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A System Engineering Approach to a Sustainability Decision Support System Based on the Global Reporting Invitiative

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Abstract

This study proposes a novel Sustainability Decision Support System (SDSS) architecture based on the Global Reporting Initiative (GRI) using a systems engineering approach. The system integrates GRI indicators with campus-level data, visualizes key sustainability metrics, and incorporates multi-criteria analysis to enhance transparency and institutional accountability. Developed at Institut Teknologi Bisnis dan Bahasa Dian Cipta Cendikia (ITBA DCC), the system follows a structured engineering lifecycle: requirements analysis, system design, implementation, testing, deployment, and maintenance. Results indicate successful facilitation of GRI-based reporting across economic, environmental, social, and governance dimensions. The model emphasizes stakeholder collaboration and demonstrates potential for replication in higher education institutions to support digital sustainability governance.

Keywords:
Sustainability;
GRI;
SDSS;
System Engineering;
Higher Education

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1. Introduction

Climate change and environmental degradation have urged institutions to contribute actively toward the Sustainable Development Goals (SDGs)[1]. One key challenge is integrating sustainability principles into higher education governance, particularly in strategic decision-making processes. Institut Teknologi Bisnis dan Bahasa Dian Cipta Cendikia (ITBA DCC), an institution committed to sustainable development, requires a system of Supporter Decision (DSS) based on the Global Reporting Initiative (GRI) framework. This ensures transparency and accountability in sustainability reporting [2].

Although awareness of the importance of sustainability is increasing, institutions, including ITBA DCC, still face challenges in integrating sustainability indicators into their decision-making processes. A System Sustainability Decision Support System (SDSS) can become a solution by applying the principles of an engineering system (system engineering) for collecting, analyzing, and reporting sustainability data by GRI standards. This system will assist ITBA DCC in monitoring progress, identifying areas for improvement, and communicating achievement sustainability to stakeholders' interests.

System engineering was chosen as the approach because of its ability to integrate technical, social, and environmental aspects in a holistic manner [3]. The study by [4] shows that the adoption of technology, such as artificial intelligence (AI), can increase management energy sustainability in colleges. Meanwhile, [5] emphasized the role of digitalization in enhancing efficiency and public participation. On the other hand, [6] identified a sustainable AI-based public education model that can be adapted to support DSS at ITBA DCC.

Various studies have developed a framework Work Innovative for the Global Reporting Initiative (GRI), starting from the application of the AHP model in evaluating materiality report sustainability in the company construction, which reveals critical such as anti-corruption, water management, and problem worker children and force [7] up to development AHP-Delphi framework for evaluating sustainability campus, such as studies UNDIP case entered "very sustainable " category even though Still weak in management waste and efficiency energy [8]. In sector education, research shows that 78% of European universities prioritize stakeholders' internal interests and aspects of the economy (63%) than impact social-intellectual [9], while analysis of Global cement companies reveals domination disclosure qualitative (83%) about CO_2 emissions and water management, with only 29% verified party third [10]. In Africa, there is a positive correlation between the disclosure aspect of social-environmental and performance finance, even though reporting is Still stagnant and has minimal assurance [11], while in Pakistan, the quality of CSR disclosure based on GRI principles is assessed weak in balance and accuracy even though fulfill aspect accuracy time [12]. Meanwhile, Brazilian companies face a gap between the importance of the GRI social indicator and its implementation, with larger companies giving more care to K3 issues; however, this is not yet significant in decision-making [13]. Globally, research on GRI has increased significantly since 2013, with contributions mainly from the US, Spain, and Australia [14]. In India, factors such as profitability, company size, and governance drive sustainability disclosure [15]. However, criticism has also emerged, starting from a mismatch in GRI's sustainability-oriented framework business with a mark education high [16], decreased quality reporting automotive even though GRI compliance increased [17], up to unreliability ESG rating because of change methodology retroactive [18]. Greenwashing practices at Scottish universities, which focus on environmental economics aspects without transparent standard reporting [19], have a significant impact on GRI compliance and bank profitability in the UAE and Iraq. This is because environmental considerations increase profits, while environmental consequences result in high costs [20], which is worth noting. On the other hand, a collaboration between the government and universities in Malaysia has successfully utilized reporting on sustainability to increase employability among post-COVID-19 graduates [21], indicating that GRI's potential as a tool for sustainable development can be realized when implemented critically and contextually.

This study presents three aspects of novelty, the main thing that distinguishes it from previous studies. First, how to design a System Sustainable Decision Support (SDSS) based Global Reporting Initiative (GRI) with a systems engineering approach at ITBA DCC. Second, factors that affect the effectiveness of the Decision Support System (DSS) in supporting decisions related to sustainability, including how to measure the impact of SDSS implementation on achieving Global Reporting Initiative (GRI) goals in the campus environment. Thus, this research aims to develop an integrated DSS model based on the Global Reporting Initiative (GRI) with a system engineering approach, Analyze the connection dynamic between GRI indicators and policies on campus through a modeling system, as well as Evaluate SDSS performance to increase transparency and accountability sustainability at ITBA DCC, besides That This model expected can overcome challenge like lack of standardization reporting [22]. The novelty lies in the integration of system dynamics, multi-criteria decision analysis (MCDA), and data analytics in SDSS to support college tall.

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.

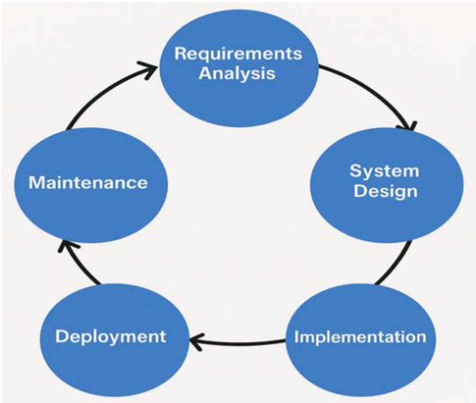

Figure 1. Engineering process system For developing a Sustainability Decision Support System using the Global Reporting Initiative (GRI).

Phase Engineering Process Approach System in developing a Sustainability Decision Support System (SDSS) using the Global Reporting Initiative (GRI).:

1. Requirements Analysis
   The first phase in the development of the Sustainability Decision Support System (SDSS) is Requirements Analysis, which aims to identify the needs of both functional and non-functional systems. At this stage, the team developer collaborates with stakeholders, including companies, regulators, and end-users, to understand conditions based on Global Reporting Initiative (GRI) standards. The analysis encompasses mapping indicators relevant to GRI sustainability indicators, including reporting on environmental, social, and governance (ESG) aspects, as well as the requirements for data processing, visualization, and informed decision-making. The result is the Software Requirements Specification (SRS) document, which serves as a guide for the next stage of development.
2. System Design
   After the need is defined, the System Design stage is carried out to design the system architecture, database, user interface, and module analysis. SDSS must be capable of integrating sustainability data from various sources, processing it by GRI standards, and presenting recommendations based on the data. The design system includes data flow diagrams (DFDs), Unified Modeling Language (UML), and supporting database design, as well as tracking ESG metrics. Additionally, the interface is designed to be interactive, allowing users to filter reports based on GRI criteria and gain insights through a visual dashboard.
3. Implementation
   In the Implementation phase, the design system is converted into program code using appropriate technologies, such as Python for data analysis, SQL for database management, and web frameworks like Django or React for user interfaces. Integration with GRI standards is implemented using algorithms that transform raw data into standardized metrics, such as carbon emissions or policy diversity. The developer also ensures the system can connected with external data sources, such as APIs from sustainability data providers or manual input from users.
4. Testing
   Testing is phase-critical for validating the reliability, accuracy, and security of SDSS. Testing includes unit testing (checking every component's code), integration testing (ensuring modules Work together), and user acceptance testing (UAT) to verify that the system fulfills users' needs based on GRI standards. Additionally, performance testing is conducted to handle large data volumes, and security testing is performed to protect sensitive data. Test results are used to fix bugs before the system is launched.
5. Deployment
   After passing the test, the system is Ready to be implemented in the production environment during the Deployment phase. This involves server installation, database configuration, and training users. If the SDSS is cloud-based, deployment can be done using a service like AWS or Google Cloud for scalability. The IT team also ensures that data migration progresses smoothly and that the system is integrated with the existing company tools. Technical documentation and user guidance are prepared to facilitate easier system adoption.
6. Maintenance
   The final phase is Maintenance, which has the purpose of ensuring that SDSS remains optimal over time, taking into account development needs and updates to GRI standards. The team conducted bug monitoring, updated features, and customized the algorithm in response to changes in ESG regulations. Additionally, the system can be improved with AI integration for predictive sustainability or automated reporting. Maintenance also includes periodic training for new users and evaluation of the performance system based on stakeholder feedback.

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3. Results and Discussion

The development and deployment of the SDSS involved collecting and processing institutional data from various departments including academic affairs, finance, HR, and operations. Using the GRI framework, the system enables stakeholders to assess performance across economic, social, environmental, and governance dimensions. A multi-criteria decision-making (MCDM) method was employed to prioritize action areas. Data was visualized through dashboards, enabling easy interpretation.

Quantitative results demonstrate the system's impact: approximately 76% of administrative staff adopted the system within the first three months; data validation with historical records revealed 91% accuracy; and user satisfaction was recorded at 4.3 out of 5 based on post-implementation surveys.

Figures 1 and 2 illustrate the SDSS engineering workflow and reporting process. These figures clarify system stages from requirements analysis to maintenance, and visualize how sustainability data flows across departments. The effectiveness of SDSS was reinforced through performance testing and user feedback during pilot trials, confirming the system's scalability and adaptability.

Analysis results are then visualized in the form of interactive graphs, charts, or dashboards to facilitate easier understanding for stakeholders. The report evaluation covers the assessment of sustainability, achievements, challenges, and recommendations for improvement in the quality of academics, governance, finance, cooperation, and HR. Report This was delivered to the rector as a material consideration in making decisions, planning term length, and allocation of budget to support the sustainability of ITBA-DCC in the future. Here is the process report of image sustainability at ITBA-DCC using the Global Reporting Initiative (GRI).

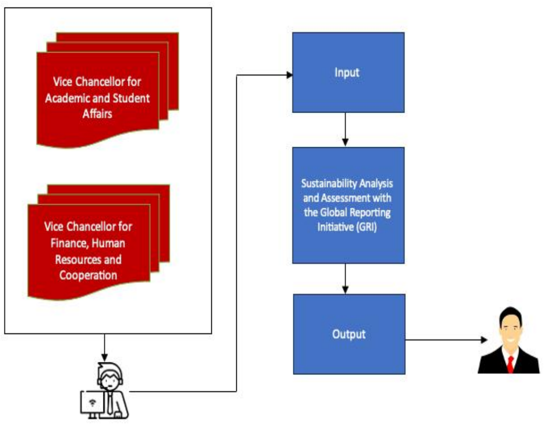

Figure 2. Reporting process sustainability at ITBA DCC using the Global Reporting Initiative (GRI).

Based on the matter, a required tool is needed to help utilize a system based on a computer medium that can power medical work in the field. This project aims to develop a Sustainability Decision Support System (SDSS) at ITBA-DCC, utilizing the System Engineering Process (SEP) methodology, which necessitates a comprehensive design. The System Engineering Process (SEP) is an approach that is systematic in 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, aiming to ensure the system fulfills user needs and functions optimally. The System Engineering Process (SEP) is very suitable for projects that require coordination between elements and ensure that the system is technically and operationally sound. Methodology involves a number of stages that focus on understanding, designing, testing, and maintaining a system.

1. Requirements Analysis

   Requirements Analysis is a fundamental phase in the development of the Sustainability Decision Support System (SDSS), which aims to identify, analyze, and document all the system's needs in a detailed manner. The ITBA-DCC system is designed to support decision-making based on sustainability, which refers to the Global Reporting Initiative (GRI) standards. Phase This ensures that the SDSS was built to meet the needs of institutions, as well as academic, operational, and government sustainability requirements. Requirements Analysis Stages

   a. Stakeholder Identification

      Key stakeholders in SDSS development at ITBA-DCC includes:

      - Leader Institution (Rectorate / Board of Directors): Required report strategic For taking policy sustainable.
      - Campus Sustainability Team: Responsible answer on implementation ESG (Environmental, Social, Governance) practices.
      - Lecturers and Researchers: Need supporting data For study related to sustainability.
      - Student : Required access information about the green program campus.
      - Administrative Staff: Need tools for manage operational data (such as energy, waste and responsibility answer social).

   b. Collection Requirements Elicitation

      Techniques used For gather need:

      - Interview Deep with leadership and sustainability team for understand ITBA-DCC priorities in ESG aspects.
      - Survey to lecturers and students For identify required features.

- Analysis Document like report annual, policy campus, and GRI guide version latest.
- Participatory Workshop with all stakeholders to brainstorm needs functional and non- functional.

Example Identified Needs :

- Tracking use energy electricity (GRI 302).
- Scholarship program monitoring and engagement social (GRI 413).
- Reporting impact carbon from activity campus (GRI 305).

c. Classification Need

Need grouped become :

a) Need Functional :
   - Real-time data input (example : energy sensors in buildings) campus).
   - Reporting module automatic in accordance GRI standards (for example, GRI 400 for aspect social).
   - Analysis features predictive (e.g., projections) subtraction emission carbon).
   - Interactive dashboard For ESG data visualization.

b) Non- Functional Requirements :
   - Data Security : Protect sensitive data like information finance and students.
   - Convenience Access : User-friendly interface for non- technical staff.
   - System Integration : Compatibility with system academics who have there is (like SIAKAD).
   - Compliance Regulation : Compliance GRI standards and regulations education tall related to sustainability.

d. Analysis Need GRI Based
   - SDSS must support relevant GRI indicators with environment education, such as :
   - GRI 301 (Material): Management source power and cycle repeat.
   - GRI 403 (Health & Safety): Conditions Work lecturers and staff.
   - GRI 418 (Privacy) Students): Protection of personal data.

e. Prioritization Need

Use method MoSCoW Prioritization:
   - Must Have: Basic GRI reporting, manual/ automatic data input.
   - Should Have: Integration with IoT (smart energy meters).
   - Could Have: AI for recommendation policy green.
   - Won't Have: Features that don't exist yet urgent (e.g., blockchain for audits).

f. Validation and Documentation
   - Prototyping: Making dashboard mockup for validation design.
   - SRS (Software Requirements Specification) document:
   - Description projects and goals.
   - List of adopted GRI indicators.
   - Use case diagram (example:"Admin enters water consumption data").
   - Specification technical (example: PostgreSQL Database, Python for analytics).

2. System Design

The system design stage is a phase-critical one, following Requirements Analysis, which aims to translate the needs for both functional and non-functional requirements into comprehensive architectural systems. In the context of ITBA-DCC, SDSS design must accommodate:

- Standard Global Reporting Initiative (GRI) reporting
- Need special environment education tall
- Integration with existing campus system
- Convenience use for stakeholders with background behind technical limited

1) Components of System Design

a. Architecture System

Using 3-Tier Architecture to ensure modularity and scalability:

a) Presentation Layer:
   - Interactive dashboard web-based (React.js/Vue.js)
   - Mobile responsive design
   - Role-based access control (Admin, Lecturer, Student, External Stakeholder)

b) Application Layer:
   - Microservices architecture for flexibility:
   - Data Collection Service
   - GRI Reporting Engine
   - Analytics & Visualization Services
   - Notification Service
   - RESTful API for integration system

c) Data Layer:
   - Relational database (PostgreSQL) for structured data
   - Data warehouse for analytic historical
   - Cache system (Redis) for real-time performance

b. GRI Based Modular Design

Every module designed in accordance GRI Standards categories:

a) Environmental Module (GRI 300):
   - Sub- module energy (GRI 302)
   - Sub- module emissions (GRI 305)

- Water and waste sub- module (GRI 303, 306)

b) Social Module (GRI 400):
- Sub- module employment (GRI 40-403)
- Sub- module community (GRI 413)
- Sub- module education (Custom indicator)

c) Governance Module (GRI 200):
- Sub- module policies (GRI 205-206)
- Sub- module compliance (GRI 419)

c. Data Design

a) Data Model:
- Entity-Relationship Diagram (ERD) focuses on:
- Entity " Activity Campus " (classroom, lab, office)
- " GRI Indicators " Entity
- "Stakeholder" Entity

b) Data Flow:
- ETL (Extract-Transform-Load) system for:
- IoT sensor data (smart meters, water meters)
- Manual data input
- External data (weather API, etc.)

c) Data Standardization:
- Mapping table to GRI standards
- Unit conversion engine (eg : kWh to CO2e)

d. Interface Design Users

a) Main Dashboard:
- Sustainability Scorecard
- Trend analysis (3-5 years)
- GRI Compliance Level

b) Special Features :
- Report Generator (PDF/Excel)
- Alert system for threshold breach
- Collaborative platform for sustainability team

c) Accessibility:
- WCAG 2.1 compliant
- Multi-language support (Indonesia-English)

2) Technology Used

a. Frontend:
- React.js with the D3.js library for visualization
- Progressive Web App (PWA) technology

b. Backend:
- Python (Django) for business logic
- Node.js for real-time features
- Apache Kafka for event streaming

c. Data & AI:
- PostgreSQL with PostGIS for geospatial data
- TensorFlow.js for predictive analytics
- Elasticsearch for search fast

d. Infrastructure:
- Docker containerization
- Kubernetes for orchestration
- Hybrid deployment (On-premise + Cloud)

3) Security Design

a. Data Protection:
- Encryption at rest & in transit
- GDPR-like data governance
- Blockchain for audit trail (optional)

b. Access Control:
- Role-based access control (RBAC)
- Multi-factor authentication
- Biometric login for admin level

c. Compliance:
- Regular penetration testing
- Automated compliance checker for GRI Standards

4) Integration Design

a. Internal Systems:
- Single Sign-On (SSO) with system academic
- API gateway for SIAKAD integration
- Data sync with system finance campus

b. External Systems:
- API for government sustainability reporting
- Webhook for NGO partners
- IoT device management platform

5) Maintenance Design

a. Update Mechanism:
- Automated GRI standards updates
- Hot-swappable modules
- Version control system (Git)

b. Monitoring:
- Real-time system health dashboard
- Predictive maintenance alerts
- Usage analytics for optimization

6) Design Deliverables

a. Document Architecture System :
- Component diagram
- Sequence diagram
- Deployment diagram

b. Prototype:
- High-fidelity UI mockup
- Clickable prototype (Figma/Adobe XD)

c. Technical Specifications:
- API documentation (Swagger)
- Database schema
- Security protocols

7) Challenges and Mitigation

a. Challenge :

- Complexity integration with legacy systems
- Variability stakeholder needs
- Dynamic nature of GRI standards

b. Mitigation Strategy :
- Agile development approach
- Modular design for flexibility
- Regular stakeholder review sessions

3. Implementation

Implementation Stages, or implementation in the engineering process system, are a crucial phase where the system design, previously arranged in stages, is realized to form an operational system. The development of the Sustainability Decision Support System (SDSS) based on the Global Reporting Initiative (GRI) encompasses both technical activities to ensure alignment with the institution's objectives, as has been achieved. This is ITBA-DCC. Steps for Implementing GRI-Based SDSS.

a. Preparation Infrastructure Technology
- Provide device hardware (servers, computers, storage) and devices soft supporting (database, SDSS platform, system) digital reporting).
- Ensure Network and Security cyber adequate For support sustainability data storage and processing.

b. Development Devices SDSS Software
- Develop or integrate system web based or desktop application that allows reporting in accordance GRI standards (for example : GRI 102, GRI 200, GRI 300, and GRI 400).
- Key features includes : sustainability data input, analytical dashboards, real-time data integration, and report automatic.

c. Data Migration and Integration
- Collecting historical and current data from various work units like financial, academic, operational campus, and devotion public.
- Standardize data to suit with GRI indicators and integrate them to in SDSS system.

d. Initial Testing
- Perform unit testing, integration testing, and system testing to ensure all over module walk in accordance specifications.
- Test whether GRI indicators appear in report end in accordance expectations and needs stakeholders interest.

e. Training User (User Training)
- Give training to staff administration, lecturers, and managers reporting sustainability about method use SDSS system.
- Material training includes data input, interpretation reports, as well as utilization system For planning strategic.

f. Trials Field (Pilot Implementation)
- Implementing system on one or several work units as pilot.
- Evaluate effectiveness system in support taking decisions and drafting report sustainability.

g. Improvement Based on Bait Come back
- Gather input from user initial (pilot users) related convenience usage, accuracy reports, and views system.
- Do repair system before done implementation full.

4. Testing

The testing stage is a crucial phase in the engineering process, where a system is developed to ensure that it meets the needs that have been determined, is free from errors (bugs), and is ready for operational use. In context-based SDSS development, testing is crucial to ensure that the system supports reporting sustainability in a manner that is accurate, reliable, and consistent with GRI standards types Testing in GRI-Based SDSS.

a. Unit Testing
- Test every component or module individual from system in a way separated.
- Example : Emission data input module carbon tested For ensure data can be inputted and saved according to the GRI standard format (for example GRI 305 for emissions).

b. Integration Testing (Integration Testing)
- Test interaction between module in system, for ensure data flows with Correct.
- Example : Testing integration between module finance and modules reporting environment For produce report sustainability holistic.

c. System Testing (Testing) System In general Overall)
- Test system end -to-end as One complete unity.
- Focus on aspects functionality system : what all over feature Work in accordance need user institutions and standards GRI reporting.

d. User Acceptance Testing (UAT / Testing) Reception User)
- Involving user end (eg. staff reporting, SDSS manager, lecturer) for try system in a way direct.
- Objective : To assess whether system fulfil expectation user friendly and easy used in activity reporting sustainability.

e. Performance Testing

- Measure performance system in condition burden high, like when lots of sustainability data accessed or entered in a way simultaneously.
- Aspects tested : speed response system, stability, efficiency processing report.

f. Security Testing (Testing) Security)
- Ensure system safe from access No valid and maintain integrity as well as sustainability data confidentiality.
- Including testing encryption, management right access, and protection to attack cyber.

5. Deployment

The Deployment Stage, or implementation system, is the phase in which the system has been developed and tested and then moved to an operational or production environment for use in a real-world setting by all users. In the context of GRI-based SDSS development at ITBA-DCC, this stage is critical because it marks the beginning of utilizing the system for official activity reporting and decision-making sustainability within the institution. GRI -Based SDSS Deployment Steps.

a. Preparation Environment Production
- Setting up a reliable and secure production server.
- Ensure configuration systems, databases, and security network is optimal for used in a way wide.

b. Migration Systems and Data
- Move system from environment development / testing to environment operational.
- Aligning previous data used in trial to in system actual to be ready used by users.

c. Installation and Configuration
- Installing device SDSS software on the main server and/ or device user If system is hybrid in nature.
- Adapt configuration system to fit with need ITBA-DCC specific, including arrangement right access, GRI report templates, and system parameters other.

d. Preparation of Guidelines and Documentation Users
- Provides a user manual system, guide filling GRI indicators, as well as SOP (Standard Operating Procedure) reporting document sustainability.
- Documentation This become reference important for staff and management in use system in a way consistent.

e. Socialization and Training Advanced
- Stage session training comprehensive for all over user system, including lecturer, staff education, and sustainability unit managers .
- Explain method use systems, GRI data interpretation, and procedures access the dashboard and create report sustainability.

f. Launch System (Go-Live)
- Set date official use SDSS system in the environment institution.
- Ensure support technical Ready standby moment system launched For respond constraint possible beginning happen.

g. Post-Deployment Monitoring
- Observing performance system in period beginning use.
- Provide channel bait come back user For take notes complaints, suggestions, or bugs found after system used in a way active.

6. Maintenance

The maintenance Stage or maintenance system is the final phase in cycle engineering, a system that aims to ensure the system still operates optimally, safely, and relevantly, in line with the development needs of users as well as applicable standards. In the context of developing the Sustainability Decision Support System (SDSS) based on the Global Reporting Initiative (GRI), the maintenance system encompasses data updates, improvement features, management of technical disturbances, as well as adjustments to changing GRI indicators and regulations, which are dynamic types of Maintenance in GRI-Based SDSS.

a. Corrective Maintenance

Done For repair error or the damage that occurred moment system used.

Example : Repair data input module if happen error in calculation GRI indicators such as emissions (GRI 305) or use energy (GRI 302).

b. Adaptive Maintenance

Adjustment system to change environment operational, such as Updates structure organization, regulation government, or Updates GRI version.

Example : Adjustment module reporting when GRI publishes standard new or renew indicator.

c. Perfective Maintenance

Done For increase performance system or add feature new based on bait come back user.

Example : Addition feature sustainability data visualization in form chart interactive or real-time dashboard.

d. Preventive Maintenance

Proactive action For prevent the occurrence damage system in the future.

Examples : Periodic data cleaning, automatic data backup, and testing system security in a way routine.

4. Conclusions

The implementation of a GRI-based SDSS at ITBA-DCC demonstrates how systems engineering can effectively facilitate sustainable governance in higher education. Compared with prior works, this study distinguishes itself by integrating GRI indicators directly into decision-support workflows and embedding visual analytics for stakeholder use. The study also confirms findings from international research that emphasize the importance of digital tools in sustainable planning.

Challenges encountered included data standardization and initial user resistance, which were overcome by modular architecture design, interactive dashboards, and inclusive training programs. The results highlight that a properly engineered SDSS can significantly improve transparency, strategic alignment, and ESG performance in academic institutions.

Future work should explore AI-based predictive analytics and automatic regulatory compliance features. This study offers a replicable model for other higher education institutions aiming to strengthen digital sustainability initiatives.

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