

CHAPTER 3 - RESEARCH METHODS

3.1 Research Framework

This chapter presents the research methodology used to investigate the integration of IT Service Management (ITSM) and COBIT 5 frameworks for sustainable data center cooling efficiency. The research framework is structured to align IT governance models with sustainable energy practices, ensuring compliance, efficiency, and long-term cost-effectiveness. The output of this research is a policy recommendation for Sinergy Data Center to improve cooling efficiency and align with government regulations and industry best practices. (see figure 3.1)

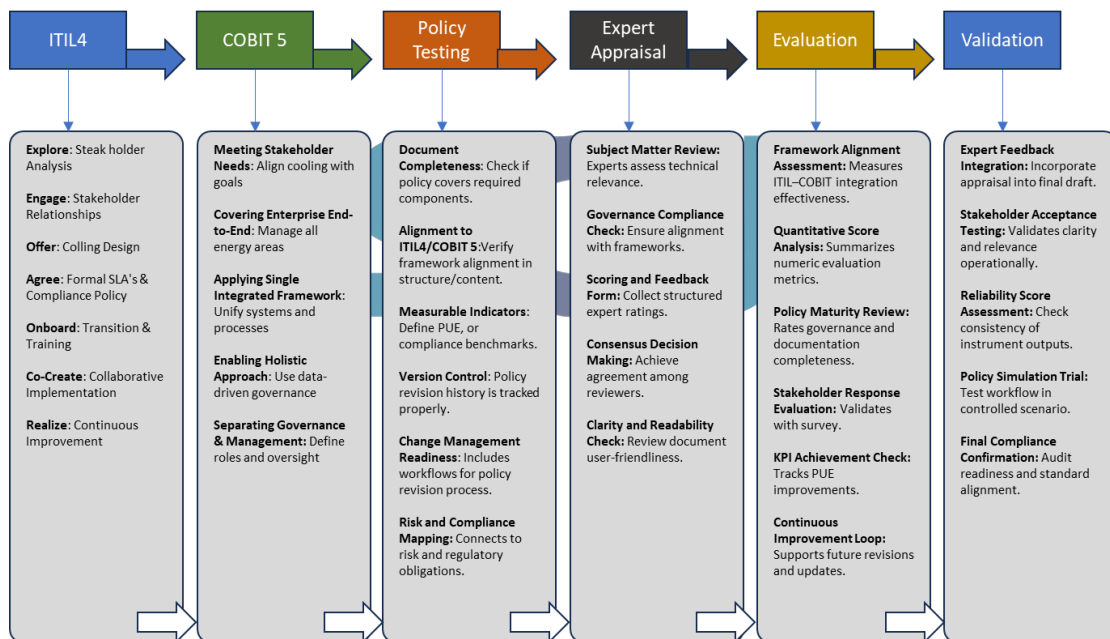


Figure 3.1. Research Framework

3.2 Analytical Methods

To systematically evaluate the effectiveness of integrating IT Service Management (ITSM) and COBIT 5 frameworks in enhancing sustainable data center cooling efficiency, this research employs a quantitative analytical approach. This quantitative methodology allows precise measurement and statistical validation of improvements resulting from the implementation of governance frameworks.

1. Power Usage Effectiveness (PUE)

Power Usage Effectiveness (PUE) is an industry-standard metric for evaluating data center energy efficiency. It is calculated by dividing the total energy consumption of a data center by the energy consumed by the IT equipment alone (Shehabi et al., 2016).

$$\text{PUE} = \frac{\text{Total Facility Energy Consumption}}{\text{IT Equipment Energy Consumption}}$$

A lower PUE indicates higher efficiency, with 1.0 representing an ideal efficiency scenario. In this research, the PUE metric will quantitatively assess improvements in energy efficiency following the integration of ITSM governance practices, allowing clear comparisons before and after policy implementation.

However, typical data centers have higher PUE values due to additional energy requirements for supporting infrastructure. For instance, as of 2021, Google's data centers reported an average PUE of 1.1, reflecting their efforts towards energy efficiency, comparing with the global average PUE of 1.7. (Le et al., 2021)

2. Cooling Efficiency Ratio (CER)

The Cooling Efficiency Ratio (CER) measures how effectively a cooling system converts electrical input into cooling output (ASHRAE, 2021). CER is calculated by dividing the cooling capacity delivered (kW) by the electrical power input required for cooling operations.

It is calculated by dividing the cooling output (in kilowatts) by the energy input required to produce that cooling:

$$\text{CER} = \frac{\text{Cooling Output (kW)}}{\text{Energy Input (kW)}}$$

Higher CER values reflect better cooling performance, reduced operational costs, and improved sustainability. In this study, CER will indicate the direct impact of IT governance frameworks such as COBIT 5 and ITSM in optimizing cooling system performance, enabling precise assessment of their effectiveness.

CER > 1: Efficient cooling system (the higher the CER, the better).

CER = 1: Input energy is equal to output (inefficient).

$CER < 1$: Inefficient system (cooling output is lower than energy used).

Ideal CER varies by technology. Traditional systems (HVAC) typically have a CER of 1.5–2.5, while advanced technologies (liquid cooling) can reach 3–5 (ASHRAE, 2021).

3. Carbon Emissions Reduction

Reducing carbon emissions is critical to data center sustainability. Quantifying emissions reductions involves calculating the reduction in greenhouse gases based on decreased energy consumption post-implementation of AI-driven cooling optimization (Haghshenas et al., 2022). Carbon emission reduction will be measured using established emission factors to accurately assess the environmental impact of improved governance and cooling management practices.

Quantitative data for these metrics will be gathered through monitoring systems installed at Sinergy Data Center, providing empirical evidence of performance changes resulting from the IT governance framework integration. Statistical analysis, including paired t-tests and regression analysis, will validate the significance of observed changes.

3.3 Data Collection Timeline

Effective data collection is crucial for evaluating the integration of ITIL-4 and COBIT 5 frameworks to enhance cooling efficiency at Sinergy Data Center. This study adopts a structured methodology encompassing both primary and secondary data sources to ensure comprehensiveness and reliability.

1. Primary Data

Primary data collection involves obtaining real-time empirical data directly from the operational environment of Sinergy Data Center. Data will be gathered using advanced cooling management systems equipped with IoT (Internet of Things) sensors and smart meters. These instruments provide accurate, real-time measurements of energy consumption, cooling performance metrics (such as Power Usage Effectiveness PUE and Cooling Efficiency Ratio CER), and environmental conditions such as temperature and humidity levels within server rooms (Haghshenas et al., 2022). The data collection instruments will continuously record these parameters to track cooling performance and energy

efficiency before and after implementing the ITIL-4 and COBIT 5-based policies.

The collected data will offer quantitative evidence of how ITIL-4 governance frameworks impact the operational efficiency and sustainability of cooling practices within the data center environment. This approach enables the analysis of performance improvements in response to newly adopted policy implementations.

2. Secondary Data

Secondary data collection involves comprehensive reviews of existing literature, academic articles, industry reports, and international standards relevant to data center cooling practices. Essential literature includes research findings and compliance guidelines from recognized sources such as ISO 50001 (Energy Management Systems) and ASHRAE TC 9.9 (Thermal Guidelines for Data Centers). These documents provide foundational knowledge on energy efficiency benchmarks, sustainability practices, and governance frameworks, crucial for validating the primary data findings.

Secondary data sources will also include previous academic research, industry best practice reports, and technology assessments to ensure alignment with current trends and technological innovations in sustainable cooling management. Utilizing secondary data strengthens the study's foundation by contextualizing real-time data with established theoretical and empirical insights.

The phases are structured to maximize data collection, analysis, and reporting within the given timeframe in Table 3.1.

Table 3. 1. Time Frame this Project

Week	Phase	Detailed Activities	Deliverables
1	Initial Preparation	- Define research objectives and questions clearly. - Initial meeting with advisor to	Approved Research Objectives

		confirm topic and scope. - Identify key literature and initial readings.	
2	Literature Review & Framework Development	- Collect and review relevant journals, articles, standards (ISO 50001, ASHRAE TC 9.9). - Identify key concepts (ITSM, COBIT 5, PUE, CER). - Develop theoretical framework draft	Draft Literature Review and Framework
3	Literature Review Completion	- Synthesize literature insights and finalize theoretical framework. - Confirm alignment with ITSM and COBIT 5 frameworks.	Final Literature Review & Framework
4	Methodology Development	- Clearly define quantitative analytical methods. - Develop methodology for primary data collection (IoT sensors). - Define secondary data sources.	Approved Methodology Chapter
5	Instrument Design & Validation Planning	- Design standardized survey questionnaire (IT governance, cooling technology efficiency, compliance).	Draft Survey & Validation Plan
6	Pilot Study & Validation	- Conduct pilot test of survey instruments with a small group. - Perform preliminary reliability and validity checks. - Expert validation review meeting.	Validated Survey Instrument

7	Primary Data Collection Setup	- Set up IoT sensors and real-time monitoring systems at Sinergy Data Center. - Test system accuracy and data collection processes.	Operational Data Collection System
8 - 9	Data Collection	- Begin systematic primary data collection (PUE, CER). - Distribute and collect survey questionnaires. - Continue secondary data collection.	Raw Data (Primary & Survey)
10	Data Cleaning & Preparation	- Verify accuracy and completeness of collected data. - Perform data cleaning and prepare data for analysis (organize databases, code survey responses).	Cleaned and Prepared Dataset
11 - 12	Quantitative Data Analysis	- Perform statistical analysis (PUE). - Conduct factor analysis (construct validity).	Analysis Results
13	Results Interpretation & Discussion	- Interpret results in context of ITIL-4 & COBIT 5 frameworks. - Analyse implications for policy development. - Prepare comprehensive discussion on findings.	Draft Results & Discussion Chapter
14	Policy Formulation	- Develop cooling efficiency policies (energy efficiency, risk management, compliance, technology integration).	Policy Recommendations Document

		- Validate policies with industry experts.	
15	Thesis Draft Completion	- Consolidate all chapters into a complete thesis draft. - Ensure coherence between literature, methodology, results, and policy recommendations. - Initial advisor review.	Complete Draft Thesis
16	Thesis Revision & Submission	- Incorporate feedback from advisor and expert reviewers. - Final proofreading, formatting, and referencing (Harvard style). - Submission of finalized thesis document.	Final Thesis Submission

3.4 Instrument Development

To ensure accurate and reliable data collection, the research will develop carefully structured instruments, primarily a standardized survey questionnaire. The instrument development process will follow established guidelines from literature to ensure validity and reliability.

1. IT Governance Implementation

This dimension measures the maturity and effectiveness of COBIT 5 and ITSM adoption levels within Sinergy Data Center. Questions will assess the alignment between organizational policies, cooling efficiency objectives, and IT governance practices.

2. Cooling Technology Efficiency

Questions will evaluate stakeholders' perceptions and experiences related to AI-driven cooling systems, liquid cooling adoption, and IoT-enabled monitoring systems. The survey items are derived from the energy management standards

recommended by ISO 50001, capturing the effectiveness of these technological implementations in practical settings.

3. Compliance with Energy Regulations

This dimension captures how effectively Sinergy Data Center adheres to international sustainability standards. Questions will evaluate knowledge, implementation practices, and compliance levels regarding energy management frameworks like ISO 50001 and PP No. 70 Tahun 2009 providing insights into organizational readiness and regulatory alignment

3.4.1 Instrument Grid Variable X: Cooling technology type

In this study, the cooling technology type is defined as an independent variable, which is hypothesized to influence the cooling efficiency of the data center environment. To assess this variable empirically, a structured instrument grid has been developed using a Likert-scale questionnaire format, as shown in Table 3.2. The design of this instrument is intended to evaluate respondents' perceptions regarding the types and characteristics of cooling systems currently implemented within their data center infrastructure.

The table includes three primary indicators:

1. Use of traditional CRAC units
2. Automation for thermal regulation
3. Sustainability-oriented design

Each indicator is represented through a corresponding statement, to which respondents indicate their level of agreement using a 5-point Likert scale, ranging from 1 = Strongly Disagree to 5 = Strongly Agree. This structure facilitates quantitative data collection while capturing the subjective assessment of operational technology alignment.

The first item assesses reliance on conventional cooling infrastructure, specifically Computer Room Air Conditioning (CRAC) units, which are typically less efficient under high-density IT loads.

The second item explores the integration of automation technologies, such as AI-driven temperature regulation systems and IoT-enabled cooling controls, which are increasingly vital in modern, energy-optimized data centers.

The third item focuses on the presence of sustainability-oriented cooling designs, including the use of liquid cooling, containment zoning, and free cooling techniques, which align with international environmental and energy efficiency standards such as ISO 50001.

The implementation of this measurement grid allows for standardized and reliable evaluation of how advanced or traditional the cooling solutions are, and how well these solutions are aligned with best practices in sustainable data center design. The resulting data will support further analysis to examine the relationship between cooling technologies and operational efficiency, as measured through dependent variables like PUE, energy consumption, and sustainability benchmarks.

Table 3. 2. Instrument Grid Variable X: Cooling technology type

No.	Variable	Indicator	Statement (Likert Scale 1–5)	Scale
1	Cooling Technology Type	Use of traditional CRAC units	The data center uses traditional CRAC units as the main cooling method.	1=Strongly Disagree 5=Strongly Agree
2	Cooling Technology Type	Automation for thermal regulation	The cooling architecture automation to dynamically control temperature.	1=Strongly Disagree 5=Strongly Agree
3	Cooling Technology Type	Sustainability-oriented design	The cooling design supports sustainability through energy-efficient technologies.	1=Strongly Disagree 5=Strongly Agree

3.4.2 Instrument Grid Variable Y: Cooling efficiency

This section presents the instrument grid for the dependent variable in the study show in Table 3.3., namely cooling efficiency. This variable is critical in evaluating the effectiveness of various cooling technologies in achieving sustainable and energy-optimized data center operations. The grid was developed to enable respondents to assess performance outcomes across multiple indicators using a 5-point Likert scale, where 1 represents “Strongly Disagree” and 5 represents “Strongly Agree.”

Table 3. 3. Instrument Grid Variable Y: Cooling efficiency

No.	Variable	Indicator	Statement (Likert Scale 1–5)	Scale
1	Cooling Efficiency	PUE (Power Usage Effectiveness)	The data center achieves a PUE value that reflects high energy efficiency (e.g., close to or < 2).	1=Strongly Disagree 5=Strongly Agree
2	Cooling Efficiency	Total energy consumption (kWh/year)	The total energy consumption of the cooling system is significantly lower than industry averages.	1=Strongly Disagree 5=Strongly Agree
3	Cooling Efficiency	% Energy savings compared to baseline	The cooling system demonstrates substantial energy savings compared to previous systems or baseline data.	1=Strongly Disagree 5=Strongly Agree

3.4.3 Instrument Grid Variable Control: IT load, ambient temperature

(Mediator)

Table 3.4 presents the instrument grid used to measure the control variables in this study: IT load and ambient temperature. These variables are considered mediators, as they may influence the relationship between cooling technology type (independent variable) and cooling efficiency (dependent variable), and must therefore be held constant or normalized during analysis. The instrument utilizes a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) to assess the stability and consistency of operational conditions across different testing environments.

The control variable consists of four key indicators, each accompanied by a measurable statement. The first indicator, server utilization rate (% load), is captured by the statement: “The server utilization rate is consistent and stable throughout the measurement period.” (Row 1). This ensures that IT load variation does not skew the cooling efficiency results. The second indicator, total IT equipment power (kW), is evaluated using the statement: “The total power demand from IT equipment remains within a predictable and controlled range.” (Row 2), which reflects electrical consistency in processing load.

The third indicator is ambient temperature range (°C), assessed via the statement: “The ambient temperature in the data center is kept within a consistent range during operations.” (Row 3), validating environmental stability. Finally, the fourth indicator, HVAC setpoints and thresholds, is measured with: “The HVAC setpoints and thermal thresholds are properly configured and maintained consistently.” (Row 4). Collectively, these items ensure that environmental conditions are uniform, enhancing internal validity during performance comparisons of cooling technologies.

Table 3. 4. Instrument Grid Variable Control: IT load, ambient temperature

No.	Variable	Indicator	Statement (Likert Scale 1–5)	Scale
1	IT Load & Ambient Temperature	Server utilization rate (% load)	The server utilization rate is consistent and stable throughout the measurement period.	1=Strongly Disagree 5=Strongly Agree
2	IT Load & Ambient Temperature	Total IT equipment power (kW)	The total power demand from IT equipment remains within a predictable and controlled range.	1=Strongly Disagree 5=Strongly Agree
3	IT Load & Ambient Temperature	Ambient temperature range (°C)	The ambient temperature in the data center is kept within a consistent range during operations.	1=Strongly Disagree 5=Strongly Agree
4	IT Load & Ambient Temperature	HVAC setpoints and thresholds	The HVAC setpoints and thermal thresholds are properly configured and maintained consistently.	1=Strongly Disagree 5=Strongly Agree

3.5 Evaluation Method

The evaluation method is critical in measuring the effectiveness and practical applicability of the policy framework proposed in this research, specifically tailored for Sinergy Data Center. A structured evaluation approach provides clear evidence of policy performance, facilitates continuous improvement, and ensures alignment with best practices and regulatory standards. The evaluation methodology adopted in this

thesis will encompass quantitative approaches to systematically validate and confirm the impact of implemented cooling policies.

3.5.1 Performance Metrics Evaluation

The evaluation of the proposed cooling policies will be conducted through quantitative metrics to objectively assess the performance and effectiveness of implemented strategies:

1. Power Usage Effectiveness (PUE)

PUE remains the primary metric used to evaluate data center energy efficiency improvements. It quantifies the effectiveness of energy usage across IT and cooling infrastructure. Reducing PUE values is directly correlated with lower energy consumption and increased operational efficiency (Shehabi et al., 2016)

2. Cooling Efficiency Ratio (CER)

CER is utilized to quantify the efficiency of cooling systems by comparing cooling output with energy consumption. Enhanced CER values indicate that cooling governance and technological implementations such as AI-driven optimization and liquid cooling systems significantly improve operational performance (ASHRAE, 2021).

3. Carbon Emissions Reduction

Monitoring and reporting carbon emissions reduction provide a tangible evaluation of environmental impact. This metric assesses the direct environmental benefits from energy-efficient technologies and improved cooling management practices, aligning closely with corporate sustainability objectives and global climate goals (Haghshenas et al., 2022).

3.5.2 Evaluation Process

The evaluation process involves sequential, structured steps to ensure systematic analysis and validity of policy outcomes:

1. Baseline Measurement

An initial assessment of current cooling practices and performance at Sinergy Data Center is conducted prior to policy implementation. Baseline data such as initial PUE values, CER values, and carbon emissions will be recorded, providing a reference point against which improvements can be accurately measured (Shehabi et al., 2016).

2. Implementation Monitoring

Post-policy implementation, continuous monitoring using IoT-based real-time sensors and data analytics will capture ongoing performance metrics. This approach ensures the accuracy of data collected and provides immediate feedback on policy effectiveness, facilitating rapid identification and resolution of operational inefficiencies (Haghshenas et al., 2022).

3. Benchmarking

Benchmarking Sinergy Data Center's performance against industry standards and best practices (e.g., global average PUE values, ASHRAE guidelines) is essential for contextualizing results. This comparative analysis ensures that the data center meets or exceeds industry-leading efficiency standards and validates policy effectiveness relative to peer performance.

4. Expert Reviews and Recommendations

Expert validation from industry professionals ensures the practicality, relevance, and applicability of policy recommendations. Experienced IT governance specialists, sustainability officers, and data center management experts will review the evaluation results to confirm their practical relevance and to suggest refinements to ensure policy recommendations align with industry expectations and best practices (Boateng et al., 2018).

3.6 Validation Methods

Ensuring robust validation is essential for research reliability and accuracy. This research employs a triangulation approach, combining multiple validation techniques to strengthen findings:

1. Construct Validity (Factor Analysis): Factor analysis will assess the construct validity of survey items, confirming the relationships between IT governance

implementation, cooling technology effectiveness, and regulatory compliance. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) will validate the underlying constructs and ensure the survey instrument measures the intended theoretical concepts effectively (An Gie Yong, 2013).

2. Expert Validation: An expert review will complement quantitative validation methods, providing qualitative validation of the survey instruments and policy recommendations. Subject matter experts from data center management, IT governance specialists, and sustainability officers will evaluate the relevance, clarity, and applicability of the survey instrument and the resulting policy proposals. This approach ensures that findings and recommendations are not only statistically valid but practically applicable within the industry context (Boateng et al., 2018).

