be capable of handling dynamic and structured SDG indicators in a multidimensional format (e.g., environmental, social, and economic data). The database schema employs a data warehouse or OLAP (Online Analytical Processing) approach to support complex analysis. Normalization and indexing are applied for query optimization, particularly when integrating data from multiple sources.
   c. Interface User (UI/UX)
   The interface must be intuitive and supportive, with interactive visualization (e.g., dashboards, heatmaps, geospatial mapping). Human-Centered Design (HCD) principles are applied to ensure accessibility for various stakeholders' interests. Tools such as Figma or Adobe XD are used to create wireframes and prototypes before development.
   d. Algorithm and Logic Design Business
   The algorithm for analysis sustainability (e.g., carbon footprint calculation, SDG progress tracking) is designed based on a recognized methodology. Machine learning can be integrated for predicting SDG trends.
   e. Security and Performance
   The system must fulfill standard security requirements, such as encryption, role-based access control (RBAC), and GDPR compliance. Load testing and scalability testing are conducted to ensure optimal performance when handling large datasets.
3. Implementation
Implementation phase involves:
   a. Election Technology and Environment Development
      - Tech stack selection is based on scalability , compatibility with SDGs data, and needs analytical . Example :
      - Backend: Python (Django/Flask) or Java (Spring Boot) for logic business and data integration .
      - Frontend: React.js or Vue.js for interface interactive .
      - Database: PostgreSQL (for structured data) or MongoDB (for unstructured data such as SDGs report).
   b. Core Module Development
      - SDGs Data Integration: Using ETL (Extract, Transform, Load) tools like Apache NiFi or Talend for import data from source official (e.g., UNSDG Database).
      - Analytic Sustainability: Implementation algorithm such as Multi-Criteria Decision Analysis (MCDA) for assessing trade-offs between SDGs.
      - Data Visualization: Libraries like D3.js or Tableau Embedded for creating interactive dashboards.
   c. Implementation DevOps Principles
      - Continuous Integration/Continuous Deployment (CI/CD) using GitHub Actions or Jenkins to automation testing and deployment.
      - Containerization with Docker and Kubernetes orchestration for ensure portability .
   d. Code Management and Collaboration
      - Use of version control (Git) and agile tools (Jira) for track development team.
      - Documentation code and API using Swagger/ OpenAPI .
   e. Handling Code Quality
      - Static code analysis with SonarQube for ensure standard cleanliness code.
      - Unit testing (pytest for Python, JUnit for Java) and integration testing (Selenium).
4. Testing
Phase Testing involves**:**

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a. Testing Strategy
   SDSS testing adopts a V-Model approach to ensure every stage of development (such as requirements and design) has phase-appropriate testing. This strategy encompasses testing tiers, including starting testing, integration testing, system testing, and acceptance testing. Priority Based on Risk: Focus on critical modules, such as SDG data analysis and predictive algorithms.
b. Type Testing
   a) Functional Testing
      - Unit Testing: Testing individual components (e.g. , functions) calculation SDG index) using frameworks such as JUnit (Java) or pytest (Python).
      - Integration Testing: Verifying interaction inter-module (example : integration) between environmental and economic data modules) with tools such as Postman or TestNG.
      - Regression Testing: Performed after Updates code For ensure No There is broken feature .
   b) Non- Functional Testing
      - Performance Testing: Measuring response system moment handling big data (e.g. , UN SDGs indicators dataset) using JMeter or Locust.
      - Security Testing: Checking vulnerability like SQL injection or access No legitimate with OWASP ZAP.
      - Usability Testing: Evaluation interface user involving stakeholders through SUS (System Usability Scale) questionnaire .
   c) Data Validation and Logic Business
      - Data Quality Testing: Ensuring accuracy of imported SDGs data from source external (example: data consistency between UNStat and World Bank) use tools such as Great Expectations.
      - Algorithm: Verification of analytical models (e.g. , MCDA algorithms for SDGs priorities) with benchmark datasets.
c. Automation Testing
   - CI/CD Pipeline: Test integration automatic in DevOps flow using GitHub Actions or Jenkins.
   - Test Script: Using Selenium for UI testing and Robot Framework for end-to-end testing.
d. Reporting and Correction
   - Defect Tracking: Bug tracking using Jira or Bugzilla.
   - Traceability Matrix: Mapping results testing to need beginning (example: link) between SDG 7 testing and needs energy clean).

5. Deployment
   Phase Deployment involves:
   a. Deployment Planning
      Planning comprehensive done with consider :
      - Rollout Strategy: Choosing between big-bang, phased rollout, or canary deployment approaches based on complexity systems and stakeholder needs .
      - Analysis Impact : Assess risk to operation existing business and prepare plan mitigation
      - Scheduling : Determine optimal time with consider cycle SDGs reporting .
   b. Preparation Infrastructure
      - Environment Setup: Preparing environment production with configuration :
        Cloud servers (AWS/Azure) with auto-scaling for handle fluctuation burden .
        Containerization using Docker and Kubernetes orchestration .
        Configuration security : firewall, data encryption , and RBAC.
      - Data Migration:
        historical SDGs data from legacy systems using ETL tools such as Apache NiFi .
        Validation post-migration data integrity .
   c. Deployment Implementation
      - Automated Deployment:
        CI/CD pipeline using GitHub Actions or GitLab CI/CD.
        Infrastructure as Code (IaC) with Terraform or Ansible.
      - Zero-Downtime Deployment:
        Blue-green deployment or canary releases technique.
        Load balancing with NGINX or AWS ELB.
   d. Transition Users
      - User Training:
        Special workshop for administrators and users end.

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Documentation interactive using platforms like GitBook .
- Change Management:
  approach (Awareness, Desire, Knowledge, Ability, Reinforcement).
  24/7 helpdesk support during the transition period.

e. Post -Deployment Monitoring
- Real-time Monitoring:
  Tools like Prometheus + Grafana for metric performance.
  Log management with ELK Stack.
- Feedback Mechanism:
  Integrated ticketing system (Jira Service Desk)
  Survey satisfaction user.

6. Maintenance
   Phase Maintenance involves**:**
   a. Classification Maintenance Activities
      a) Maintenance Corrective
         - Handling bugs and anomalies system through structured ticketing mechanism.
         - Example: Repair error calculation SDG index due to change UNDP methodology.
      b) Maintenance Adaptive
         - Adjustment system to:
         - Change regulations (e.g. updating national SDGs targets).
         - Migration technology (analytical framework upgrade).
      c) Maintenance Perfective
         Optimization performance:
         - Query tuning for the ever-growing SDGs dataset increase.
         - Enhancement dashboard visualization based on bait come back user.
      d) Maintenance Preventive
         Monitoring proactive:
         - Log analysis for detect anomalies.
         - Security audit periodic follow ISO 27001 standard.
   b. Mechanism Updates SDGs Content
      a) Automatic Data Synchronization:
         - Scheduled ETL jobs for indicator updates from source official (World Bank API, UNStats).
         - Validation data quality using data quality frameworks.
      b) Version Model:
         Versioning system for track change SDGs methodology (e.g. revision of SDG 12.2.1).
   c. Management Evolution System
      a) Technology Roadmap:
         - Mapping technical debt and enhancement priorities.
         - Cycle minor/major releases follow global SDGs development.
      b) Governance Committee:
         - Multi-stakeholder forum for evaluation maintenance needs.
         - specific change advisory board (CAB) mechanism.
   d. Performance Measurement Strategy
      a) SDSS Specific Metrics:
         - System uptime during period SDGs reporting (quarterly/annual).
         - Accuracy analytical model prediction vs actual data.
      b) Balanced Scorecard

4. Conclusion

Study to develop a Sustainability Decision Support System (SDSS) based on the Sustainable Development Goals (SDGs) using a System Engineering approach at the Institut Teknolgi Bisnis dan Bahasa 'Dian Cipta Cendikia' (ITBA DCC). This system is designed to overcome challenges in integrating environmental, social, economic, and governance aspects into the policy campus while ensuring decisions are based on transparent and accountable data. Through a methodology that includes six phases Main Requirements Analysis, System Design, Implementation, Testing, Deployment, and Maintenance research creates a solution structure that combines techniques such as Multi-Criteria Decision Making (MCDM), system modeling, and data analytics. As a result, SDSS can visualize

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SDG progress through interactive dashboards, prioritize sustainability programs, and provide recommendations that align with stakeholders' interests. The novelty of this study lies in its multidisciplinary and contextual integration approach for college-level vocational institutions in Indonesia, which has not yet been explored in similar research. Besides supporting the achievement of the 2030 SDG targets at ITBA DCC, the system also has the potential to be replicated in other institutions, making it an innovative model for sustainable management in the education sector. Thus, this research Contributes Not only to the academic literature but also provides practical solution to dynamic policies and limitations, drawing on power sources

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