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ENHANCING THE SUSTAINABILITY OF HIGHER EDUCATION IN INDONESIA: A SIX-SIGMA APPROACH

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INTRODUCTION

In the contemporary era characterized by rapid information exchange, the education sector encounters evolving challenges, such as the proliferation of teaching learning mechanism and the emergence of a digitally native generation. Higher education institutions are also expected to be able to meet these problems by maintaining focused on developing exceptional human resources, global competitiveness, and noble character, resulting in world-class education (Findler et al., 2019). The vision of "Golden Indonesia 2045" embodies aspirations for a more prosperous and developed nation. This goal of an advanced, esteemed, and thriving Indonesia serves as a source of motivation, inspiring the Indonesian people to exert greater effort and adopt more strategic approaches in their endeavors. Universities are expected to contribute with more focus in developing human resources that are superior, have global competitiveness, and have noble character (Elmassah et al., 2022).

Thus, higher education institutions are not only responsible for producing quality graduates, but also in providing world-class education that is able to support the achievement of the ideals of the “Golden Indonesia 2045” (Malihah, 2015). Thus, necessitates transformation and collaboration among the corporate world and industry (DUDI), government, non-governmental institutions, professional groups, the general public, and the media. Transformation and collaboration are also required to make higher education world class, through revitalizing the management of the education system and developing research by prioritizing good university governance through values such as transparency, accountability, responsibility, independence, fairness, quality assurance, and relevance (Serafini et al., 2022). Higher education institutions play an important role as leaders in knowledge creation and dissemination by setting the grounds for society to advance and to improve welfare (Sunder M & Mahalingam, 2018).

Various studies has been carried out in various fields of science to solve problems and phenomena of sustainable higher education, one of which is an operational approach with the tools used in this research is Six-Sigma (Sabtu & Matore, 2024). According to the American Society of Quality, Six-Sigma is a tool or way companies can develop business process capacity (Hahn et al., 2000). The purpose of this method is to improve performance and reduce the possibility of error. Six-sigma gets its name from the words “six” which means six (6) and “sigma” which means standard deviation, which is one measure of the distribution of data in statistics. Six-Sigma has indeed made many and amazing changes for the

manufacturing, services and healthcare industries (Stankalla et al., 2018). This methodology is derived from the bell curve in statistics, where one sigma represents one standard deviation from the mean or mean, if a process has six-sigma consisting of three sigma above and below, the failure rate is rated low.

Applying the Six-Sigma technique to higher education (HE) can still be very successful, even though it is true that the area does not have the same standard metrics as manufacturing fields, such as inventory, real income, or equipment. Despite the absence of conventional metrics, Six-Sigma's emphasis on continuous improvement, defect reduction, and efficiency enhancement applies to education (Sunder M & Antony, 2018). Low student retention, subpar instruction, or inefficient administrative procedures could all be considered "defects" in the context of education (Clemons & Jance, 2024). Instead of depending just on measurable measures like production or inventory, higher education institutions can use Six-Sigma techniques to improve procedures, improve the learning environment, and increase overall outcomes. Therefore, the methodology's emphasis on quality improvement and problem-solving is still important and helpful even when the education sector may not adhere to typical Six-Sigma criteria. To track the success and advancement of the programs being and will be implemented, the Directorate General of Higher Education has established program objectives, performance, and performance targets for the 2020–2024 period. Based on the measurement of program and activity performance indicators, three primary goals have been established: (1) enhancing higher education's accessibility, relevance, and quality of learning; (2) raising the caliber of instructors and other educational staff; and (3) achieving the Directorate General of Higher Education's quality governance (Table 1).

Table 1: Overview of Higher Education (HEI) Indonesia

Variables	Kemendikbud/MoEC		Total of MoEC	Religius HE Institution	Gov.HEI	National
	Public	Private				
	No.	No.	No.	No.	No.	No.
Institutions	122	3044	3166	1240	187	4593
University	63	583	646	19	2	667
Institute	12	120	132	138	1	271
School of Higher Learning	-	1361	1361	1080	24	2465
Academy	-	772	772	3	55	830
Community Collage	4	32	36	-	2	38
Polytechnic	43	176	219	-	103	22

Sources: Higher Education Statistic 2025

In Indonesia, universities are dispersed over numerous regions with diverse topographies and concentrations of inhabitants. There are 4,593 universities in Indonesia, which is home to 270.20 million people. These include 122 state institutions, 3,044 private universities, 187 PTK/L, and 1,240 PTA. The government bases its policy-making regarding the availability of higher education facilities on the differences in population and universities throughout each province. The Human Development Index (HDI) and the 2019 poverty rate demonstrate that, despite the abundance of colleges, there is still a disparity in the caliber of human resources. With Jakarta (80.76) and Yogyakarta (79.99) having the highest HDI and Papua (60.84), West Papua (64.70), and NTT (65.23), among the lowest, Indonesia's average HDI was 71.92. Papua has the greatest poverty rate (26.55%), while Jakarta has the lowest (3.42%).Given that campuses can stimulate local economic growth, equitable university development may be a way to lessen economic.

The number of students enrolled in all universities in Indonesia reached 8,483,213 million people. To improve the quality of human resources, the sustainability of student studies needs to be encouraged. *Kampus Merdeka* is a new policy from the Ministry of Education and Culture that gives students the freedom to develop their potential according to their interests and career goals. Currently, many university graduates cannot always be absorbed into the workforce as expected. The growth in the number of universities also risks reducing the quality of graduates if they only focus on quantity without paying attention to quality standards despite the fact that economics graduates are supposed to assist the government in resolving economic issues, another issue is the high dropout rate in the economics faculty (Digdowiseiso, 2020). Systemic changes are required to increase educational accessibility and affordability in order to increase the sustainability of higher education. Increased government funding for educational subsidies, the growth of scholarship programs, and collaborations with the corporate sector to lower financial obstacles are examples of sustainable solutions (Kyrychenko, 2018). Enhancing the quality of education and increasing retention rates in these faculties would enable us to give students the skills and information they need to address urgent societal concerns like economic inequality, unemployment, and poverty. By finding and removing inefficiencies, lowering dropout rates, and consistently enhancing the educational experience, applying the concepts of Six Sigma to these interventions could further optimize the process (Figure 2). Higher institutions might evaluate and enhance their teaching and student assistance strategies using techniques like DMAIC (Define, Measure, Analyze, enhance, Control), which would guarantee efficient resource

allocation and continuously improved results (Asif et al., 2013). In addition to creating a workforce that is more skilled and competitive, these initiatives would strengthen and fortify the economy. Long-term social, economic, and environmental sustainability may be supported by incorporating Six Sigma principles into the educational process, which may ultimately lead to a more fair allocation of opportunities and resources (de Freitas et al., 2017).

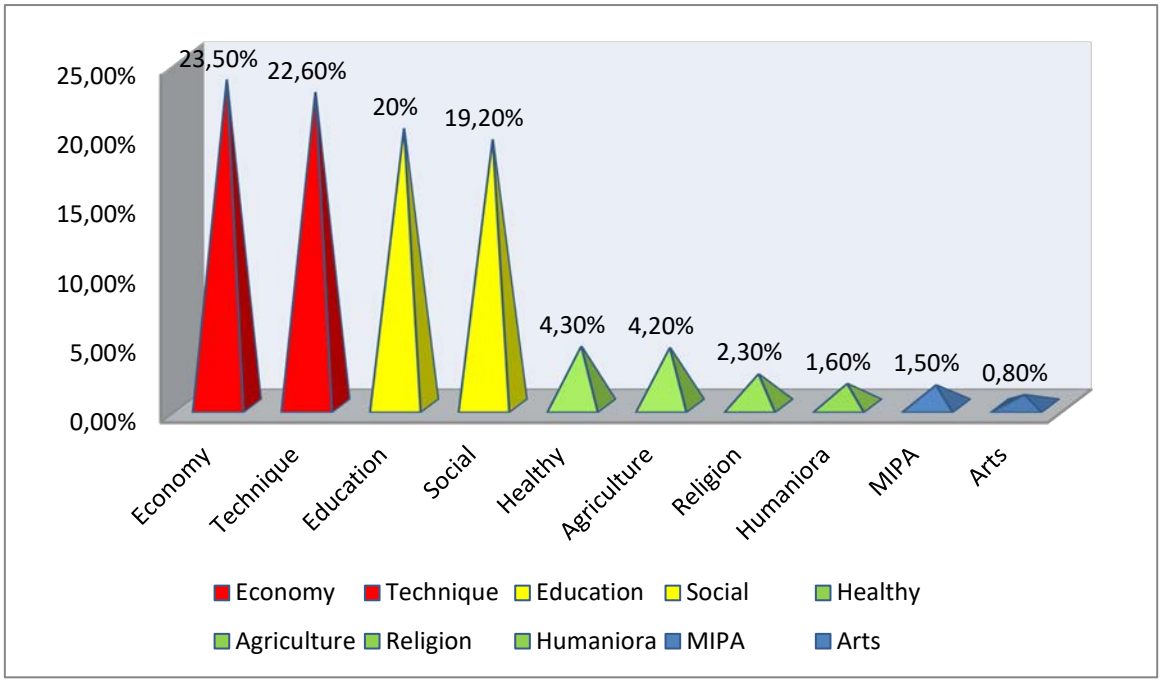


Figure 1: Number of Dropout Rate based on Field of Study

Sources: Higher Education Statistic 2025

Through teaching, research, and community involvement, lecturers play a vital role in the transformation, advancement, and dissemination of science and technology as professional educators (Christie et al., 2015). Currently, Indonesia has 312,890 lecturers, both permanent and non-permanent, with a range of functional levels, including professors, head lecturers, lectors, and expert assistants. Higher education's viability is influenced by both the quantity of universities and the caliber of their faculty. Better social welfare and economic prosperity will emerge from graduates who are more equipped to compete in the workforce thanks to the efforts of qualified instructors. Graduates from universities that do not uphold quality standards are typically less competitive, increase economic inequality, and contribute to educated unemployment. Therefore, in the endeavor to create a more sustainable and inclusive higher education system, raising the caliber of lecturers is an essential first step. One tactic to close the research gap and raise the efficiency of the higher education system is to apply the Six Sigma methodology. Universities can use this approach to pinpoint important

problems with human resource management, boost productivity, and guarantee higher standards for instruction and research. Furthermore, by promoting more effective resource usage, cutting down on waste in the educational system, and assisting in the creation of a curriculum centered on sustainability, the implementation of Six Sigma principles in education also benefits the environment. As a result, graduates of an effective educational system and skilled instructors will be highly competitive and capable of solving upcoming social, economic, and environmental problems.

Due to a lack of agreement on sustainability capabilities that are essential for businesses, Indonesian higher education has difficulty successfully incorporating sustainability into its curriculum. The Six Sigma methodology, which emphasizes enhancing quality and efficiency through data-driven approaches, may offer a calculated way to enhance the system of sustainability education. To develop future leaders who are not just business-savvy but also highly conscious of sustainability, there is an urgent need for international cooperation, interdisciplinary projects, and thorough integration of SDGs in higher education (Nguyen et al., 2025.). Therefore, in order to achieve a more sustainability-oriented transformation of business education, this research challenges the existing paradigm by promoting collaboration between universities and important stakeholders, such as students, institutional leaders, governments, ministries, and industries.

1. INTRODUCTION OF THE TOPICS AND OBJECTIVE

1.1. Aim and Research Question

The background of the research has explained that there is no denying that efforts to increase competitive advantage closely related to improving the quality of Indonesian human resources which incidentally cannot be separated from the role of education in Indonesia. In fact, education takes place lifelong and carried out in the economic, social, and environments. Improving the quality of human resources should be a mistake one of the main focuses in the national education system, especially with regard to implementation of the educational process by educational institutions, especially universities.

The purpose of this study is to identify and analyze the impact of implementing Six-Sigma methods on improving sustainability in higher education institutions. Specifically, this research aims to understand how the application of Six-Sigma can help higher education institutions improve operational efficiency, reduce waste, and improve the quality of educational services. This research aims to identify barriers that may arise, such as limited human resources, lack of understanding of Six-Sigma methods, or resistance to change. In addition, this research also aims to explore opportunities that can be utilized, such as improving the quality of academic services, operational process efficiency, and developing a culture of continuous improvement. By understanding these challenges and opportunities, the research is expected to provide strategic recommendations for higher education institutions in Indonesia to implement Six-Sigma effectively and sustainably. The aim of this research is to explore the potential of the Six-Sigma approach in supporting the sustainability of higher education in Indonesia. Specifically, it aims:

1. To investigate how Six-Sigma principles can contribute to the long-term sustainability and improvement of higher education in Indonesia.
2. To identify and analyze the challenges associated with the implementation of Six-Sigma in Indonesian higher education institutions.
3. To examine how sustainability can be effectively measured and achieved in the context of higher education in Indonesia through the application of Design for Six-Sigma (DFSS) methodology.

Several statistical and non-statistical tools from the Six Sigma methodology were used to analyze and in order to better understand the current occurrences; research hypotheses in the

form of research questions are employed. The goal is to determine the elements that impact the sustainability of higher education and investigate how Six Sigma implementation might address these issues. As a result, this study will provide more precise answers about how Six Sigma may raise educational standards and help Indonesian higher education meet its sustainability objectives:

1. How can Six-Sigma approach contribute to the existence sustainability of higher education in Indonesia?
2. What are the challenges of Six-Sigma implementation in higher education in Indonesia?
3. How can sustainability be measured in the context of higher education in Indonesia, by using Design for Six-Sigma (DFSS) methodology?

1.2. Research Gap

The topic of education, particularly higher education in Indonesia, is always being discussed. This is because education is a fundamental issue that is directly tied to the endeavors to educate the populace and mold Indonesia's human capital overall. The author discovered a number of results or research gaps that should be noted in the field of education based on the problem formulation in the preceding section. At least, there are several basic obstacles that exist in the world of higher education, the first of which is the low quality of educators. This is a crucial issue that must be addressed immediately, as it will have a direct impact on the quality of graduates produced. One of the most affected aspects is Indonesia's Human Development Index (HDI), which is still relatively low compared to other countries. The Six Sigma methodology may be a useful way to fill this research void in this situation. With its emphasis on quality control and continual development, Six Sigma can be applied to raise the caliber of instructors and the educational system overall. Universities can pinpoint the underlying issues that impair the caliber of instruction and learning, such as inadequate training, sluggish curriculum revisions, or poor teacher motivation, by implementing the Six Sigma technique. In order to support the sustainability of higher education, universities can create data-driven solutions to enhance the quality of teaching and learning through technologies like DMAIC (Define, Measure, Analyze, Improve, and Control).

1.3. Research Benefits

1.3.1. Theoretical Contribution

The theoretical contribution of research that examines Six-Sigma's contribution to the development of quality management methods in higher education is significant. The following is an in-depth description of its contribution.

1. This research contributes to the academic literature related to quality management, particularly in the context of higher education. Six-Sigma, which initially developed in the manufacturing industry, is rarely applied in the education sector. By conducting this research, the Six-Sigma approach will be better recognized as an effective method to improve efficiency, reduce process errors, and optimize results in higher education institutions and can be applied to address specific issues faced by universities, such as resource management efficiency, teaching quality, or infrastructure management.
2. This research can reduce variability in processes and ensure consistent results. In the context of higher education, this means that standards of teaching, evaluation, and services to students can be improved to be more consistent and measurable. The results of this research will provide theoretical contributions on how university management can be optimized to produce quality graduates not only at the operational level (e.g. facilities management) but also in the academic process (e.g. curriculum, learning).
3. This research can encourage innovation in university management by introducing a more efficient and structured management system through Six-Sigma. This includes continuous improvement in various aspects, ranging from student services, resource utilization, to the achievement of academic outcomes to identify the most effective teaching methods or improve the curriculum to better suit the needs of students and the job market.

Academically, this research has the potential to enrich and develop the literature in the field of quality management in higher education by introducing Six-Sigma as an effective tool to improve efficiency, consistency, and sustainability. In addition, this approach could change the way Indonesian universities run their operations, focusing not only on educational outputs (such as the number of graduates), but also on continuous improvement of overall quality.

1.3.2. Higher Education Relevance Perspective

The practical benefits of the research provide important recommendations for university managers in adopting Six-Sigma to create sustainable education. The following is a full description of these benefits:

1. Six-Sigma helps universities to identify and reduce waste in operational processes, such as the use of electricity, water, and other resources. By applying this approach, universities can optimize the use of resources in a more efficient and environmentally friendly manner, supporting sustainability efforts through energy savings and better waste management through the use of Information technology and digital infrastructure are essential in modern education. Six-Sigma can be used to analyze technology-based operational processes, such as academic administration systems or e-learning, and recommend improvements to enhance their performance and efficiency.
2. In creating sustainable education, the implementation of the green campus concept is essential. Six-Sigma can be used to measure and monitor environmental sustainability initiatives, such as carbon emission reduction, energy efficiency, and waste management. Universities can use the data generated by this method to make more informed decisions in environmental initiatives.
3. Trough Six-Sigma approach, university managers can make more informed and measurable decisions based on data analysis. For example, in terms of budget allocation, investment prioritization, or human resource management, as well as periodic continuous evaluation of institutional performance in areas such as resource management, curriculum effectiveness, or administrative efficiency.

The practical benefit of this research is to provide university managers with powerful tools and approaches to improve the efficiency, quality, and sustainability of education through Six-Sigma. With these recommendations, the university can optimize its operations, improve services to students and staff, and build a more adaptive, innovative, and sustainable institution in the long term.

2. LITERATURE REVIEW

2.1. Sustainability

In order to meet the requirements of the current generation without endangering the resources of future generations, sustainability is a multifaceted notion that includes a balance between the environmental, economic, and social components of development. Ecosystems have historically evolved from an ecological point of view before being integrated into an economic framework using a development model that considers the sustainable expansion of communities and a social dimension that emphasizes justice and well-being (Azapagic et al., 2016). Environmental science, economics, business, public policy, and education are just a few disciplines that have extensively used the Triple Bottom Line idea (Rashidi et al., 2020).

This comprehensive approach incorporates these three dimensions. From the public policy standpoint, sustainability is the foundation for creating several national and international rules and development plans (Salas-Zapata & Ortiz-Muñoz, 2019). Through its 17 Sustainable Development Goals (SDGs), the United Nations has created a worldwide framework encouraging nations to implement sustainability policies across various industries, including infrastructure, energy, agriculture, health, and education (Boar et al., 2020). The need for regulations that promote green investment, eco-friendly technologies, and incentive programs for businesses that help meet sustainability goals is becoming increasingly apparent to governments worldwide. Education is another important factor in fostering a society that recognizes the value of sustainability. Several nations have started incorporating sustainability-based curricula into their educational systems to raise awareness among the younger generation about the significance of preserving ecosystem balance, lowering carbon footprints, and adopting more sensible consumption habits (Sengupta et al., 2020). Students can gain a more tangible and useful understanding of sustainability through environmental education incorporating real-world applications, such as recycling initiatives, sustainable agriculture, and energy conservation in higher education institution (Ramakrishna, 2021).

Public awareness efforts using social media, seminars, community initiatives, and formal education are important in promoting behavioral shifts toward a more sustainable way of living. While the shift to a green economy necessitates large investments in infrastructure, education, and policies that encourage sustainable innovation, many developing nations continue to rely on fossil fuels and extractive sectors that negatively impact the environment

(Zacchia et al., 2022). Furthermore, certain industrial sectors continue to oppose sustainability regulations because they fear that they will raise production costs or impede economic growth. In order to develop sustainable solutions that may be broadly adopted without compromising economic welfare, governments, the private sector, academia, and communities must work together. Integrating sustainability ideas into the curriculum is one of the most important parts of sustainability in higher education. Around the world, many colleges have started creating curricula emphasizing sustainability (Elegbede et al., 2023).

These curricula can be integrated into other academic fields or take the shape of specialized programs like environmental studies, renewable energy, and sustainable development (Painter-Morland et al., 2016). For instance, engineering stresses the significance of environmentally friendly technology in product design and innovation, while business programs progressively embrace corporate social responsibility (CSR) and the circular economy (Shahzad et al., 2020). Examining the ethical and social facets of sustainability, such as environmental justice and public policies that promote sustainable development, is another function of the humanities and social sciences (Al-Zahrani & Alasmari, 2024). Higher education helps students acquire the knowledge and abilities necessary to become change agents in various fields in this way. Higher education is essential for sustainability research and innovation in addition to the curriculum. From the creation of sustainable agricultural systems, renewable energy technology, and climate change mitigation plans, universities act as research centers that produce answers to a variety of sustainability issues (Barile & Saviano, 2018).

In these studies, cooperation between government, business, and academics might hasten the adoption of sustainable development plans and green technologies. For instance, numerous institutions have established sustainability research institutes emphasizing waste and pollution control, resource efficiency, and renewable energy development (Guo et al., 2020). In addition to offering fresh perspectives, the research products of these universities serve as the foundation for better policy decisions that promote sustainability on a national and international scale (Shields, 2019). By implementing green campus rules, colleges can demonstrate sustainability efforts in addition to their academic accomplishments (Anthony Jnr, 2021). Numerous academic institutions have initiated the implementation of programs that promote improved waste management, carbon emission reduction, and energy efficiency. For instance, several colleges have reduced their usage of single-use plastics, shifted to renewable energy, and installed eco-friendly campus transportation systems (Uzar, 2024).

Furthermore, projects like green building construction, more effective water management, and zero-waste campuses show that educational institutions can serve as role models for the practical implementation of sustainability concepts (Budihardjo et al., 2021). Additionally, through various extracurricular activities and environmental-based groups, higher education contributes to increasing students understanding of and engagement with sustainability issues. Students can actively participate in bringing about change through sustainability-focused student organizations like environmental clubs and social movements that support climate action (Ateeq et al., 2024).

Through partnerships with green businesses, governmental entities, or nonprofits that focus on social and environmental issues, sustainability-based internships and projects also allow students to put their knowledge to use in the real world (Žalėnienė & Pereira, 2021). Students actively participating in sustainability programs acquire real-world experience and cultivate the leadership and teamwork abilities necessary to create a more sustainable future. Higher education has many promises to encourage sustainability, but some issues must be resolved. One of the biggest obstacles is the lack of funds and resources to create sustainability programs widely throughout all educational institutions (Chankseliani & McCowan, 2021). Not every university has the resources to conduct comprehensive sustainability research or access green technologies (McCowan, 2023). Furthermore, several academic disciplines have yet to fully incorporate sustainability ideas into their curricula, indicating a gap in adopting sustainability concepts across disciplines.

Therefore, to increase the role of higher education in promoting sustainability, more cooperation between the government, business community, and educational institutions is required (Mazon et al., 2020). Higher education must keep evolving and adapting in the future to meet the growing complexity of sustainability issues. Universities may contribute more to developing answers to global issues by utilizing technology advancements, enhancing interdisciplinary and applicable learning methodologies, and bolstering cross-disciplinary collaboration. Ensuring that higher education helps achieve the SDGS will require commitment from all parties involved, including academia, students, industry, and the government (Berchin et al., 2021). Higher education may generate graduates who understand sustainability and act as a catalyst in creating a more equitable, sustainable, and ecologically friendly society for coming generations if it adopts a comprehensive and scientifically grounded approach (Leal Filho et al., 2017).

2.2. Higher Education

In Indonesia, as in many other places, the issue of equality in education, especially higher education, has been a subject of intense debate (Van Der Kroef, 1955). Several factors contribute to this. First, higher education is often viewed as a public good. Second, it is seen as a means to train future elites who will play a key role in the country's development, which has made higher education institutions (HEIs) politically significant. Third, inequality in education is also driven by expectations in the job market, where graduates are anticipated to secure well-paying jobs in the formal sector, which is perceived as more advantageous than the informal sector. Hence, there is a strong political drive to ensure access to higher education for all social groups.

Historically, Indonesia’s political and economic progress has been closely tied to the influence of HEIs (Rosser, 2023). For instance, the independence movement was primarily driven by well-educated young Indonesians, and political unrest in the country has often been connected to the activism of university students (Symaco & Hayden, 2021). As a result, graduates of HEIs hold high social status. The 1945 Constitution mandates efforts to educate the nation's life and so that the government endeavor and organize a national teaching system regulated by law. From the realization of the mandate, the enactment of Law No 2003, that the national education system must be able to ensure equal opportunity education, improvement and relevance and efficiency of education management to deal with challenges in accordance with the changing demands of local, national, global life so it is necessary education reforms are carried out in a planned, directed, and sustainable manner. Therefore, education management must be oriented to how to create better changes in the face of future national education. One of the future challenges is the 21st century which is marked by the century of knowledge, which consists of quality human resources, namely individuals who are independent, willing and able to realize the ideals of their nation (Sakhiyya & Rahmawati, 2024).

Higher education in Indonesia contributes significantly to the sustainability agenda through research, curriculum, and campus operations (Nugraha et al., 2023). Although sustainability has started to be included in several higher education regulations, many obstacles must be removed before implementation (Fatimah et al., 2025). In keeping with the growing global recognition of the significance of sustainable development, numerous Indonesian universities are currently beginning to offer sustainability-focused courses and study programs (Sari et al.,

2020). Additionally, a few colleges have taken proactive measures to implement the green campus idea, conduct research on sustainability, and promote student participation in social and environmental projects. One noteworthy development in Indonesian higher education is the growing number of colleges incorporating sustainability themes into their courses. Numerous academic institutions have provided sustainability courses, including green economics, environmental engineering, and sustainable development studies (Hartanti et al., 2022). Furthermore, many colleges have started incorporating sustainability ideas into business, engineering, and social science curricula. For instance, the Center for Sustainable Development Goals Studies (SDGs Center) at the University of Indonesia (UI) focuses on sustainable development-related research and instruction. In addition, Universitas Gadjah Mada (UGM) maintains several sustainability programs, such as research, volunteer work, and greener campus administration. Through the curriculum, several Indonesian universities are actively advancing sustainability-related research and innovation (Sakhiyya & Rahmawati, 2024). Renewable energy, sustainable agriculture, preserving natural resources, and adapting and mitigating climate change are the subjects of several scholarly investigations (Figueiró et al., 2022). To create green technology and sustainable development plans, Indonesia's major universities work with the government, the business community, and foreign organizations. For instance, research on renewable energy, including solar panel technology and biomass to lessen reliance on fossil fuels, is being conducted by Diponegoro University (UNDIP) and the Bandung Institute of Technology (ITB).

From an operational standpoint, several Indonesian universities have started using the green campus idea as part of their initiatives to lessen their environmental effect (Andriani et al., 2024). Universities that follow this idea aim to adopt more ecologically friendly transportation systems, cut waste, and improve energy efficiency. For instance, the UI GreenMetric World University Rankings, a global rating that evaluates campus sustainability based on factors like waste, water, transportation, education, energy and climate change, and infrastructure, has included Universitas Indonesia (UI) on multiple occasions. In order to maintain the ecosystem's equilibrium on campus, UI has put in place several eco-friendly measures, including encouraging the use of electric cars, improving trash management, and making the most of green spaces (Suwartha & Sari, 2013).

However, Indonesia has also seen a rise in student participation in the sustainability movement (Kusumawanto & Setyowati, 2020). On many campuses, several student organizations devoted to sustainability and the environment have grown, launching recycling

initiatives, environmental awareness campaigns, and community-based initiatives to enhance social welfare (Handayani et al., 2024). Several universities have started implementing programs like thematic community service (KKN) that address sustainability issues. These programs allow students to apply sustainability concepts in a community setting, such as ecotourism development, sustainable agriculture initiatives, and community-based waste management. Issues still need to be resolved, even with the advancements in integrating sustainability principles into Indonesian higher education. One of the biggest obstacles is the lack of funds and resources to assist campus sustainability research and implementation (Wimala et al., 2016). Due to a lack of funding and infrastructure, many universities particularly those in the regions continue encountering challenges when implementing sustainability policies or embracing green technologies fully.

Furthermore, public and private institutions continue to execute sustainability differently, with larger universities typically having greater access to resources to create sustainability programs than smaller ones. According to Modugno & Di Carlo (2019) financial limitations and institutional and individual understanding and commitment to sustainability influence the success of applying this idea in higher education. Not all academic personnel and students fully comprehend the significance of sustainable development, and not all faculties and study programs actively include sustainability in their curricula. As a result, more methodical initiatives are required to raise awareness and educate students about sustainability in the classroom, including curriculum creation, seminars, and teacher and lecturer training (Leal Filho et al., 2018). Higher education in Indonesia has a fantastic chance of contributing significantly to sustainable development in the future. Higher education is anticipated to be more active in creating innovation, research, and policies that support sustainability principles due to the growing worldwide awareness of sustainability challenges and Indonesia's commitment to accomplishing the Sustainable Development Goals (SDGs) (Ambariyanto & Utama, 2020). Accelerating the adoption of sustainability in higher education requires cooperation between academia, business, government, and society.

Research by Rosser (2023) reveal the condition of higher education in Indonesia, which still has many mismatches with the demands of the world of work, is also impact on our competitiveness globally is very low. UNESCO in the Education Development Index states that the level of development of Indonesian education is ranked 102 in the world, while the illiteracy-free Indonesian community is ranked 95 at 87.9%. This condition is a condition that is quite alarming, because it shows that the education system in Indonesia has not been

running optimally. Judging from the practical reality, our education is still concerned with education that is materialism-capitalist ideology (Logli, 2016). Higher education in Indonesia plays a strategic role in producing competent human resources to support national development. Accessibility of higher education relates to the opportunities for people to continue their education to higher education. The theory of equity of access emphasizes the importance of equal opportunities for all levels of society, including the underprivileged and those from remote areas (McCowan, 2016). Although the number of tertiary institutions continues to grow, disparities in access to higher education are still evident, especially between urban and rural areas. Many universities face challenges in maintaining the quality of education. Not all universities have excellent accreditation, and the quality gap between public and private universities is still a concern (Akita, 2017). Employability theory highlights that higher education should be able to equip students with relevant skills for the world of work (Digdowiseiso, 2020). This approach involves collaboration with industry to align the curriculum with market needs. Many graduates still experience skill mismatch, where their skills do not match the needs of the labor market. This creates a significant level of educated unemployment (Hakim et al., 2024).

The government through the Ministry of Education, Culture, Research and Technology has launched various programs, such as *Kampus Merdeka*, vocational revitalization, and scholarship support through LPDP (Yusuf, 2021). In addition, collaboration between universities, industry, and the government continues to be encouraged to improve the relevance and quality of higher education. According to Haerizadeh & Sunder (2019) empirically validate the application of Six-Sigma in HEI highlighting practically about the challenges and benefits of Six-Sigma in HEI. In-depth empirical analysis of the application of the Six-Sigma toolkit and change management as a result Six-Sigma can be applied and can provide positive benefits for HEI. Finding every issue that exists within an organization including higher education institutions is the true goal of the Six-Sigma methodology (Ratvasky & Furterer, 2024).

2.3. Six-Sigma Concepts

The Six-Sigma methodology was introduced by Bill Smith at Motorola in the 1980s (Timans et al., 2016) to prominence when applied by John F. 'Jack' Welch at General Electric (GE) in the 1990s (Davidson et al., 2020). Since then, Six-Sigma has spread far and wide and is now used by many companies around the world. The success factors in the introduction and

implementation of a Six-Sigma program in a company have been investigated by several authors. In a literature review (Gamal Aboelmaged, 2010) found success factors, suggested by Antony & Banuelas (2002), Brady & Allen (2006), Sandholm & Sorqvist (2002), Chakravorty (2009) and Moosa & Sajid (2010).

Six-sigma is a methodology for process improvement and a statistical concept for determining the inherent variation in any process. The overarching premise of Six-Sigma is that variations in a process create opportunities for error; opportunities lead to the risk of product defects (The Council Six Sigma, 2018). There are two primary approaches in the Six Sigma methodology: DMADV (Define, Measure, Analyze, Design, and Verify) is used in the development of new goods or services, and DMAIC (Define, Measure, Analyze, Improve, and Control) is used to improve current processes. Design for (DFSS) is a Six-Sigma strategy that works on the first step of the recycling process. DFSS is not a strategy development and improvement of existing processes and not is a strategy of modifying the fundamental structure of the process there has been (Antony, 2004).

However, DFSS is a new process design strategy by utilizing the best working tools and methods in product and process planning, be it the development process product, service process design or re-design, or internal business processes (Arumugam et al., 2016). Six-Sigma is often referred to as a 'statistical method' (i.e. quantitative method), because decisions are made on the basis of statistical analysis of quantitative data. It's only one part from the truth. Another part that should not be forgotten – especially in Six-Sigma training , without qualitative methods, Six-Sigma does not work (Cronemyr, 2007). The Define phase and the beginning of the Measure phase are mostly qualitative. A problem to be solved needs to be formulated from people's experiences. Sometimes quantitative data from process evaluations are used.

The rest of the Measure phase and the beginning of the analyze phase are mostly quantitative. It is here where the statistical analysis takes place, but the statistical analysis does not by itself reveal the underlying root causes. It rather indicates where to look deeper into the problem. If, e.g., a correlation between two variables has been found, the Six-Sigma team still needs to be discussed, by using e.g. an Ishikawa diagram, what the possible underlying root causes may be, and how these could be avoided (Cronemyr, 2007). Hence, the rest of the analyze phase and the Improve phase are mostly qualitative, even though causation – not only correlation – should always be quantitatively verified before starting improvements. Finally,

the Control phase is mostly quantitative since the improved process is measured and monitored. In a literature review by (Cudney et al., 2020) found compare suggest success factors and find broad overlap, 34 articles were selected to evaluate continuous improvement methods such of Six-Sigma and lean approaches in higher education. Furthermore, these challenges include lack of awareness of lean and Six-Sigma methodologies, failure of institutions in identifying and targeting customers, inability to cope with process changes, lack of interest and commitment from the stakeholders, and difficulty in understanding the methodologies and adapting them to the educational context. Focusing on research by (Schroeder et al., 2008) as a way to achieve quality and satisfied customers, there are many definitions but the most widely used in the context of quality, one of them (The Council Six-Sigma, 2018) defines a process as a network of repetitive activities in time, the purpose of which is to creating value for external or internal customers.

Six Sigma concepts can be beneficial in ensuring that educational institutions run as efficiently as possible while reducing their detrimental effects on the environment and society in the context of higher education sustainability (Cudney et al., 2020). For instance, colleges can attain energy efficiency and improved waste management goals by identifying and reducing waste using Six Sigma in energy and resource management. Six Sigma can also raise the caliber of research and curricula by detecting flaws in the educational system, examining their root causes, and creating data-driven remedies to enhance learning efficacy and academic relevance to global issues (Davidson et al., 2020). Therefore, incorporating Six Sigma ideas into higher education not only aids in operational efficiency but also facilitates the more methodical and evidence-based attainment of sustainable development goals (Juliani & de Oliveira, 2020).

Furthermore, Six Sigma can be applied to raise the calibers of research and curriculum, emphasizing making learning more relevant to global sustainability concerns (Fleacă et al., 2018). In this instance, Six Sigma assists in identifying the shortcomings of the educational system, such as the low student involvement in environmental initiatives or the absence of curricular integration of sustainability subjects. Universities can introduce particular modules or courses that address issues like climate change, food security, and renewable energy, create new study programs that are more pertinent to global sustainability challenges, and make sure that every department has a clear sustainability orientation by using data-driven analysis (Sanches et al., 2023). This process also encourages students to participate directly in projects that aim to achieve sustainable development goals (SDGs) and enhance the quality of

learning through more interactive and experiential teaching techniques, such as partnerships with non-governmental organizations and industry for sustainable research (Avelar et al., 2023). Therefore, applying Six Sigma principles to higher education not only aids in operational efficiency but also advances more general sustainability objectives like lowering environmental impact, promoting social inclusion, and satisfying contemporary educational demands (Sharma A.K, et al., 2025). This data-driven strategy and thorough analysis produce long-term, more quantifiable and sustainable results, guaranteeing that the tactics are methodical and quantifiable (Gastelum-Acosta et al., 2024) .

2.4. Six Sigma and Lean Six Sigma (LSS)

Six Sigma is a quality management style that employs statistical and methodical tools to reduce variation in business operations (Zu et al., 2008). By bringing the production or service process's fault level down to almost zero, this idea seeks to boost efficiency (Moosa & Sajid, 2010). In order to enhance quality and customer happiness, this method often analyses issues and develops data-driven solutions using the DMAIC (Define, Measure, Analyze, enhance, Control) cycle. Lean Six Sigma, on the other hand, blends the ideas of Lean Manufacturing, which emphasizes cutting waste in business processes, with the concepts of Six Sigma (Jeyaraman & Kee Teo, 2010). In addition to lowering variability, Lean Six Sigma expedites the process by eliminating non-value-added tasks. Because it emphasizes speed, total operational efficiency, and quality, this methodology is more adaptable than Six Sigma (Sordan et al., 2022). Six Sigma and Lean Six Sigma can enhance budget management, stakeholder involvement, facilities optimization, and resource efficiency in higher education's sustainability context (Mehrabi, 2012). Lean Six Sigma eliminates ineffective practices, like complicated bureaucracy and ineffective communication flows, to enhance the performance of academic and administrative staff (Niñerola et al., 2021), while Six Sigma helps educators and education personnel improve their skills through data-based training to increase effectiveness and job satisfaction (García-Alcaraz et al., 2020). Lean Six Sigma emphasizes maximizing the use of space and resources by identifying waste, such as excessive energy consumption or underutilized classrooms (Anthony Jnr, 2021).

On the other hand, Six Sigma uses data analysis to increase facility maintenance efficiency, minimize operational interruptions, and prolong campus infrastructure life (Jeyaraman & Kee Teo, 2010). Financially speaking, Lean Six Sigma focuses on eliminating waste by reducing needless operational expenses, like excessive procurement or sluggish administrative

procedures (Ruben et al., 2018). Six Sigma can be applied to budget planning to find inefficiencies in the distribution of funds and ensure that each expense offers the institution the best possible return on investment (Chakraborty & Leyer, 2013). By reducing red tape and encouraging curriculum and learning technique innovation, Lean Six Sigma is more effective at increasing stakeholder engagement, including that of students, instructors, and industry partners (Adhi & Muslim, 2023). Conversely, Six Sigma helps institutional leaders make data-driven decisions to improve administrative and academic services (Lu et al., 2017).

This study employs both concepts, highlighting Six Sigma while also recognizing the significance of Lean Six Sigma. In the operations of higher education institutions, Lean Six Sigma continues to advocate for waste reduction and process acceleration. Six Sigma was chosen at the same time because of its systematic approach to improving efficacy, efficiency, and quality through data-based analysis.

2.5. DMAIC

Define, Measure, Analyze, Improve, and Control are the five primary steps of the DMAIC technique used in Six Sigma to increase a process's quality and efficiency (Srinivasan et al., 2016). This approach is frequently used in the business and industrial sectors to enhance system performance and decrease unpredictability. Six-Sigma is in essence a structured way of solving problems in an existing process based on analysis of real process data, i.e. facts (Jiju Antony et al., 2007). Motorola called the procedure MAIC, which at GE became DMAIC, for Define, Measure, Analyze, Improve and Control; for the phases of the Six-Sigma process (Fig. 2).

However, it may also be used in other fields, such as sustainability projects and higher education. DMAIC can be applied as a methodical way to enhance the efficiency of research, academic programs, and campus operations in promoting sustainable development in higher education, particularly in terms of sustainability (Qureshi, M.I., Janjua, S.Y., Zaman, 2014). Universities can identify obstacles to implementing sustainability, assess their effects, determine the root causes of issues, create creative solutions, and ensure that advancements are long-lasting by implementing the DMAIC cycle. For institutions to set quantifiable goals, including lowering campus energy usage or expanding the number of study programs that embrace sustainability principles, the primary issues surrounding sustainability in higher education must be precisely identified at the define stage (Biju & Nair, 2017). The measure

stage is then completed by gathering pertinent data to comprehend the existing situation, such as the amount of garbage generated, the annual energy usage, or the degree of environmental consciousness among students (Yelamarthi et al., 2025). Universities can utilize this data to move on to the Analyze stage, which aims to pinpoint the underlying reasons for issues that impede the adoption of sustainability, such as a lack of funds, inadequate infrastructure, or a lack of environmental consciousness among academics (Hamdan, Al-Ali et al., 2024).

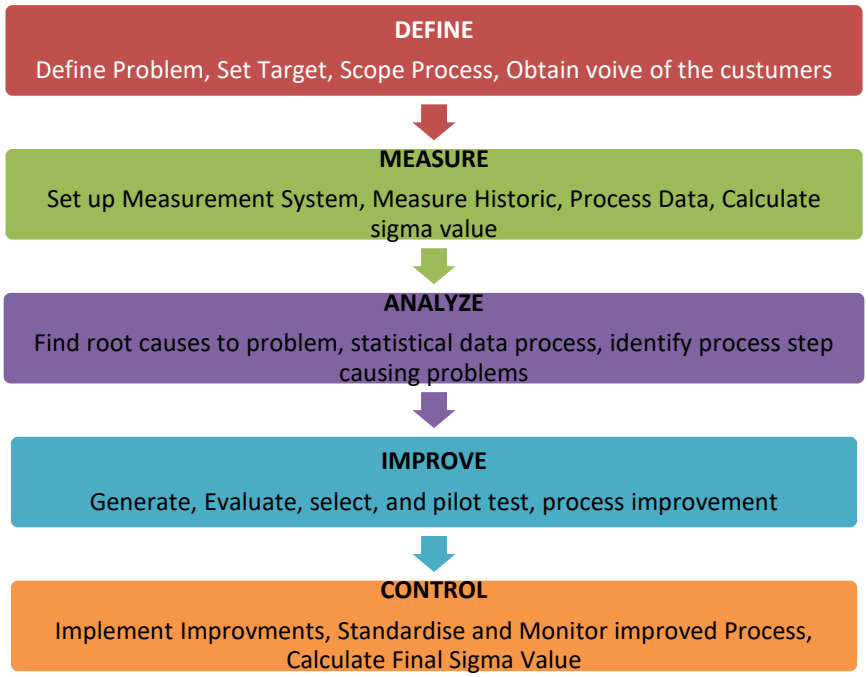


Figure 2: DMAIC

Sources: The five phases of DMAIC

Following the identification of the underlying problem, the Improve stage concentrates on creating and putting into practice workable remedies, including adding solar panels to increase energy efficiency, improving waste management regulations, or incorporating sustainability ideas into school curricula (Yu & Ueng, 2012). Universities can also train staff and students to understand sustainability better and form alliances with businesses and the government to encourage more sustainability-focused innovations. With a rigorous monitoring system, such as frequent energy audits, environmental awareness surveys, or assessments of sustainability-based curriculum, the last stage, Control, seeks to guarantee that the modifications made can be sustained over time (Thomas et al., 2017). In order to increase the effectiveness of the sustainability strategies that have been put in place and enable higher education to play a more prominent part in creating a more sustainable ecosystem, the DMAIC cycle can be reapplied if new challenges are discovered (Shanshan et al., 2022). By

using this strategy, universities can increase academic and operational effectiveness while fostering a more sustainable environment and turning out graduates who are highly conscious of social and environmental issues (Srinivasan et al., 2016). Furthermore, since many universities are now vying to adopt sustainability standards as part of their long-term plans, adopting DMAIC in higher education sustainability can also make colleges more competitive globally (Haerizadeh & Sunder, 2019). Universities may continue to evolve, bolster their role as change agents, and ensure that their sustainability policies have a meaningful impact on the environment and society by utilizing the DMAIC cycle of continuous improvement (Smętkowska & Mrugalska, 2018).

2.6. SIPOC

The Six Sigma technique uses the SIPOC idea as a visual aid to describe and analyze business processes methodically. Suppliers, Inputs, Processes, Outputs, and Customers are called SIPOC (Assis de Souza et al., 2023). By determining the connections between the components of a system, this tool offers a thorough understanding of a process. Processes can be mapped using SIPOC in a straightforward yet thorough manner, which helps stakeholders comprehend how a process operates and where possible enhancements can be made (Hasija et al., 2018). As a first tool for mapping and characterizing the processes that will be further examined inside the DMAIC framework, SIPOC is highly pertinent in Six Sigma and DMAIC, particularly in higher education. SIPOC aids in mapping the relationships between suppliers, inputs, processes, outputs, and customers in higher education, giving a thorough picture of how the different components of the educational system, from suppliers of instructional materials and human resources to institutional policies, interact and influence the result (Antony & Sunder M, 2020).

The low student involvement in sustainability programs or the curriculum's mismatch with industry developments and global sustainability needs are just two examples of the problems SIPOC assists higher education teams in precisely defining during the define stage of DMAIC (Peralta-Abarca et al., 2024). By doing this, SIPOC enables teams to pinpoint crucial process elements that require improvement and concentrate on areas that influence academic sustainability objectives, such as incorporating sustainability themes into different study plans. In the Measure phase, SIPOC helps the team collect data to evaluate the performance of the process, such as measuring the adoption of a sustainability-based curriculum, student

engagement in environmental projects, and faculty awareness of sustainability issues (Peralta-Abarca et al., 2024).

This data is essential to assess the institution's progress toward sustainability goals. In the Analyze phase, SIPOC helps identify the root causes of problems, such as educational gaps or weak collaboration among faculty in implementing sustainability curricula. In the Improve phase, the team designs data-driven solutions to improve the process, such as designing an interdisciplinary curriculum or increasing partnerships with the industry (Davidson et al., 2020). Finally, in the Control phase, SIPOC ensures that improvements can be sustained over the long term by monitoring metrics such as sustainability integration into the curriculum and sustainability program evaluation. With SIPOC, higher education institutions can ensure long-term sustainability across multiple education and campus management aspects (Li, N et al., 2019) .

The boundaries of a process are illustrated by the model in Figure 3, sometimes called SIPOC (Supplier, Input, Process, Output, and Customer). This shows the importance of the relationship with suppliers and customers, something that is not as obvious as traditional viewing organizational chart for organizations without defined processes.

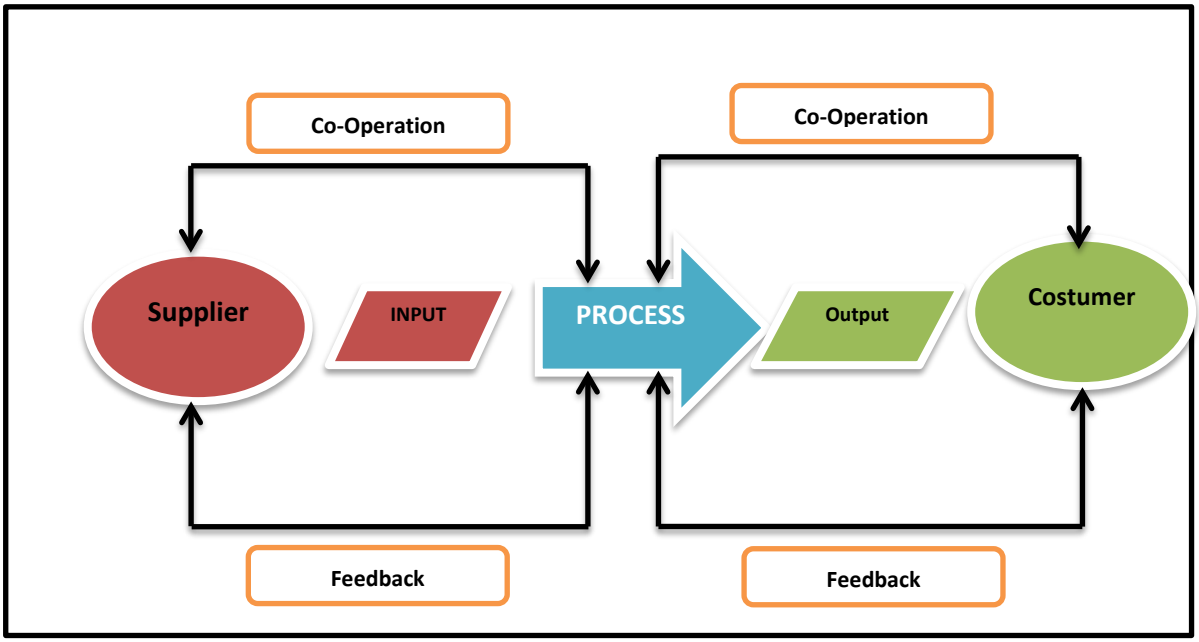


Figure 3: The SIPOC model

Sources: The SIPOC model (based on a model by Rentzhog (1998)

2.7. FISHBONE

The fishbone diagram is an invaluable tool in Six Sigma for thoroughly, methodically, and structured analyzing the root causes of issues (Coccia, 2018). This diagram enables the team to investigate possible causes that may impact the sustainability of the process under analysis within the framework of DMAIC. Fishbone diagrams, when used in conjunction with SIPOC, offer a clear and comprehensive image of the relationships between the components of the process that need to be changed. This aids the team in developing the best solution and managing the change to ensure its sustainability (Jayswal et al., 2011). In order to assess how well sustainability initiatives have been carried out, information about variables like stakeholder engagement in green policies, infrastructure facilities' ability to support sustainability, and human resource management in sustainability projects can be gathered and mapped using a Fishbone diagram during the measure stage (Maiya & Aithal, 2023). This diagram, for instance, can be used to determine whether the issue is a lack of funding for sustainability-related infrastructure or whether the current organizational culture is incompatible with the adjustments required to hasten the adoption of sustainability (Toha et al., 2020).

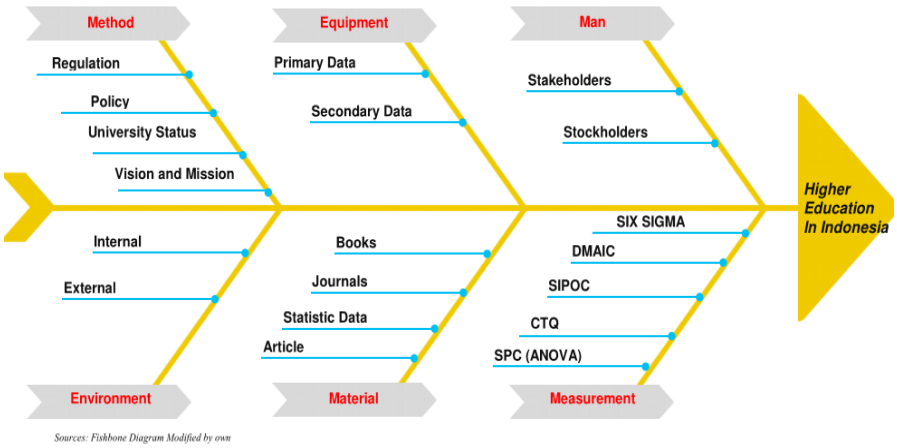
The Fishbone diagram aids the team in delving deeper into the underlying causes of new issues during the analyze stage (Shinde et al., 2018). Examples include leadership policies that fall short of meeting sustainability standards, a lack of funding for sustainability-related programs, or a lack of involvement from important stakeholders. The team can create data-driven solutions to increase the efficacy of sustainability implementation in the improvement stage thanks to the Fishbone diagram. The group could create policies that facilitate effective budget management for sustainability initiatives or methods to boost stakeholder participation in sustainability projects (Murphy et al., 2020). Here, the diagram assists the team in identifying areas that require improvement in the higher education process, such as enhancing an organizational culture that encourages green initiatives or increasing the number and caliber of sustainability-supporting infrastructure facilities.

The Fishbone graphic aids the team in making sure that advancements are long-lasting throughout the control phase (Doggett, 2005). Higher education institutions can ensure that improvements are long-lasting rather than one-time by identifying metrics to track the success of sustainability implementation, such as assessing the organization's sustainability-supporting culture or keeping an eye on stakeholder engagement. Therefore, the Fishbone

diagram offers a methodical, data-driven way to enhance performance and sustainability, guaranteeing that modifications are long-lasting and quantifiable when combined with Six Sigma, DMAIC, and Higher Education Sustainability. Institutions can also better control the sustainability processes put into place by employing SIPOC to map out the processes that require monitoring and the connections between the various components (Sarkar, S.A et al., 2013).

The initial analysis was conducted by conducting a Pre-Test. Analysis of the pre-test results in this study focuses on identifying the initial factors that contribute to the low sustainability of higher education in Indonesia. The pre-test was conducted to understand the baseline conditions of participants and higher education institutions before the implementation of the Six-Sigma approach. The data collected covered key aspects such as education financing, teaching quality, infrastructure, management efficiency, technology adoption and supporting policies. The results of this analysis provide a comprehensive picture of the main challenges faced and provide a basis for designing effective and sustainable improvement strategies. Fishbone diagrams, or Ishikawa diagrams, are used to map the root causes of problems based on the pre-test results. In this study, the fishbone diagram helped to visualize the relationships between the various factors affecting higher education sustainability (Fig.4).

The pre-test in this study aims to identify initial factors affecting the sustainability of higher education in Indonesia. Using the Six-Sigma approach, the pre-test was conducted to collect relevant data to understand the critical-to-quality issues hindering the sustainability of higher education, prior to more in-depth analysis using tools such as fishbone diagrams. The pre-test involved a range of respondents, including academics, students, administrative staff and higher education stakeholders, with instruments such as questionnaires, interviews or surveys designed to measure perceptions, barriers and challenges.



Sources: Fishbone Diagram Modified by own

Figure: 4 Fishbone Diagram

Sources: Authors 2025 Pre-test result (based on a model by Rentzhog (1998)

2.8. Six Sigma, Higher Education and Sustainability

At first, education and Six-Sigma may seem incompatible. Many fields of higher education have responded well to the presence of the Six-Sigma methodology. Several useful activities enable colleges and universities to educate students by benefiting from the application of Six-Sigma principles (Li, N. et al., 2019). How is Six-Sigma related to higher education? A successful college or university is one where students can focus on learning and lecturers, enriched by their own research so they can focus on teaching. As implied above, not every activity that takes place in universities is compatible with Six-Sigma principles, however higher education can benefit from following the Six-Sigma methodology carefully in defining, measuring, analyzing, improving and controlling (Davis & Fifolt, 2018). In principle Six-Sigma can reduce variation and increase efficiency in key areas such as: admissions and registration, applying learning technology, student recruitment, certification, building repairs and maintenance and procurement processes (Adina-Petruţa & Roxana, 2014).

Studies reveal three main reasons why higher education can implement Six-Sigma, and these are very important for higher education to a greater extent (Thomas et al., 2017) :
(1) The service process can be slow and, therefore, expensive, often causing errors and thus impacting customer satisfaction.
(2) Many service processes are complex and have too much work in progress, which lead to an increase in waiting time, which is a non-value added cost.
(3) The Pareto principle applies well to slow processes – 80 percent of delays are caused by 20 percent of activities. Hence, increasing that speed a critical 20 percent will lead to an 80 percent reduction in cycle time.

One of the keys to the success of Six-Sigma is teamwork as well as tools used can give strength to the business process improvement and learning effort. Quality Function Deployment (QFD) is a process systematic way to motivate a business to focus more on customer. QFD is used to identify and solve problems involved in providing products, processes, services and strategies that will satisfy customers. It is a process to understand desire customers and the importance of the benefits to be obtained. Tools that can be used in the Design for Six-Sigma (DMADV) process are as follows (Francisco et al., 2020): cause

and effect diagram, control chart, check sheet, histogram, pareto diagram, scatter diagram, flowchart. Other studies investigated by Ameen Abdulla & Kavilal (2022) in India which is identifying of Higher Education Quality Improvement by using Six-Sigma Approach findings that Six-Sigma has two main methodologies namely DMAIC and DFSS. DMAIC is the methodology (Define, Measure, Analyze, Improve, and Control) is applied to the existing system, while DFSS (Design for Six-Sigma) is to ensure the quality of new products. Various statistical and non-statistical tools were used in this study.

The DMAIC methodology is very commonly used in Lean Six-Sigma initiatives (Hasija et al., 2018). DMAIC is implemented in projects that aim to improve product and process quality, in processes that are currently running (but not yet effective). While DFSS or DMADV is more widely used when designing (or redesigning) a product or process that is not yet running (Purushothaman & Ahmad, 2022). The success of the implementation of Six-Sigma is highly dependent on several things, which are a challenge in its application in higher education institutions in Indonesia. This is a program that must be knocked down from above, guided by a vision (which is shared by top leaders) and a high level of commitment. The challenge of environmental sustainability in higher education institutions, seen from a Six-Sigma perspective, focuses on reducing variability, improving efficiency, and ensuring processes on campus produce minimal environmental impact (Sabtu & Matore, 2024).

Six-Sigma as a quality management method offers a systematic framework to identify, analyze, and reduce waste and inefficiencies that affect sustainability. Many universities in Indonesia still face challenges in waste management, including organic, inorganic and hazardous waste from laboratories. These wastes are often poorly segregated, not recycled, or disposed of in ways that damage the environment. Six-Sigma approach can be used to identify sources of waste in waste management and develop data-driven solutions to reduce the volume of waste generated. The DMAIC (Define, Measure, Analyze, Improve, Control) method can be applied to analyze waste collection and processing processes, with the aim of improving efficiency and lowering environmental impact (Hamdan, Al-Ali, et al., 2024). The next challenge in the environmental field is climate change, which is also a problem in almost all parts of the world. Climate change presents major challenges to university infrastructure, such as the risk of flooding, increased temperatures, and changing weather patterns that affect academic facilities and processes (Nguyen et al., 2025).

Six-Sigma approaches help universities map environmental risks associated with climate change and design data-driven mitigation measures. For example, through DMAIC-based risk analysis, universities can identify infrastructure that is most vulnerable to climate change and plan more sustainable improvements, such as the construction of more energy-efficient buildings or the utilization of technology to deal with extreme weather conditions (Pongboonchai-Empl et al., 2023). In addition, Six-Sigma can identify efficiencies in resource use to help universities adjust to the impacts of climate change. Some universities in Indonesia have tried to implement sustainability programs such as the Green Campus program, but often these programs do not run consistently or integrate well into the daily operations of the universities. Six-Sigma approach is expected to be able to assist universities in ensuring the sustainability of environmental programs through a rigorous quality control approach to identify the causes of programs ineffectiveness and provide measurable solutions to ensure sustainability implementation goes well. With measurable data, universities can better analyze environmental impacts and plan more effective mitigation measures (Clemons & Jance, 2024). Moreover, universities leader can monitor environmental performance on a regular basis and follow up on the analysis results to improve or enhance sustainability strategies.

From a social sustainability perspective, one of the biggest challenges is the gap in access to higher education, particularly between urban and rural areas (Wolff & Ehrström, 2020). Many students in remote areas struggle to access quality higher education due to geographical, economic and infrastructure issues. This leads to widening social inequality. Higher education in Indonesia needs to be more inclusive, especially for marginalized groups such as people with disabilities, indigenous people and other minority groups (Sonhaji et al., 2024). While there are laws that support inclusivity, implementation is often limited, leaving many students from these groups without adequate services. Another important issue is that many higher education institutions in Indonesia have not fully adapted their curricula to evolving social needs, such as environmental issues, gender equality, mental health, and technological change. This leaves graduates sometimes unprepared for complex social realities, as rigid bureaucracy in universities often slows down social innovation and collaborative initiatives between campuses and communities (Kumari et al., 2020). Low flexibility in responding to social change leaves universities behind in their role as agents of social change (Valle & Covarrubias, 2024). Social challenges in higher education are closely related to how universities provide equitable access and opportunities for all levels of society

and contribute to social welfare. In the Indonesian context, higher education is faced with various societal challenges, including access gaps, unequal quality of education, and the institution's contribution to the local community and society at large. The Six-Sigma concept can help universities to analyze data related to the participation of students from different socio-economic and geographical backgrounds. Six-Sigma uses the DMAIC (Define, Measure, Analyze, Improve, and Control) approach to identify factors that limit access, such as tuition fees, poorly targeted scholarships, or lack of facilities in remote areas (Sonhaji et al., 2024). After identifying the root causes, universities can implement more inclusive policies, such as expanding scholarships for low-income groups (Lukman, 2024). With the Six-Sigma approach, these challenges can be systematically identified, analyzed, and addressed through data-driven process improvement.

The economic aspect of sustainability relates to the university's ability to remain financially viable while providing quality and affordable education to the community. Many public universities rely heavily on government funding. When national education budget allocations are reduced, universities often struggle to finance their operations, including paying lecturers, maintaining facilities, and developing research and innovation (Mazumder, 2014). Lack of diversification of funding sources is a crucial problem. Universities in Indonesia, especially those outside Java, often lack the budget to conduct research and innovation. In fact, the sustainability of higher education also depends on its contribution to innovation and technology development that can address various global and local problems (Ho et al., 2006).

The ever-increasing cost of higher education can be a barrier for many prospective students, especially those from the lower middle class. Although the government offers various scholarships, the unequal education financing scheme is still a big challenge for inclusive education accessibility (Holmes et al., 2008). In the era of globalization, Indonesian universities must compete with international universities that have greater resources. Domestic universities face challenges in attracting international students, quality teaching staff, and funding international standard research. In addition, rapid technological changes require universities to constantly update their facilities and competencies, which require large investments. The sustainability challenges of higher education in Indonesia are complex and multidimensional. From an environmental perspective, universities must endeavor to reduce ecological impacts through efficient resource management and the implementation of green campus concepts. Socially, equitable access to education and curriculum relevance to social issues should be the main focus. Meanwhile, from an economic aspect, universities must find

solutions to ensure financial stability without burdening students and still provide quality education.

Successfully addressing these challenges requires a strong commitment from various stakeholders, including the government, universities, the private sector, and society at large. In addition, innovative approaches, such as the application of Six-Sigma methods, can help improve the efficiency and effectiveness of universities in managing these sustainability challenges (Cudney et al., 2020). The economic aspect of sustainability in higher education relates to the ability of universities to maintain financial viability while still offering quality, affordable and inclusive education for all. Indonesian universities face great challenges in managing operational costs, maintaining academic quality, and providing equitable access to education without overburdening students. The Six-Sigma approach, with a focus on improving efficiency and reducing variability, offers a data-driven solution to help universities manage these challenges effectively and sustainably.

Although not the only determining factor, educational philosophy is believed to be able to determine the direction of a nation's education; if the Indonesian people carry out education, then of course it is based on their educational philosophy (Shoeibi & Zahmatdoost, 2015). Many issues and programs, although designed to improve the quality of our higher education; so that as a nation we are not only large quantitatively but also qualitatively large, and do not sink further into the valley of backwardness (Pizzutilo & Venezia, 2021). These include: issues of management, financing, equity, work ethic, and learning motivation of participants, empowerment of lecturers, procurement of educational infrastructure and infrastructure, community participation in education, quality of teaching and learning process, quality of graduates, and so on need to be handled consistently and professionally (Sanches et al., 2023). The current state of higher education in Indonesia shows significant progress, both in terms of access and quality, but is also faced with various challenges, such as quality gaps between universities, curriculum relevance to industry, and limited funding management. To overcome these challenges, improvements are needed in collaboration between the government, universities, and the industrial world, as well as efforts to utilize technology and improve teaching quality continuously through a Six-Sigma approach (Tetteh, 2015).

In an effort to improve process quality and efficiency, various methodologies and analytical tools have been developed to assist organizations in identifying and addressing problems. In its application, the DMAIC (Define, Measure, Analyze, Improve, Control) methodology is an

important foundation for achieving continuous improvement (Li.N, et al., 2019). As part of the Analyze phase in DMAIC, tools such as SIPOC (Suppliers, Inputs, Process, Outputs, Customers) and Fishbone diagrams are very useful to explore the root causes of problems in more depth, in this case related to the problems of higher education in Indonesia. Fishbone diagrams, or cause-and-effect diagrams, are tools used to identify, analyze and structure factors that may influence a problem or undesirable outcome (Arp Jr, 2020). In the context of higher education in Indonesia, Fishbone diagrams can play an important role in analyzing the various problems faced by the country's higher education system. Fishbone diagrams help in identifying the various causes that may underlie the problems occurring in higher education, which often have complex and interrelated factors such as people, methods, machines, environmental materials and measurements (Shinde et al., 2018). Fishbone diagrams play an important role in analyzing problems in higher education in Indonesia by systematically identifying, classifying and arranging causal factors. By applying this tool, stakeholders in higher education can more easily find the root of the problem and formulate appropriate solutions to improve the quality and relevance of higher education in Indonesia. Figure 5 below is an illustration of the fishbone diagram to be used as a basis for solving problems in higher education in Indonesia and at the same time summarizes the Six-Sigma approach and its portfolio to be used in analyzing data. Fishbone diagrams and Six-Sigma have a close relationship in process improvement efforts (Sunder M & Mahalingam, 2018) . Fishbone diagrams serve as a tool to identify potential causes of problems, while Six-Sigma provides a data-driven approach to analyze and reduce variability in processes. These two tools, when used together, will make it faster and easier to achieve high quality and efficiency in organizations, especially in higher education institutions (Davidson et al., 2020; Haerizadeh & Sunder, 2019; Li.N, et al., 2019).

The management and development of human resources that can help accomplish sustainability goals are included in Six Sigma, sustainability, and higher education (Sunder M & Antony, 2018). Students, faculty, and administrative personnel are the primary players in implementing sustainability in higher education. Human resources must possess the necessary knowledge and abilities to assist in implementing green policies and sustainable initiatives to guarantee sustainability on campus. In order to improve student accomplishment and reach long-term objectives, HR based on the Six Sigma methodology can be beneficial (Antony & Sunder M, 2020). By maximizing HR's potential in higher education, environmental programs and policies can be implemented more efficiently, and staff and

students will be inspired to become leaders who can incorporate sustainability into their daily lives.

While managing infrastructural assets, universities must prioritize effective energy use, eco-friendly building materials, and proper water and waste management. The space layout must also facilitate the best possible learning environment for lecturers and students. Infrastructure facilities must also support deploying new technologies that can minimize waste and maximize the utilization of current resources (Ratvasky & Furterer, 2024). To meet sustainability targets, universities must establish specific objectives, such as reducing water or energy use. Institutions can assess the effectiveness of adopted sustainability programs by gathering and examining data on energy and water use, as well as the efficiency levels of other campus infrastructure (Chankseliani & McCowan, 2021). The group can investigate the reasons behind waste or inefficiency in facility management, such as structures that disregard sustainability principles or rules that do not encourage energy efficiency. Data-based solutions can then be used, for instance, by adopting more effective waste management procedures, developing campus buildings with a greener aesthetic, or putting energy-efficient technologies into place (Gastelum-Acosta et al., 2024). Institutions can guarantee that gains may be sustained over time by routinely assessing and monitoring water usage, energy, and other resources. Thus, achieving sustainability objectives in higher education is substantially aided by the practical and ecologically responsible management of infrastructural facilities. In addition to minimizing adverse environmental effects, well-managed facilities also lower operating expenses on campus, improve teacher and student comfort, and aid in developing a sustainable green campus (Kusumawanto & Setyowati, 2020).

Establishing campus rules that reflect sustainability principles or promoting faculty collaboration in environmental research are two examples of how higher education institutions can foster a culture that supports incorporating sustainability (Fatimah et al., 2025). Campuses should encourage everyone in the academic community to become more conscious of and adopt sustainable practices. This can involve setting up campaigns to promote eco-friendly lifestyles or offering training and workshops to broaden sustainability awareness (Muzayyinah Andriani et al., 2024). The current corporate culture needs to be assessed and changed to support sustainability objectives in order to accomplish this. For instance, it is crucial to identify limiting constraints, such as inadequate policies or a lack of acknowledgement for individual contributions to the effort, if the campus culture does not encourage student involvement in sustainability activities (Leal Filho et al., 2018). A stronger

culture can be achieved by data-driven solutions, such as creating programs that include students in sustainability initiatives or incorporating sustainability-related themes into events held on campus. Institutions can ensure that a culture supporting sustainability is maintained and grown by routinely tracking and assessing the cultural change process (Nugraha et al., 2023). Examples include surveys of faculty participation in sustainability initiatives or evaluations of policies that have been put into place. In addition to supporting the development of a campus focused on a greener, more sustainable future, an organizational culture that prioritizes sustainability will assist universities in bringing about long-lasting change at the academic and operational levels (Juliani & de Oliveira, 2020).

Research by de Freitas et al (2017) stated in higher education, leadership is critical in promoting university sustainability initiatives. The entire organization can be guided to make strategic decisions that support long-term sustainability goals by visionary leadership and a dedication to sustainability principles. Effective leaders in higher education must guide and lead the way in incorporating sustainability into all campus facets, whether in academic and extracurricular programming, curriculum design, or resource management (Serafini et al., 2022). University leaders must encourage and involve all academic community members in sustainability projects, including instructors, students, and support personnel. Strong leadership will guarantee that the campus's daily policies and practices match the sustainability vision, which is not merely a theoretical idea (Budihardjo et al., 2021). Additionally, leaders need to support the faculties and units in charge of formulating and executing sustainability programs and policies that result in improved environmental management and more economical use of resources.

However, managing changes and obstacles during the sustainability implementation is another aspect of effective leadership (Sunder M & Antony, 2018). Leaders need to recognize obstacles to implementing sustainability initiatives, whether caused by a lack of resources, a lack of understanding of the significance of sustainability, or disparities in stakeholder priorities (Žalėnienė & Pereira, 2021). Using a data-driven approach, leaders can create solutions that help achieve these objectives, like boosting openness in campus sustainability reporting and evaluation or incorporating more stakeholders in planning and decision-making. Leaders may make sure that sustainability programs and policies are still relevant and continue to expand by regularly evaluating their implementation (Cudney et al., 2020). For higher education institutions to keep moving toward a more sustainable vision, sustainability-focused leadership must also be prepared to modify its methods and plans in

response to the findings of these assessments. According to Juliani & de Oliveira (2020) a strong leadership may help campuses accomplish sustainability objectives more quickly and successfully while fostering a more creative, inclusive, and sustainable learning environment over time through Six Sigma approaches.

One of the most important aspects of attaining sustainability is managing financial resources and the budget (Adhi & Muslim, 2023). Higher education institutions with tight resources must make sure that the money they have available is used effectively and suitably to support sustainability activities, including waste management, carbon footprint reduction projects, and the creation of curricula focused on sustainability (Savelyeva & McKenna, 2011). An eco-friendly campus, less waste, and benefits for students, employees, and the community can be achieved with careful budgeting and resource allocation. In this instance, Six Sigma is critical in optimizing financial resources and budget management (Niñerola et al., 2021). By employing methodical data-based techniques, Six Sigma can assist in identifying and minimizing waste in budget management, whether it pertains to operating costs, energy expenditures, or costs associated with sustainability initiatives (Smętkowska & Mrugalska, 2018). For instance, universities can gather information about energy consumption, facility maintenance expenses, or costs for ongoing sustainability projects during the Measure stage of Six Sigma. This information can then be examined to find areas where savings can be achieved. This makes it possible for organizations to support sustainability more effectively and allocate resources more wisely (Hamdan, Al-Ali, et al., 2024).

Six Sigma assists in identifying the reasons for budget waste or inefficiencies in resource management, such as determining whether suboptimal practices exist in acquiring products and services or whether current resources are not being used to their full potential (Ruben et al., 2018). After identifying the reasons, Six Sigma can be used to create data-driven solutions in the Improve stage. Examples include deploying more economical technology, renegotiating service provider contracts for more affordable prices, or applying more economical management techniques. By practicing innovative financial management, universities can guarantee the smooth operation of sustainability programs without deficits or harmful waste (Sordan et al., 2022). All things considered, Six Sigma offers a data-driven method for effectively managing budgets, promoting sustainability, and guaranteeing that monetary resources are allocated to meet higher education's more comprehensive sustainability objectives (Qureshi, M.I., Janjua, S.Y., Zaman, 2014).

In order to achieve sustainability in higher education, stakeholder engagement is essential. Students, faculty, the government, business, and the community are just a few of the stakeholders essential to implementing and supporting campus sustainability efforts. These parties' active participation guarantees that the sustainability policies and initiatives put into place are pertinent, beneficial, and long-lasting (Findler et al., 2019). As a result, institutions of higher learning must establish strong channels of communication and cooperation among all parties involved. In the context of stakeholder engagement, Six Sigma's function is to assist in identifying and improving the current procedures for communication and interaction between institutions and stakeholders (Adhi & Muslim, 2023).

A summary of how healthy stakeholder involvement is proceeding in line with the intended objectives will be given by this data. Through the support of Six Sigma, teams can examine potential impediments to active stakeholder engagement, such as poor communication, a lack of knowledge of sustainability objectives, or a lack of platforms that promote participation (Haerizadeh & Sunder, 2019). Following the identification of the causes, Six Sigma assists in the design of data-driven remedies during the Improve stage (Elegbede et al., 2023). Examples include enhancing communication channels, providing rewards for proactive participation, or establishing cooperative programs involving students, staff, and the community on sustainability projects. Universities can monitor the efficacy and sustainability of these engagement procedures by employing the appropriate indicators, such as engagement surveys or stakeholder impact assessments of sustainability programs. In this sense, Six Sigma assists institutions of higher learning in creating more robust and long-lasting connections with stakeholders, guaranteeing that sustainability is attained through efficient, data-driven cooperation (Joghee & Varghese, 2024).

This study provides a brief explanation of the VOSviewer bibliometric analysis results, which are shown in Figure 5, in order to support the theoretical underpinnings of the connection between Six Sigma sustainability and higher education. The relationship between higher education, Six Sigma, and sustainability reflects a growing trend where universities apply industrial process improvement strategies to achieve environmental, economic, and social sustainability, according to the findings of a study that focused on business and economics research over the past 15 years and narrowed down to 985 keywords on the SCOPUS database, Web of Science, and Google Scholar. Of these, 38 met thresholds that placed higher education as the core topic, integration of Six Sigma in education, and how it correlates to long sustainability.

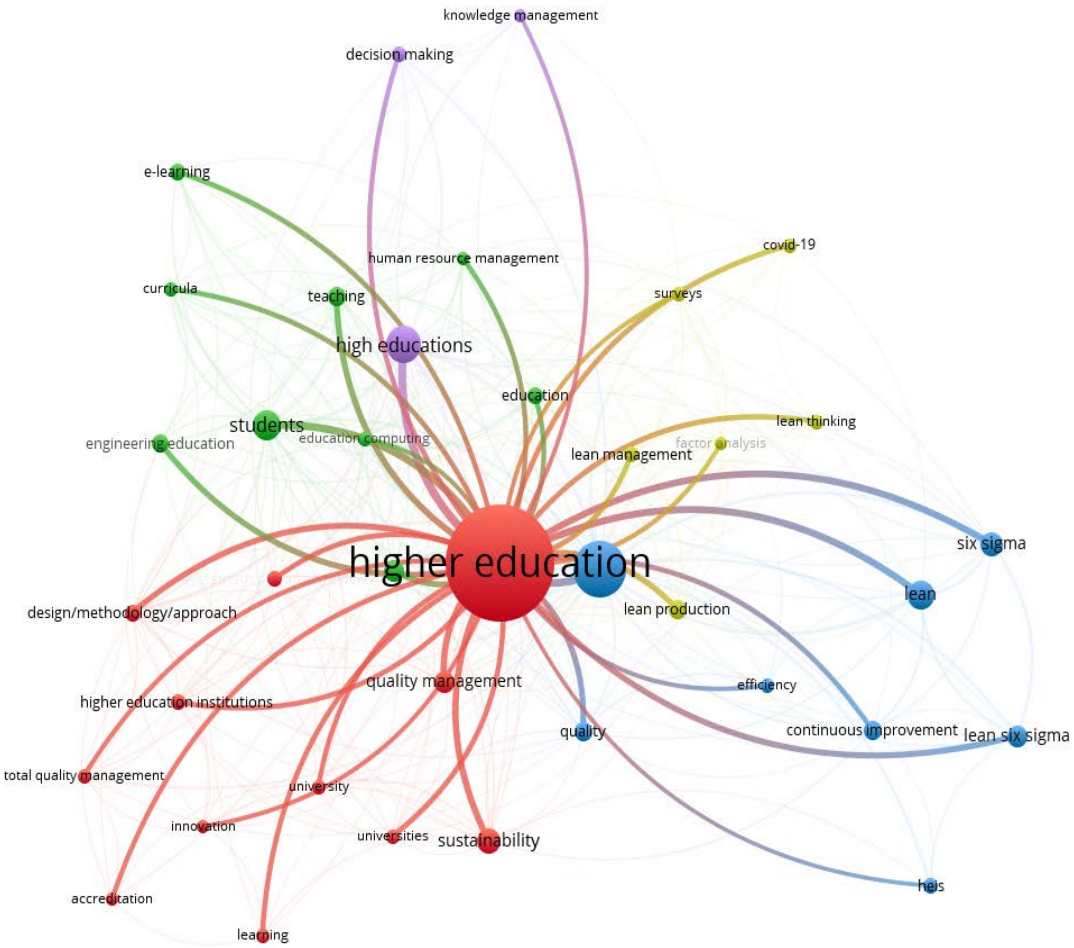


Figure: 5 Bibliometric results of Six Sigma, Higher Education and Sustainability

Sources: Authors VOSviewer result, 2025

2.9. Summary of Literature Review

The main point found in the literature review is to summarize the definition of higher education, Six-Sigma model executed with quantitative and qualitative approaches. One thing is necessary what needs to be underlined is the implementation of Six-Sigma in higher education used in this study. In conclusion, for to facilitate understanding, the authors present several previous studies so that there is no different perspective on the relationship between higher education and the Six-Sigma model. According to (Svensson et al., 2015) found that the implementation of the LSS methodology at King Abdullah University of Science and Technology has resulted in improvements in business processes and efficiency. This has been accomplished through project implementation and training programs. Similar studies validate the application of Six-Sigma in higher education. Furthermore, the results of the study highlight the practical challenges and benefits of implementing Six-Sigma in higher

education. In-depth empirical analysis of Six-Sigma toolkit applications change management by involving students as objects in Six-Sigma project management, the conclusion is Six-Sigma can be applied and can provide positive benefits for higher education (Sunder M & Mahalingam, 2018) and mention by (Antony et al., 2012) findings the challenges and obstacles faced by higher education can be solved with tools and techniques Six-Sigma and useful for processes improvement issues, critical success factors for the implementation and sustainability of higher education. Although Six-Sigma is widely used by manufacturing companies such as research conducted by (Joseph De Feo & Bar-El, 2002) findings implementation of Six-Sigma is more efficient in all its forms can increase productivity elsewhere significant ways, including career development for employees and responsibilities at work in manufacturing companies, but (Chroeder et al., 2008) The results of this study indicate that although the tools and techniques in Six-Sigma are very similar to the previous quality approach management, Six-Sigma helps the organization controls process improvement activities, while at the same time being able to create an enabling context exploration of problems between members of different organizations. Although Six-Sigma provides benefits over previous approaches to quality management, it also creates new challenges for researchers and practitioners. The summary of the literature review is presented in table 2.

Table 2: Summary of the Main Literature Review

No.	**Authors**	**Topic**	**Result**
1	Svensson, Carsten Antony, Jiju Ba-Essa, Mohamed Bakhsh, Majed Albliwi, Saja	A Lean Six-Sigma program in higher education	The implementation of LSS methodology at King Abdullah University of Science and Technology has resulted in improvements in business processes and efficiency. This has been achieved through project execution and training programs
2	Sunder M, Vijaya Mahalingam, Sanjay	An empirical investigation of implementing Lean Six-Sigma in Higher Education Institutions	The paper empirically validates the application of LSS in HEIs. Further, it highlights the practical challenges and benefits of LSS in the HEI setup. An in-depth empirical analysis of LSS toolkit application, LSS change management and using student teams in LSS project management are the highlights of this paper. The paper concludes that LSS is applicable and could provide positive benefits to HEIs
3	Antony, Jiju	Lean Six-Sigma for higher	The paper presents the challenges

	Krishan, Netasha Cullen, Donna Kumar, Maneesh	education institutions (HEIs): Challenges, barriers, success factors, tools/techniques	and barriers to be encountered during the introduction of LSS in the higher education sector, most useful tools and techniques for process improvement problems, success factors which are essential for the implementation and sustainability of LSS
4	Chroeder, Roger G. Linderman, Kevin Liedtke, Charles Choo, Adrian S.S	Six-Sigma: Definition and underlying theory	Research argues that although the tools and techniques in Six- Sigma are strikingly similar to prior approaches to quality management, it provides an organizational structure not previously seen. This emergent structure for quality management helps organizations more rigorously control process improvement activities, while at the same time creating a context that enables problem exploration between disparate organizational members
5	Adina-Petruţa, Pavel Roxana, Sârbu	Integrating Six-Sigma with Quality Management Systems for the Development and Continuous Improvement of Higher Education Institutions	A synergetic approach created by analyzing and simultaneously using the benefits of Six-Sigma and ISO 9000 plays an important role in the development and success of HE.
6	Ameen Abdulla, M. S. Kavilal, E. G.	Analytical Investigation of Higher Education Quality Improvement by Using Six-Sigma Approach	Identified that the factors that have a risk priority number (RPN) greater than 300 need improvement, such as versatility in program curriculum, laboratories and workshops, and credibility among universities. Six-Sigma can be achieved by developing proper strategies for mitigating

Sources: Base Own Works, 2025

3. MATERIAL AND METHOD

3.1. Research Design

The research approach plays a vital role in ensuring this dissertation is systematically structured, relevant, and effective in addressing the research questions and achieving its objectives (Reosekar & Pohekar, 2014). A mixed-methods approach, integrating both qualitative and quantitative methods, is employed in this study to provide a comprehensive understanding of the research problem. Specifically, the study adopts a sequential exploratory design, which begins with the collection and analysis of qualitative data to gain in-depth insights into the phenomenon (Haile, 2023). These insights are then expanded and generalized through the subsequent collection and analysis of quantitative data, ensuring a well-rounded and robust exploration of the topic. This approach is particularly suited for analyzing complex processes, identifying factors influencing the sustainability of higher education, and delivering evidence-based, measurable recommendations through the Six-Sigma framework (Ray, S & Das, 2010). It emphasizes practical solutions to sustainability challenges in higher education by leveraging data-driven insights, process evaluation, and actionable improvements. The mixed-methods strategy is designed to tackle the multifaceted nature of sustainability issues, encompassing interactions among management, operations, human resources, and environmental dimensions. This study employs a case study design centered on higher education institutions in Indonesia. This approach was selected to gain a comprehensive understanding of sustainability phenomena across diverse higher education contexts. The research design encompasses several key stages:

- Identifying critical issues related to sustainability.
- Analyzing data and measuring process quality.
- Applying the Six-Sigma methodology to drive continuous improvements.

The unit of analysis for this study is higher education institutions in Indonesia, emphasizing the following aspects:

- Operational processes in both academic and non-academic domains.
- Sustainability policies concerning resource management, financial practices, and environmental stewardship.
- Stakeholder perspectives, including faculty members, staff, and institutional leadership.

The qualitative approach in Six-Sigma research is crucial for exploring the non-quantifiable aspects of the issue being examined. Within the Six-Sigma framework, this method is employed to uncover in-depth insights, identify the root causes of problems, and design solutions tailored to specific contextual requirements (Krueger et al., 2014). This study employs a quantitative approach, emphasizing objective measurements and statistical, mathematical, or numerical analysis of data gathered through polls, questionnaires, and surveys, or by modifying pre-existing statistical data using computing tools. Quantitative research focuses on gathering numerical data and generalizing it across groups of people or to explain a particular phenomenon (Ameen Abdulla & Kavilal, 2022).

3.2. Qualitative Data Analysis

The goal of this study's qualitative data analysis was to have a thorough grasp of sustainability concerns at Indonesian colleges, especially as they relate to applying the Six Sigma methodology. According to Mezmir (2020) the procedure was carried out in a methodical manner, beginning with the gathering of qualitative data via in-depth interviews with important stakeholders, such as staff, management, students, and lecturers, to investigate their perspectives on operational effectiveness and sustainability. Document analyses of sustainability policies, annual reports, and operational documents were also carried out, along with field observations that offered firsthand insights into academic and non-academic processes and focus group discussions (FGD) to gather a variety of ideas and suggestions for improvement (Bulmer, 1979). Following data collection, data reduction was the next step in the analysis process.

Research by Uluskan (2016) stated this involved organizing, filtering, and classifying the raw data from observations, interviews, and documents in accordance with pertinent sustainability issues and the Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) phases. Key themes pertaining to sustainability issues, obstacles to the execution of policies, and opinions on operational efficiency in higher education were then identified in order to code the data. Patterns in the data were then found using thematic analysis, exposing significant problems disconnected between the creation of policies and their practical application, as well as the absence of stakeholder involvement in sustainability policy. By comparing insights from many sources, data triangulation was used to increase the validity of the findings and ensure a thorough and trustworthy examination of sustainability concerns in the context of Six-Sigma in Indonesian universities.

3.3. Quantitative Data Analysis

Quantitative analysis plays a crucial role in Six-Sigma research as it centers on evaluating and enhancing quality through objective data collection. The goal of Six-Sigma is to minimize variation in processes and achieve minimal error rates (Shokri, 2017). By leveraging quantitative analysis, the performance of processes can be accurately measured and tracked, forming the foundation for improvements driven by data. In Six-Sigma, quantitative analysis is used to assess data and pinpoint issues within processes, such as non-conformance in quality or inefficiency, helping identify areas for improvement in higher education in Indonesia.

By offering unbiased insights that support decision-making and process enhancements, quantitative data analysis is crucial to the Six-Sigma approach, especially within the DMAIC (Define, Measure, Analyze, Improve, and Control) framework (Muraliraj et al., 2018). In order to properly identify the main causes and make sure that troubleshooting efforts are focused and supported by evidence, statistical tools like regression analysis and hypothesis testing are used during the analyze phase (da Silva et al., 2018). Using quantitative data, the efficacy of suggested modifications may be methodically assessed during the Improve phase, enabling objective evaluation and predictive modeling of their possible effects on process performance. Additionally, continual monitoring through quantitative analysis guarantees that improvements are maintained over time throughout the control phase, which maintains continuous quality control. Every stage of the Six-Sigma process is measurable and successful in increasing operational efficiency thanks to this data-driven approach, which also reduces subjectivity and increases the dependability of decision-making (Patel & Patel, 2021).

This study employs Structural Equation Modeling (SEM) to examine variations in data from various sources, such as differences in output resulting from variations in inputs, processes, or other factors. By using multiple regression, Six-Sigma can determine if significant differences exist in the data that may influence process performance (Kumar et al., 2013). SEM enables the identification of factors or variables contributing to variations in the process (Ruben. et al., 2020). For instance, in higher education, SEM can be applied to assess whether factors like teaching methods, resources, or instructor experience levels significantly impact learning outcomes. In this way, SEM helps pinpoint the root causes of variation that need to be addressed to achieve more consistent results. Multiple regression provides a solid

statistical foundation for more precise decision-making (Bzik, 2004). In Six-Sigma research, particularly when analyzing data from experiments or case studies, multiple regression allows researchers to test hypotheses about factors influencing the process, ensuring that decisions are based on objective and measurable data (Joghee & Varghese, 2024). By comparing data variations before and after improvements, SEM helps ensure that the implemented changes lead to stable and sustainable performance.

Six-Sigma implementation supports process efficiency, variability reduction, and service quality improvement, which in turn can improve higher education sustainability through operational optimization and resource management. Along with that, the quality and competence of human resources (HR) play a key role in Six-Sigma implementation and sustainability achievement, which is achieved through consistent training, skill development, and motivation of both academic and non-academic staff. In addition, the educational infrastructure, which includes physical facilities, technology, and digital resources, serves as a key supporting element to streamline Six-Sigma implementation, which is directly orientated towards improving sustainability (Parmar & Desai, 2020).

Furthermore, an organizational culture that supports innovation, collaboration and continuous improvement accelerates the Six-Sigma implementation process, thus strengthening the sustainability of higher education. In this context, visionary, inclusive and strategic decision-based leadership is essential, as it can create a framework that is aligned with sustainability goals (Walter et al., 2023). Equally important, budget availability and efficient financial management are solid foundations to support Six-Sigma implementation and ensure the sustainability of higher education operations. Finally, the active involvement of stakeholders-including students, lecturers, industry, and the community-is an important element that supports Six-Sigma implementation and enhances the sustainability of higher education through collaboration and alignment of goals. As a result, in this study, the independent variables consist of Six-Sigma Implementation, Human Resources, Infrastructure Facilities, Organizational Culture, Leadership, Budget and Financial Resources, and Stakeholder Engagement. Meanwhile, the dependent variable that is the focus of the research is Sustainability of Higher Education.

To ensure valid and reliable interpretation in SEM models, several important tests need to be conducted, especially related to reliability and construct validity. Reliability measures the consistency of a construct's measurement, which in SEM is tested using Cronbach's Alpha. A

Cronbach's Alpha value ≥ 0.7 indicates good reliability, although a value of 0.6 is still acceptable for exploratory research (Christmann & Van Aelst, 2006; Taber, 2018). Meanwhile, validity measures the extent to which indicators represent the construct being measured, with an AVE value ≥ 0.5 indicating that more than 50% of the indicator variance is explained by the construct. To avoid multicollinearity issues, the Variance Inflation Factor (VIF) should be ≤ 5 (Bearman et al., 2012; Thompson et al., 2017). Finally, model fit indicates the extent to which the data fits the theoretical model. RMSEA values < 0.08 are considered good, and values < 0.05 are excellent (Palací-López et al., 2020).

The next stage is the improve stage, which aims to optimize the solutions offered will meet or exceed the improvement goals of the project. During the improve phase, the project team plans optimization process through the design of experiment (Cudney et al., 2020a) and finally Control is the last operational stage in a Six-Sigma quality improvement project. On this stage the results of quality improvement are documented, good procedures documented and used as standard work guidelines, as well as ownership or responsibility transferred to the owner or person in charge of the process (O'Reilly et al., 2019).

3.4. Diagram Analysis

Several analytical tools from Six-Sigma are applied to interpret qualitative data, including, Fishbone Diagram, SIPOC, and DMAIC.

3.5. Integration with Six-Sigma Framework

This research focuses on improving the sustainability of higher education in Indonesia utilizing the Six-Sigma framework as the main methodology to identify, analyze and resolve issues that affect operational efficiency and effectiveness. The Six-Sigma framework consists of five main stages (Define, Measure, Analyze, Improve, Control or DMAIC), which are integrated with data and the local context of higher education in Indonesia. The following is a description of the integration.

In this phase, Six-Sigma defines the improvement goals and the issues to be addressed in higher education in Indonesia. SIPOC is used to map the entire process. By utilizing SIPOC, the team can outline the connections between suppliers, inputs, processes, outputs, and customers, which help in understanding the current system and establishing the scope of the problem to be tackled (Salah et al., 2010). Once the problem is defined, the measure stage focuses on gathering data to assess the performance of the existing process. SIPOC proves

useful here to ensure all elements of the process—from suppliers and inputs to outputs and customers—are clearly identified. This allows the team to gather relevant data and assess the performance of each component within the higher education system. In the Analyze phase, the data collected is analyzed to pinpoint the root causes of the problem. SIPOC aids the team in examining the process flow and identifying where issues occur—whether in the inputs from suppliers or at specific stages of the process (Ameen Abdulla & Kavilal, 2022). This insight enables the team to analyze the factors influencing the sustainability of higher education. During the Improve stage, corrective actions are planned and executed to enhance the current process. SIPOC helps evaluate how changes to any element (such as inputs or processes) may impact outputs and stakeholders (Fleacă et al., 2018). The improvements should contribute to enhancing the quality and sustainability of higher education in Indonesia, with SIPOC providing a framework to ensure changes are made in a coordinated and comprehensive way. The final stage focuses on controlling and monitoring the process after improvements are implemented. SIPOC ensures that all process elements continue to function effectively and sustainably (Rodriguez et al., 2022).

By consistently monitoring suppliers, inputs, processes, outputs, and customers, the team can ensure the sustainability of improvements and maintain the quality of higher education. The combination of qualitative and quantitative methods within the Six-Sigma framework (DMAIC and SIPOC) provides a holistic approach to addressing higher education challenges in Indonesia. According to Chakrabarty & Kay Chuan (2009) qualitative methods, such as interviews and focus groups, help gain a deep understanding of the issues and perceptions within the education sector, while quantitative analysis offers objective measurements of process performance and highlights areas needing improvement (Shokri, 2017). Within Six-Sigma, the DMAIC (Define, Measure, Analyze, Improve, and Control) stages integrate these methods to uncover the root causes of problems, develop data-driven solutions, and track the successful implementation of improvements. SIPOC, as a tool for process mapping, plays a key role in ensuring that all aspects of the education process, from suppliers to customers, are considered in a comprehensive manner to ensure sustainable and effective improvements.

The research methodology of the Six-Sigma method is used. Starting from the define stage or determining the problems that will be used as the basis for improvement. Next measure, namely carry out the necessary measurements as the basis for proposed improvements to be carried out. Then analyze or analyze the measurement results and formulate steps repairs that need to be made and control or supervisory actions on the implementation of repairs which is

conducted. Six-Sigma originates from a set of practices designed to improve processes manufacturing and eliminating defects, but its application then extends to other types of business processes another. In Six-Sigma, a defect is defined as any process output that does not meet customer specifications or which could lead to non-compliant outputs customer specifications (Laux et al., 2017). The purpose of the define step in the DMAIC approach is to identify the determine of subject matter, research objectives, and scope of the process (Qureshi, M.I., Janjua, S.Y., Zaman, 2014).

The following is a SIPOC Diagram (Suppliers, Inputs, Process, Outputs, Customers) within the context of higher education sustainability in Indonesia, aimed at providing a clear understanding of the elements and variables considered in this study showed by Table 3.

Table 3: Latent Variables and Manifest Variables (Indicators)

Element/Acronym	Description	Sources
Six-Sigma Implementation (SS)	- DMAIC - KPI (Merdeka Belajar Program) - Quality Improvement - Data-Driven Decision Making	(Cudney et al., 2020), (Svensson et al., 2015)
Human Resources (HR)	- Resource Management - Curriculum Development - Training and Development	(Sunder M & Antony, 2018)
Infrastructure Facilities (IF)	- Information Technology and Systems - Security and Safety Systems - Advanced Laboratories & Equipment - Physical Infrastructure	(Davidson et al., 2020)
Organizational culture (OC)	- Relevant curriculum and teaching materials - Integrated sustainability programs on campus - Green Universities	(Ameen Abdulla & Kavilal, 2022)
Leadership (LD)	- Visionary Leadership - Transformational Leadership - Ethical Leadership	(Davis & Fifolt, 2018)
Budget and	- Financial Planning and Allocation	(Li et al., 2019)

Financial Resources (BF)	- Revenue Generation and Diversification - Financial Accountability and Transparency - Cost Efficiency and Resource Optimization	
Stakeholder Engagement (SE)	- Students and Alumni - Society - Government	(Haerizadeh & Sunder, 2019)
Sustainability of Higher Education (SHE)	- Environmental Sustainability - Economic Sustainability - Social Sustainability - IT and Data Management Systems	(Adina-Petruţa & Roxana, 2014)

Sources: Base own work, 2025

The SIPOC Diagram above provides a comprehensive overview of the elements involved in achieving sustainability in higher education in Indonesia. By understanding the relationships between suppliers, inputs, processes, outputs, and customers, educational institutions can plan and implement sustainability initiatives more effectively, thereby providing benefits to all stakeholders involved.

3.6. Survey and Collecting Data

The survey and data collection stage in this study is a crucial step in supporting the application of the Six-Sigma approach to enhance the sustainability of higher education in Indonesia. This process aims to gather relevant information regarding the factors that influence the performance and sustainability of higher education at leading universities in Indonesia.

3.6.1. Data Collection Objectives

Finding the main problems impeding long-term viability is essential to fully improving the sustainability of higher education in Indonesia, especially at the nation's best Universities. These difficulties could be caused by a number of things, such as ineffective use of resources, out-of-date courses, a lack of programs for faculty development, and weaknesses in institutional governance. Efforts to enhance the sustainability and quality of higher education run the risk of becoming dispersed and ineffectual if these obstacles are not well understood.

Building on this foundation, it is crucial to collect detailed information from the main players in the academic ecosystem, which include teachers and administrative personnel. The sustainability of higher education institutions is significantly shaped by their opinions about the standard of instruction, the accessibility of resources, the efficacy of educational policies, and other important factors. By taking into account their viewpoints, this study guarantees a comprehensive assessment of the difficulties universities encounter, enabling a more sophisticated comprehension of the elements impacting academic caliber, operational effectiveness, and institutional robustness.

3.6.2. Survey Methods

The survey's questionnaire will be carefully crafted to include a range of aspects pertinent to higher education sustainability. It will include key areas such as teaching quality, student satisfaction, technological integration, resource management, and institutional policies. For example, questions about the quality of instruction will evaluate how well teaching strategies work and how relevant the course materials are, making sure they meet industrial and academic requirements. Comparably, the effectiveness of administrative services and the sufficiency of university facilities, both of which are critical in determining the overall quality of the educational experience will be examined in order to assess student satisfaction. This study intends to provide a well-rounded analysis of the factors influencing the sustainability of higher education in Indonesia by integrating multiple data collection methods, including both online and face-to-face survey methods that will allow participation from a variety of university stakeholders, as well as in-depth interviews with key figures, including deans, faculty, students, and rectors, who will provide deeper insights into the opportunities and challenges associated with achieving sustainable higher education. These interviews will complement the quantitative survey findings with qualitative perspectives.

3.6.3. Sampling

This study involve 15 top universities in Indonesia with 588 respondents, which can be selected based on national university rankings or other relevant factors, such as the university’s contribution to research, innovation, and community development. This research uses a mixed-methods approach with the stratified random sampling technique for quantitative data collection and purposive sampling for qualitative data, This approach guarantees that each subgroup is represented proportionately from a quantitative standpoint, minimizes prejudice, and investigates sustainability challenges from a qualitative standpoint

as well as strategic viewpoints (Nguyen T. D et al., 2021). Respondents will be carefully chosen from a variety of groups within the academic ecosystem to guarantee an appropriate representation of each university. Lecturers from a range of academic programs and levels; undergraduate, graduate, and doctoral as well as full professors will participate in the survey. A thorough grasp of instructional quality, curricular relevance, and overall academic experiences across several disciplines is made possible by this wide inclusion. Faculty members with substantial teaching experience, both full-time and adjunct, will participate in the study in addition to lecturers. Their perspectives will be helpful in evaluating pedagogical efficacy, institutional difficulties, and the incorporation of cutting-edge teaching techniques. Through the collection of viewpoints from academics with different levels of involvement, this study guarantees a comprehensive assessment of sustainability in higher education (Chakrabarty & Kay Chuan, 2009). Administrative personnel who oversee everyday operations and university policies will also be included. Their involvement is essential to comprehending how policy execution, resource allocation, and institutional management support the general sustainability and effectiveness of higher education (Kumar et al., 2013). The study intends to offer a comprehensive and well-balanced examination of the major issues influencing higher education sustainability in Indonesia by integrating insights from these many stakeholder groups.

3.6.4. Types of Data Collected

Both qualitative and quantitative data will be used in the study to guarantee a thorough examination of sustainability in higher education. Focus groups and in-depth interviews with university employees and professors will be used to collect qualitative data. In order to gather perspectives, experiences, and opinions from stakeholders about academic quality, resource availability, and institutional policies, these talks will delve deeper into topics pertaining to the potential and difficulties of maintaining higher education. This strategy will give important insights into the practical difficulties of managing and developing higher education by interacting directly with important players (Six Sigma Project Selection Methodology, 2010). Conversely, standardized questionnaires intended to gauge important metrics pertaining to the sustainability and quality of education will be used to gather quantitative data. Numerical numbers or scores that represent satisfaction levels, institutional performance, and other quantifiable elements will make up this data. Satisfaction ratings, for instance, will give a general picture of the educational experience, and information on how often technology is used in the classroom will show how much digital integration there is in

the learning process. A crucial indicator for evaluating professional development initiatives will also be the quantity of training sessions offered to professors. This study guarantees a fair and fact-based assessment of the variables impacting the sustainability of Indonesian higher education institutions by integrating qualitative and quantitative methodologies.

3.6.5. Data Collection Instruments

A structured questionnaire will be used in the study to gather quantitative information suitable for statistical analysis. A variety of questions intended to gauge important facets of sustainable higher education, including student satisfaction, the efficiency of instructional methods, and the use of institutional resources, will be included in this survey. The questionnaire will use a Likert scale format 1 to 5, allowing respondents to indicate how much they agree or disagree with a variety of assertions, in order to guarantee consistency in responses and enable insightful comparisons (Jebb et al., 2021). This method makes it possible to gather unbiased, quantitative data that may be used to gauge performance, spot patterns, and assess the general caliber of universities. Key stakeholders, such as academics, administrators, and other pertinent university staff, will participate in semi-structured interviews in addition to the structured questionnaire. By capturing viewpoints that might not be fully represented in the quantitative data, these interviews will offer deeper insights into the potential and difficulties facing Indonesian higher education. This approach will enable a more nuanced understanding of institutional policies, resource limitations, and potential long-term sustainability initiatives by permitting open-ended debates. A thorough research methodology is ensured by the mix of structured surveys and in-depth interviews, which strike a balance between statistical rigor and qualitative depth to produce a well-rounded study of the higher education scene.

3.6.6. Data Analysis

Following the completion of the data collection procedure, a thorough analysis will be carried out utilizing both descriptive and inferential statistical techniques. The features of the data will be described using descriptive statistics, which will give a summary of important variables including academic achievement, satisfaction levels, and institutional efficiency. Structural Equation Modeling (SEM) using SMART PLS 4 will be used for inferential analysis, in order to investigate correlations further and test for significant differences between groups (Rosak-Szyrocka & Tiwari, 2023). This method makes it possible to comprehend the elements affecting perceptions and satisfaction in higher education

institutions on a deeper level. Transcripts of focus groups and interviews will be analyzed using NVivo 15 for qualitative data as suggest research by (Allsop et al., 2022). Thematic analysis will be made easier with the use of this program, which will help uncover underlying ideas, important themes, and patterns pertaining to the potential and difficulties of sustainability in higher education. In order to supplement the quantitative results gathered from structured questionnaires, NVivo 15 is used to ensure that qualitative findings are methodically categorized and evaluated. Additionally, the relationships between various elements of the higher education system will be examined through the use of SIPOC (Suppliers, Inputs, Process, Outputs, and Customers) process mapping. This approach will assist in discovering inefficiencies and potential improvement areas by visualizing these links.

3.6.7. Challenges in Data Collection

In conducting this study, the diversity of the universities involved must be taken into account, as each institution has unique characteristics that influence the sustainability of its higher education system. Factors such as institutional size, location, academic focus, and available resources can vary greatly across universities, and therefore, data collection methods need to be tailored to capture the specific context of each institution (Khoa et al., 2023). This ensures that the findings are reflective of the distinct challenges and opportunities faced by different universities, allowing for a more accurate and relevant analysis. Finding the current problems and inadequacies in Indonesia's higher education system depends heavily on the survey and data collection procedure. The application of Six-Sigma concepts will be based on this data, which will serve as a strong basis for creating data-driven, evidence-based solutions. The study will provide important insights that can direct strategic interventions meant to improve the sustainability and long-term profitability of higher education at the top 15 Indonesian universities by determining the underlying reasons of inefficiencies and difficulties.

3.6.8. Research Framework

The research framework serves as a structured guide that outlines the key concepts, relationships, and processes underlying the study. It provides a clear roadmap to connect the research objectives with theoretical foundations and methodologies, ensuring a systematic approach to addressing the research problem. In the context of the research titled ‘Improving Higher Education Sustainability in Indonesia: A Six-Sigma Approach’, the framework

integrates sustainability principles, higher education management, and Six-Sigma methodology to address critical challenges in achieving long-term sustainability.

The framework identifies core dimensions such as financial accessibility, quality of teaching and learning, adequacy of infrastructure, technology integration, resource management, and policy support, which collectively affect the sustainability of higher education institutions. Using the DMAIC (Define, Measure, Analyze, Improve, Control) process from Six-Sigma, the framework systematically examines current inefficiencies, analyses root causes using tools such as fishbone diagrams, and proposes data-driven strategies for improvement (Fig 6). The combination of theoretical insights and practical tools ensures that this study not only highlights existing challenges, but also offers actionable solutions to improve the sustainability and resilience of higher education in Indonesia.

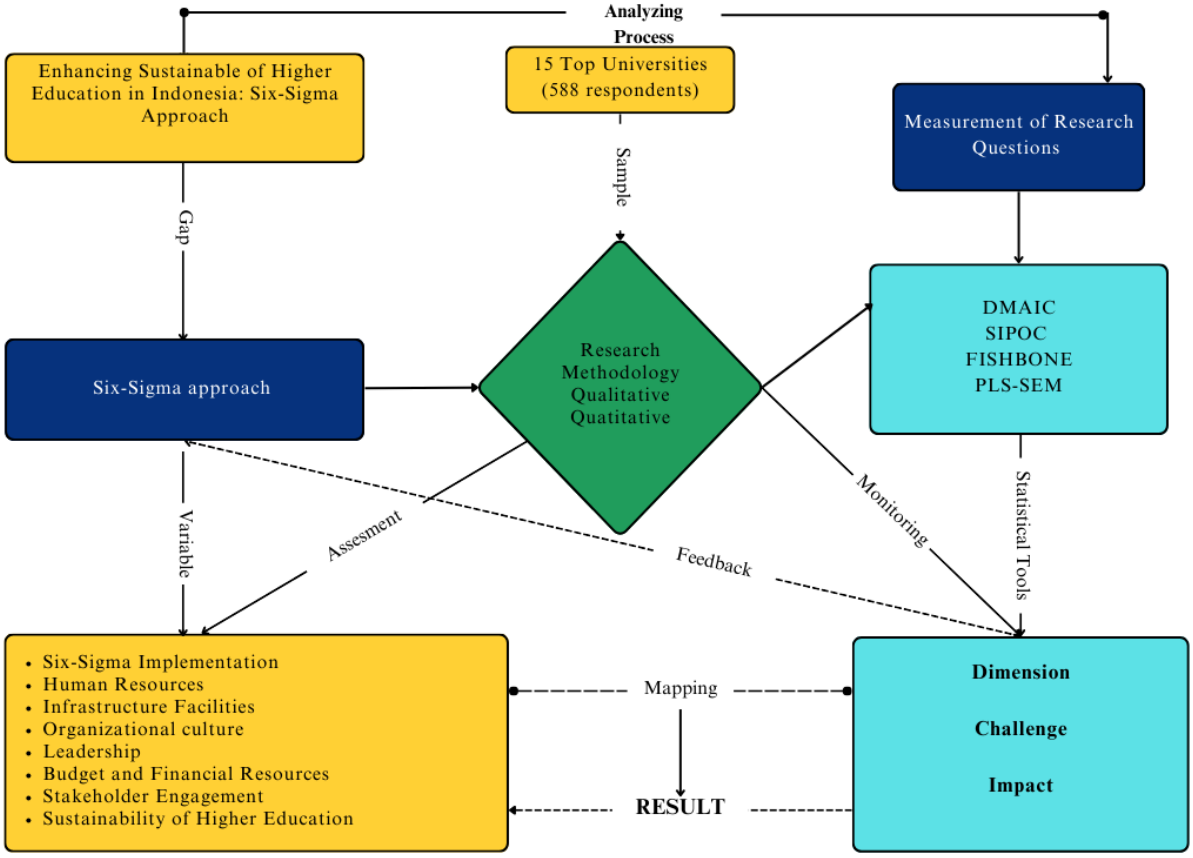


Figure 6: Research Framework

Sources: Based on own work, 2025

4. RESEARCH FINDING AND THEIR EVALUATION

4.1. Qualitative Analysis

This chapter presents the findings of a study examining the use of the Six-Sigma approach to enhance the sustainability of higher education in Indonesia. Using a qualitative methodology, data collected through in-depth interviews, observations, and document analysis offer a thorough understanding of the factors that impact the quality and sustainability of higher education. The study's findings aim to offer valuable insights and strategic recommendations for higher education institutions on how to apply Six-Sigma to boost operational efficiency and secure long-term sustainability in addressing global challenges. The data analysis was supported by the use of NVivo software, which facilitated the coding process and the organization of complex qualitative data. NVivo advanced capabilities allowed for the systematic identification of key themes and patterns across the data, providing a deeper understanding of the factors influencing sustainability in higher education. Through this software, the research efficiently processed large volumes of qualitative data, ensuring that the findings were both comprehensive and grounded in empirical evidence. To address the challenges faced by higher education in Indonesia, the study applied the DMAIC (Define, Measure, Analyze, Improve, and Control) methodology as a structured approach to identify and resolve key issues. In the define phase, the study clearly identified the primary challenges related to the sustainability of higher education, including resource management, quality assurance, and alignment with global standards. During the measure phase, data was gathered to quantify the extent of these challenges and their impact on institutional performance. The analyze phase involved a detailed examination of the data to identify root causes and patterns, while the improve phase generated targeted interventions, focusing on improving operational efficiency and student satisfaction. Finally, the control phase emphasized the implementation of mechanisms to sustain improvements over time, ensuring that higher education institutions in Indonesia can adapt to evolving global demands while maintaining long-term sustainability.

To effectively monitor and control these improvements, NVivo was utilized for continuous coding and categorization of data across the various phases of the Six-Sigma implementation. In this phase, the software allowed for the creation of coding structures that aligned with key variables critical to the success of higher education institutions, including Six-Sigma

implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, stakeholder engagement, and sustainability.

Through NVivo's coding functionality, the study identified recurring patterns and interrelationships among these variables. For instance, the analysis of human resources revealed the need for skilled staff and professional development programs to support Six-Sigma initiatives. The infrastructure facilities coding highlighted areas where investments in technology and campus facilities were essential for the long-term sustainability of educational programs.

The organizational culture code showed that fostering a culture of continuous improvement and adaptability was critical for sustaining Six-Sigma practices over time. Similarly, leadership was identified as a central element driving the successful implementation of Six-Sigma, with a focus on visionary and supportive leadership styles. Financial sustainability was another recurring theme, with coding related to budget and financial resources underscoring the necessity of effective budgeting and financial management to support long-term improvements. Lastly, stakeholder engagement codes emphasized the importance of involving faculty, students, government bodies, and industry partners in the ongoing efforts to ensure the sustainability of higher education institutions. By integrating these coded elements, the control phase ensured that the mechanisms to sustain improvements were data-driven and aligned with the broader strategic goals of enhancing the sustainability of higher education in Indonesia.

4.1.1. Data Coding

In the initial stage of coding, NVivo was used to conduct open coding, which identifies small segments of data that can provide insights into the variables under study. Each segment or piece of text relevant to the research elements, such as Six-Sigma implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, stakeholder engagement and sustainability of higher education. For this research, some relevant codes are:

- Six-Sigma implementation: codes relating to Six-Sigma practices, the use of Six-Sigma tools and methodologies in higher education institutions.
- Human resources: codes for data relating to HR skills, training and management in the context of Six-Sigma.

- Infrastructure facilities: codes related to physical and technological infrastructure that supports Six-Sigma implementation and educational sustainability.
- Organizational culture: codes that touch on aspects of organizational culture that support learning and continuous improvement.
- Leadership: codes that describe the role of leadership in supporting and driving Six-Sigma implementation.
- Budget and financial resources: codes that relate to budget allocation, fund management, and financial sustainability.
- Stakeholder engagement: codes that record interactions with various stakeholders such as the government, industry sector, and campus community.
- Sustainability of higher education: codes relating to factors that affect the long-term sustainability of higher education institutions.

Once the clustering of nodes is complete, the next step is to perform advanced coding by revisiting more specific data. In this case, NVivo allows researchers to create additional codes based on narrower or more detailed themes, according to the research objectives. For example, under the node 'Six-Sigma Implementation,' the researcher could add further codes, such as 'DMAIC Process' or 'Six-Sigma Training,' which refer to important elements of Six-Sigma implementation in higher education. These codes would then be interconnected to provide a more comprehensive picture of the factors that contribute to the success or failure of Six-Sigma in the context of higher education. Once all the data is coded, NVivo allows researchers to use various query features (e.g. text search query, word frequency query, or matrix coding query) to analyses the relationships between codes and explore patterns. With the text search query, researchers can search for terms or concepts that appear frequently in the text, for example searching for keywords such as 'sustainability' or 'quality.' Matrix coding query allows researchers to analyze the relationships between various nodes, for example, to identify how leadership relates to human resources and six-sigma implementation in supporting higher education sustainability.

In this study, qualitative data analysis was conducted to identify key themes related to the implementation of the Six-Sigma approach in supporting higher education sustainability in Indonesia. To simplify the analysis process and increase objectivity, the Auto Code Themes feature in NVivo was used to automatically recognize and classify themes that emerged from interview data, institutional documents, and open-ended surveys as shown in Table 4. Auto

Code Themes in NVivo is a feature used to automatically identify and organize key themes or patterns in qualitative data, such as interviews, open-ended surveys, or other texts (Jackson & Bazeley, 2019). It utilizes text-based analytics algorithms to find frequently occurring or relevant words or phrases, and then groups them into themes or categories that allow researchers to explore relevant key patterns, such as Six-Sigma implementation challenges, sustainability enablers, and innovations in the higher education system.

Table 4: Auto Code Themes Result Sustainability Higher Education in Indonesia

	Child Node													
Parents Node	A : energy consumption	B : external experts	C : failure modes	D : financial savings	E : Financial Support	F : insufficient knowledge	G : programs	H : reputation	J : research projects	K : DMAIC	M : stakeholder engagement	N : sustainability	O : training	P : waste production
Codes\\Budget and Financial Resources	11.79%	14.9%	11.9%	11.73%	20.49%	15.66%	18.48%	13.33 %	15.98%	15.26%	13.1%	17.93%	17.2 %	18.87%
Codes\\Human Resources	4.47%	0%	3.86%	3.98%	4.68%	0%	4.27%	12.73 %	5.22%	4.21%	0%	3.08%	4.84 %	3.11%
Codes\\Infrastructure Facilities	18.7%	17.79%	28.62%	17.04%	21.16%	24.56%	20.62%	12.73 %	16.3%	20.16%	20.42%	22.83%	20.9 7%	18.09%
Codes\\Leadership	10.98%	12.74%	4.18%	10.62%	5.35%	11.74%	9.95%	10.3%	9.97%	9.23%	10.21%	6.88%	9.68 %	8.95%
Codes\\Organizational culture	13.41%	14.18%	9.97%	13.72%	10.24%	11.74%	10.9%	12.73 %	13.45%	12.19%	13.29%	9.96%	10.7 5%	12.84%
Codes\\Six-Sigma Implementation	21.54%	21.88%	26.69%	23.01%	20.49%	20.64%	18.01%	20%	21.68%	19.7%	22.93%	21.56%	18.8 2%	22.18%
Codes\\Stakeholder Engagement	3.66%	0%	1.93%	2.65%	3.12%	0%	0.95%	5.45%	3.48%	1.82%	3.08%	3.08%	1.08 %	2.33%
Codes\\Sustainability of Higher Education	15.45%	18.51%	12.86%	17.26%	14.48%	15.66%	16.82%	12.73 %	13.92%	17.43%	16.96%	14.67%	16.6 7%	13.62%

Description
High
Medium
Low

Sources: Author Data Processing (NVivo) 2025

Notes: NVivo displays the frequency of data encoded in each theme or node. This can be interpreted as a 'level' that indicates the intensity or dominance of a particular theme in the dataset

Auto-coding in NVivo showed that high levels in each variable reflected factors that contributed significantly to the research objectives. In this case:

- Six-Sigma Implementation focuses on operational effectiveness and implementation challenges.
- Infrastructure Facilities underlines the importance of quality physical facilities and technology.
- Sustainability of Higher Education emphasizes the need for strategic cooperation and policy support.

Table 5 shows a breakdown of the contribution of Six-Sigma implementation, infrastructure facilities, and sustainability of higher education to various relevant factors such as energy consumption, external expert involvement, financial savings, and others. This analysis helps to understand how each variable supports or influences the factor.

Table 5: High Level Six-Sigma Implementation, Infrastructure Facilities, and Sustainability of Higher Education

Six-Sigma Implementation	Infrastructure Facilities	Sustainability of Higher Education
Six-Sigma, through methodologies such as DMAIC helps identify and reduce variability in processes, which impacts: -energy consumption: optimizing operational processes to reduce energy wastage. -external expert: involving external experts in training and implementation to ensure successful six-sigma implementation. -failure modes: identify and address failure modes in	Adequate infrastructure facilities, both physical and digital, support operational sustainability and efficiency, contributing to: -energy consumption: improving energy efficiency with green infrastructure, such as energy-efficient lighting and green technology. -reputation: quality infrastructure enhances the institution's image in the eyes of students and partners. -research projects: state-of-	Higher education sustainability involves a strategic approach to minimizing negative environmental impacts and increasing added value to society: -stakeholder engagement: inviting active participation from various parties, including students, government, and industry partners, to support sustainability initiatives. -sustainability: integrate sustainability principles in

operational processes. -financial savings: reduce wastage and operational costs through more efficient processes. -insufficient knowledge: address staff's lack of knowledge with intensive six-sigma-related training. -waste production: reduce waste by identifying unnecessary steps in the process.	the-art research facilities enable the implementation of innovative research projects. -programs: infrastructure supports the development of high-quality academic programs. -training: provides space and technology for staff and student training. -waste production: modern infrastructure integrates better waste management.	every aspect of operations, including policies, curriculum, and infrastructure. -financial support: attract funding from government or donors to support sustainability initiatives. -reputation: commitment to sustainability increases public trust in the institution. -DMAIC: using the DMAIC approach to design a more measurable and effective sustainability strategy.

Sources: Author 2025

These three variables have significant contributions to strategic factors in improving the operational sustainability of higher education institutions. Six-Sigma focuses on process efficiency; Infrastructure facilities supports program development and research, while sustainability of higher education ensures all aspects are oriented towards long-term sustainability. The three variables at the moderate level show significant progress but are not yet fully optimized, indicating that the institution is in a transitional phase. The strategic steps needed include strengthening the financial reporting system, intensive training for leaders, and a holistic change management approach to overcome cultural resistance including:

- Budget and Financial Resources faces challenges in implementing more efficient and transparent management.
- Leadership is evolving towards inclusive leadership, but still needs to strengthen communication and consistency.
- Organizational Culture is beginning to show adaptation to sustainability, but cultural change still requires time and commitment.

Table 6 outlines the contribution of Budget and Financial Resources, Leadership, and Organizational Culture to the various factors, reflecting their relationship and impact in the context of institutional sustainability in relevance to the coding analysis in Table 4.

Table 6: Medium Level of Budget and Financial Resources, Leadership, Organizational Culture

Budget and Financial Resources	Leadership	Organizational culture
Strategic financial management plays an important role in supporting the following initiatives: -Energy Consumption: Investments in energy-efficient technologies, such as LED lighting or power-saving devices, help reduce energy consumption. Budgeting for energy audits enables identification of areas of savings. -Financial Savings: managing budgets efficiently to reduce wastage of operational funds. Better allocation of resources to high-impact programs. -Financial Support: grant funding and external support often depend on clarity of budget utilization. Build partner trust with strong financial transparency. -Research Projects: provide sufficient funding to support innovative research, including research on sustainability and energy	Effective leadership provides direction, inspiration and consistency to sustainability efforts: -Stakeholder Engagement: Inclusive leaders are able to engage a wide range of parties, including staff, students, and external partners, to support sustainability projects. -Reputation: progressive leadership enhances the institution's reputation as an entity committed to sustainability and innovation. -Insufficient Knowledge: Proactive leaders encourage staff training and development to address lack of understanding. -DMAIC (Define, Measure, Analyze, Improve, Control): Leadership plays a critical role in ensuring the success of the DMAIC methodology to improve operational processes and efficiency. -Programs: leaders play a	A strong organizational culture facilitates acceptance and sustainability of new initiatives: -Sustainability: Establish a culture that upholds sustainability through internal policies, green practices, and employee education. -Waste Production: An environmentally conscious organizational culture encourages better waste management and reduced wastage. -Energy Consumption: Instilling energy-saving behaviors among staff and students, such as switching off electronic devices when not in use. -Training: A learning culture that supports continuous training ensures organizational readiness for change. -Failure Modes: a culture of openness enables

efficiency. -Training: allocation of funds for staff training, ensuring relevant skills for sustainability and operational efficiency.	role in designing and implementing sustainability programs that are relevant to the needs of the institution and the community.	identification and learning from failures, encouraging further innovation. -Stakeholder Engagement: a collaborative culture enhances internal and external stakeholder engagement.

Sources: Author 2025

These three variables contribute significantly to building efficient, sustainable and innovative higher education institutions. Budget and financial resources provide financial support, leadership provides strategic direction, and organizational culture creates an enabling environment for sustainability. Simultaneously drive energy efficiency, waste reduction, reputation enhancement, and innovative program development. After performing Auto Coding analysis in NVivo (table.7), the low levels observed in stakeholder engagement and human resources suggest that, although there are efforts and potential for improvement in these areas, their implementation remains limited, inconsistent, or insufficient. At low levels, these two variables indicate the need to make significant changes in terms of stakeholder engagement and human resource management to improve the efficiency and sustainability of the institution which can be summarized as follows:

- Stakeholder Engagement: engagement with stakeholders remains limited and unstructured, with limited opportunities for collaboration or two-way communication. Sustainability and enhancement of communication systems and collaborative forums are needed to improve stakeholder engagement.
- Human Resources: human resources management shows a lack of attention to staff development and skills management on an ongoing basis. Efforts to improve training, employee development and more strategic recruitment should be prioritized.

A description of the contribution of Stakeholder Engagement and Human Resources to various factors related to sustainability and efficiency in a higher education institution can be seen in table 7.

Table 7: Low level of Stakeholder Engagement and Human Resources

Stakeholder Engagement	Human Resources
Engaging external stakeholders such as industry or government partners can help identify more efficient energy solutions, as well as provide resources or new technologies to reduce energy consumption. -External Experts: engaging with external experts through consultation or collaboration can provide valuable insights into best practices in sustainability, energy efficiency and other resource management. -Failure Modes: involving stakeholders in evaluations or audits can help identify potential failures in existing systems or processes, as well as provide suggestions for improvements. -Financial Savings: greater stakeholder involvement, both from the private and public sectors, can open up funding or investment opportunities in programs that lead to long-term cost savings, such as sustainability initiatives. -Financial Support: external stakeholders involved in the project can provide financial support, either in the form of grants or funding that can accelerate the implementation of sustainability programs. -Insufficient Knowledge: stakeholder engagement can help address knowledge deficiencies through information sharing and joint training between the organization and	Well-managed human resources will directly contribute to improved operational efficiency and sustainability management in the following factors: -Energy Consumption: through training and staff development, Human Resources can help prepare employees to implement energy-efficient practices in daily operations. -External Experts: human resources play an important role in selecting, recruiting and retaining external experts who can provide technical consultancy related to sustainability and energy efficiency. -Failure Modes: by strengthening HR capacity through training and experience, organizations can reduce operational failures related to the implementation of sustainability programs. -Financial Savings: good HR management contributes to cost efficiency through proper staffing and optimization of their roles, as well as reducing costs caused by turnover or labor shortages. -Financial Support: qualified human resources can play a role in sourcing and managing external funding, such as grants, needed to support sustainability projects. -Insufficient Knowledge: human resources have an important role in designing and implementing training programs that ensure

external partners. -Programs: involving stakeholders in the development and implementation of sustainability programs can result in more relevant and impactful initiatives. -Reputation: by increasing stakeholder engagement, an institution can enhance its reputation as an organization that is transparent and committed to sustainability. -Research Projects: external stakeholders can play a role in funding or supporting research projects related to sustainability, energy efficiency, and innovation in resource management. -DMAIC: stakeholder engagement, particularly through the application of DMAIC (Define, Measure, Analyze, Improve, Control), can accelerate improvement cycles in resource management and operations, taking into account diverse external perspectives. -Stakeholder Engagement: active engagement enables the establishment of strong communication channels, which in turn increases transparency and the effectiveness of collaboration in achieving sustainability goals. -Sustainability: stakeholders, both internal and external, play a role in identifying and supporting sustainability initiatives that can be widely implemented. -Training: through broader engagement, stakeholders can contribute to the	that staff has sufficient knowledge to support sustainability initiatives. -Programs: HR plays a role in designing and implementing development programs that support the institution's sustainability goals, such as sustainability-based training or up skilling staff in waste management. -Reputation: organizations with good HR management tend to have a better reputation, as skilled and actively engaged staff will demonstrate a commitment to quality and sustainability. -Research Projects: HR plays a role in supporting the development of sustainability-related research projects by ensuring the availability of competent and trained staff to engage in such research. -DMAIC: HR can support the implementation of the DMAIC methodology by developing a team skilled in analyzing and improving processes, and providing ongoing training to ensure the method is applied effectively. -Stakeholder Engagement: HR can also facilitate more active engagement with external stakeholders through structured communication and collaboration programs. -Sustainability: HR trained in sustainability principles can help accelerate the adoption and implementation of sustainability initiatives across the organization. -Training: Human Resources plays a key role in designing and delivering training programs

development of training materials and provide resources for staff education on sustainability issues. -Waste Production: stakeholder involvement in waste planning and management can introduce new technologies or more efficient methods to reduce waste production.	that support the development of skills required to support sustainability and energy efficiency. -Waste Production: through training and staff development, HR can educate staff on waste reduction practices, as well as implement more efficient waste management policies.

Sources: Based on own work, 2025

Stakeholder engagement facilitates collaboration, fosters external financial support, and bolsters the execution of sustainability initiatives by actively involving a diverse range of relevant stakeholders. Meanwhile, human resources (HD) is crucial in building internal capacity to advance sustainability efforts, enhance energy efficiency, optimize waste management, and improve knowledge management within the organization. Together, these two variables play a pivotal role in cultivating a more efficient, sustainable, and innovative environment, while also reinforcing the engagement of both staff and stakeholders in achieving the organization's objectives.

After the coding process was carried out using NVivo, the next step was to conduct thematic analysis to dig deeper into the findings obtained from the organized data. This thematic analysis aims to identify the main patterns that emerge from the codes that have been generated, as well as to explore the relationship between variables related to improving sustainability in Indonesian higher education through the Six-Sigma approach. This approach is expected to provide a more comprehensive insight into the factors that influence sustainability and how Six-Sigma implementation can accelerate the achievement of sustainability goals.

4.1.2. Thematic Analysis

Thematic Analysis (TA) is a qualitative analysis method used to identify, analyze and report patterns (themes) in data. This technique is often used in social research to provide deep insights into the experiences, views, or phenomena being studied (Nowell et al., 2017) . This study employs the Six-Sigma approach to enhance the sustainability of higher education in Indonesia. Utilizing data coding conducted through NVivo software, the subsequent thematic analysis seeks to identify and examine the predominant patterns and themes associated with the application of Six-Sigma in the context of higher education sustainability.

The analysis reveals a variety of critical factors influencing sustainability, encompassing Six-Sigma implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, and stakeholder engagement. Based on the thematic analysis of the key variables, the main themes that explain the contribution of each variable to the sustainability of higher education are described in Table 8.

Table 8: Thematic Analysis sustainability of Higher Education in Indonesia

Themes	Statement	Score based on coding
Six-Sigma implementation as the basis for operational sustainability in Indonesia	Six-Sigma Implementation is at the core of the approach used in this study. The DMAIC (Define, Measure, Analyze, Improve, Control) methodology contributes to: • Identification of Key Issues: the College used Six-Sigma to determine critical areas that needed improvement, such as waste management, energy efficiency, and effectiveness of educational programs. • Fact-based Data Collection and Analysis: Through measuring operational performance, Six-Sigma helps institutions to understand weak points in their processes and develop more efficient solutions. • Continuous Improvement: Six-Sigma promotes sustainability through better resource management, reduction of wastage, and improved service quality.	High
Human resources as the main driver of sustainability	Human resources play a central role in successful Six-Sigma implementation. The thematic analysis revealed several important contributions: • Internal Capacity Building: staff training in Six-Sigma methodology enabled the	Low

	development of technical and managerial skills relevant for sustainability. • Commitment to Sustainability: staff that are empowered and involved in decision-making processes shows higher levels of commitment to the institution's goals. • Knowledge Management: knowledge management and sharing through training and hands-on experience are keys in creating a culture of sustainability in the institution.	
Infrastructure facilities to support physical sustainability	Infrastructure is a vital element in supporting higher education sustainability programs. Some of the key aspects found include: • Energy Efficiency and Green Technology: the use of green technologies, such as LED lighting and renewable energy sources, contributes to the reduction of energy consumption. • Facility Management: optimization of campus space, waste management, and implementation of technology-based facilities help create a more sustainable environment. • Support for Educational Innovation: adequate infrastructure supports academic activities such as sustainability-orientated research and learning.	High
Organizational culture as a pillar of sustainability	An organizational culture that supports sustainability is a key success factor for the programs. Thematic analysis identified: • Adaptation of Sustainability Culture: Institutions that start to integrate sustainability in organizational values show progress in sustainability practices.	Medium

	• Resistance to Change: a rigid culture remains a challenge, with some internal parties not fully understanding the urgency of sustainability. • Collaboration and Inclusiveness: an inclusive organizational culture increases staff and student engagement in sustainability initiatives.	
Leadership as a catalyst of change	Strong leadership fuelled the success of sustainability initiatives. Themes found include: • Strategic Vision: leaders with a clear sustainability vision can steer institutions towards achieving long-term targets. • Effective Communication: leadership that is able to effectively communicate sustainability goals helps create awareness and commitment at all levels of the organization. • Staff Empowerment: leaders who empower staff through training, rewards and active engagement increase program effectiveness.	Medium
Budget and financial resources as the foundation of sustainability	Sustainability cannot be achieved without adequate budget support. Thematic analysis shows that: • Budget Transparency: transparent budget management increases trust and accountability in the use of funds. • Diversification of Funding Sources: colleges that rely on multiple funding sources, such as government grants, industry partnerships and alumni funds, tend to be more financially stable. • Funding Limitations: despite their importance, many institutions face challenges in allocating budget for sustainability initiatives, given other pressing priorities.	Medium
Stakeholder	Stakeholder engagement, both internal and external, is	

engagement as a determinant of success	an important element in higher education sustainability. The thematic analysis shows: • Multi-stakeholder collaboration: partnerships with government, industry and non-governmental organizations strengthen institutions' capacity to implement sustainability programs. • Role of Students and Lecturers: active participation from students and lecturers in research, community service, and sustainable campus activities creates significant positive impacts. • Local Community Involvement: the development of programs that involve the surrounding community increases social acceptance of sustainability initiatives.	Low

Sources: Author 2025

Through a comprehensive and in-depth thematic analysis, this study demonstrates that the sustainability of higher education in Indonesia can be significantly enhanced through the implementation of the Six-Sigma approach. This methodology serves not only as a systematic framework for identifying and resolving institutional challenges but also as a strategic tool for improving operational efficiency and fostering innovation within higher education settings. Within this framework, the analyzed variables are interdependent and play a critical role in cultivating an academic environment that prioritizes efficiency, innovation, and long-term sustainability.

Despite these promising findings, the research identifies several critical barriers that must be addressed to achieve optimal sustainability outcomes. These challenges include organizational resistance to cultural change, limited financial and human resources, and insufficient collective awareness among stakeholders regarding the importance of sustainability. Such constraints pose significant obstacles that can hinder the comprehensive implementation of sustainability initiatives.

Nevertheless, the study offers strategic pathways to mitigate these challenges. It emphasizes the importance of strengthening collaboration among various stakeholders, both internal and external, including government agencies, the industrial sector, and local communities. Visionary leadership emerges as a pivotal factor, providing the guidance necessary for institutions to adapt to changing dynamics and proactively integrate sustainability into their core missions and strategic objectives. Furthermore, the research underscores the necessity of implementing more focused and transparent resource management strategies to ensure the effective allocation and utilization of financial and material resources in support of sustainability efforts.

Finally, this research contributes significantly to the discourse on sustainable higher education by presenting a practical and contextually relevant framework tailored to the unique challenges faced by institutions in developing countries like Indonesia. By leveraging the Six-Sigma approach, the study provides valuable insights into how higher education institutions can establish environments that are not only efficient and innovative but also inclusive and sustainable. These advancements are pivotal in driving progress toward achieving both national and global educational sustainability goals. After conducting thematic analysis, this study presents a word cloud visualization generated through NVivo providing an in-depth visual depiction of the most frequently occurring keywords in the data shown by Figure 7. These words reflect the main themes related to the research variables, such as Six-Sigma implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, and stakeholder engagement. This word cloud helps identify conceptual relationships between these variables and highlights the most dominant aspects in discussions related to the sustainability of higher education. Thus, this visualization serves as a supporting tool to further understand relevant thematic patterns and provide additional perspectives on the results of the analysis.

Figure 7: World Cloud Sustainability Higher Education in Indonesia

Sources: Author Data Processing (NVivo) 2025

The resulting word cloud displays keywords such as:

- Sustainability which highlights the importance of sustainability as a primary focus in higher education management.
- Human resources, leadership, stakeholder engagement, resistance and lack knowledge emphasizes the importance of the role of human resources, leadership, and collaboration in sustainability.
- Finance: Underlines the importance of adequate financial support and facilities to achieve sustainability goals.
- Leadership often appears side by side with stakeholder engagement and human resources, reflecting the close relationship between leadership, collaboration, and human resource management in realizing sustainability goals.

This word cloud not only helps identify key themes but also provides additional insights into the priorities of higher education institutions in Indonesia. Some important things that can be concluded are:

- Dominance of operational and strategic themes which is focus on technical aspects such as infrastructure and Six-Sigma efficiency through DMAIC, as well as

strategic aspects such as leadership and collaboration. The interrelationships between variables such as organizational culture, human resources, and budget indicate the need for a holistic approach in achieving sustainability.

- Provides guidance for higher education institutions, policy makers, and researchers to understand the most relevant aspects of sustainability.

Some recommendations that can be taken based on this visualization

- Strengthening visionary leadership: focus on developing leadership that is able to integrate sustainability into the institution's vision.
- Resource optimization: allocate budget and human resources to support sustainability initiatives.
- Multi-Party collaboration: increase stakeholder engagement to strengthen sustainability programs.

The Sustainability in higher education in Indonesia word cloud provides a rich visual representation of thematic information. This visualization helps identify key words and relationships between themes, providing a new perspective to understand sustainability in higher education. By utilizing insights from the word cloud, institutions can focus more on designing holistic and effective sustainability strategies.

After completing the qualitative analysis through the coding process and thematic analysis using NVivo, the next step is to complement these findings with quantitative analysis. This quantitative approach aims to test the relationships between variables that have been identified in the thematic analysis, strengthen the validity of the findings, and provide deeper and more measurable insights into the patterns that emerge. The combination of these two approaches is expected to produce a more comprehensive understanding of the phenomenon being studied, while supporting stronger and more data-based conclusions.

4.2. Quantitative Analysis

4.2.1. Descriptive Statistic

Descriptive analysis is crucial in research because it guarantees that the data used is legitimate, interpretable, and prepared for additional testing by the study's goals. Researchers can identify patterns, trends, and potential anomalies that could impact the study's findings by using descriptive analysis to obtain a comprehensive picture of the distribution and variation of the data. This study aids in determining whether the data satisfies fundamental

presumptions for more intricate inferential studies, such as homogeneity of variance or normality of distribution, by using *the SPSS 28* version. Furthermore, descriptive analyses give the reader the background information they need to comprehend the relationships between the study's variables, facilitate their comprehension of the sample's characteristics, and offer a strong foundation for understanding the study's findings.

Based on 588 respondents with no missing data, this table displays descriptive statistics for seven variables: gender, age, job title, academic degree, university status, university origin, and significance (table 9). The mean and median values indicate the data trend; for example, according to the scale used, most respondents fall into the third age group and have code 1 for gender. Compared to other variables, University Origin has the highest standard deviation (4.63359), indicating higher volatility in this variable. A relatively symmetrical distribution is shown by skewness values primarily close to zero, except University Status (0.967), which tends to the right. In addition, almost all variables have negative kurtosis values, indicating that the data distribution is flatter than a normal distribution. The variable University Origin (1-15), which represents the variation of respondents' university origin, is one example of how the range of data fluctuates. Before additional studies were conducted, these data provided a preliminary picture of the sample characteristics.

Table 9: Frequency Table

		Gender	Age	Position	Academic Title	University Status	University Origin	Department
N	Valid	588	588	588	588	588	588	588
	Missing	0	0	0	0	0	0	0
Mean		1.398	2.641	3.170	1.918	1.561	8.494	3.139
Median		1.000	3.000	3.000	2.000	1.000	9.000	3.000
Std. Deviation		0.489	1.273	2.148	0.789	0.826	4.633	1.589
Skewness		0.418	0.303	0.244	0.146	0.967	-0.237	0.575
Std. Error of Skewness		0.101	0.101	0.101	0.101	0.101	0.101	0.101
Kurtosis		-1.83	-0.921	-1.654	-1.382	-0.839	-1.359	-0.282
Minimum		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Maximum		2.00	5.00	6.00	3.00	3.00	15.00	7.00

Sources: SPSS Author Processing, 2025

The gender distribution of study participants is displayed in Table 10. 355 (60.4%) of the 588 responders were men, and 233 (39.6%) were women. When both categories are included, the cumulative percentage indicates that the total is 100%, confirming the absence of any missing

data. According to the findings, men comprised the bulk of research participants, as confirmed by Table 10.

Table 10: Gender Frequency

		Frequency	%	Valid Percent	Cumulative Percent
Valid	**Female**	233	39.6	39.6	39.6
	Male	355	60.4	60.4	100.0
	Total	588	100.0	100.0	

Sources: SPSS Author Processing, 2025

With a total of 588 individuals, Figure 8 displays the population distribution by major. Engineering is the most popular major, with 149 respondents (25.3%), followed by health (139 respondents, 23.6%) and social sciences (110 respondents, 18.7%). Meanwhile, with just 23 respondents (3.9%), fine Arts are the major with the fewest respondents. More than half of the population comes from the first three majors, as indicated by the cumulative percentage, which displays the total accumulation of each category. After social sciences, the figure rises to 59.7%. This data gives an overview of the distribution of individuals within an institution across majors.

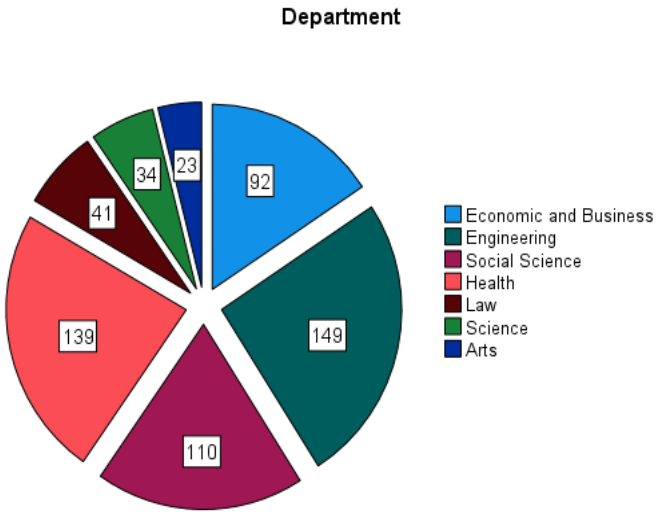


Figure 8: Department Frequency

Sources: SPSS Author Processing, 2025

The distribution of the 588 individuals by job title is displayed in this data. The largest group consists of the Head of the Institute (250, 42.5%), Admissions (173; 29.4%), and Vice Deans (101; 17.2%). Rector was the role with the fewest employees (8, or 1.4%). Although the data

includes a wide range of jobs inside the institution, the cumulative proportion indicates that 79.4% of persons are in the leading four positions (Table 11).

Table 11: Position Frequency

		Frequency	%	Valid Percent	Cumulative Percent
Valid	**Admission**	173	29.4	29.4	29.4
	Dean	36	6.1	6.1	35.5
	Head of Institute	250	42.5	42.5	78.1
	Rector	8	1.4	1.4	79.4
	Vice Dean	101	17.2	17.2	96.6
	Vice-Rector	20	3.4	3.4	100.0
	Total	588	100.0	100.0	

Sources: SPSS Authors Processing, 2025

The distribution of the 588 individuals by academic rank is displayed in Table 12. The largest group comprises assistant professor (214, 36.4%) and lectors (207, 35.2%). Professors had the fewest (72, 12.2%), while associate professor had the most (95, 16.2%). According to the cumulative proportion, 87.8% of individuals fall into the top three academic categories, with professors making up the remaining portion.

Table 12: Academic Rank

		Frequency	%	Valid Percent	Cumulative Percent
Valid	**Assistant Professor**	214	36.4	36.4	36.4
	Associate Professor	95	16.2	16.2	52.6
	Lectors	207	35.2	35.2	87.8
	Professor	72	12.2	12.2	100.0
	Total	588	100.0	100.0	

Sources: SPSS Authors Processing, 2025

This histogram displays the age distribution in a data set with 588 samples. The standard deviation (Std. Dev.) is 1.273 and the mean age is 2.64. Age group category 3 has the most prominent frequency (158 people), according to the data, followed by age groups 2 (142 people) and 1 (139 people). In contrast, there were fewer individuals in age groups 4 and 5, with 89 and 60, respectively. As seen in Figure 9, this graph indicates that most people are between the ages of one and three.

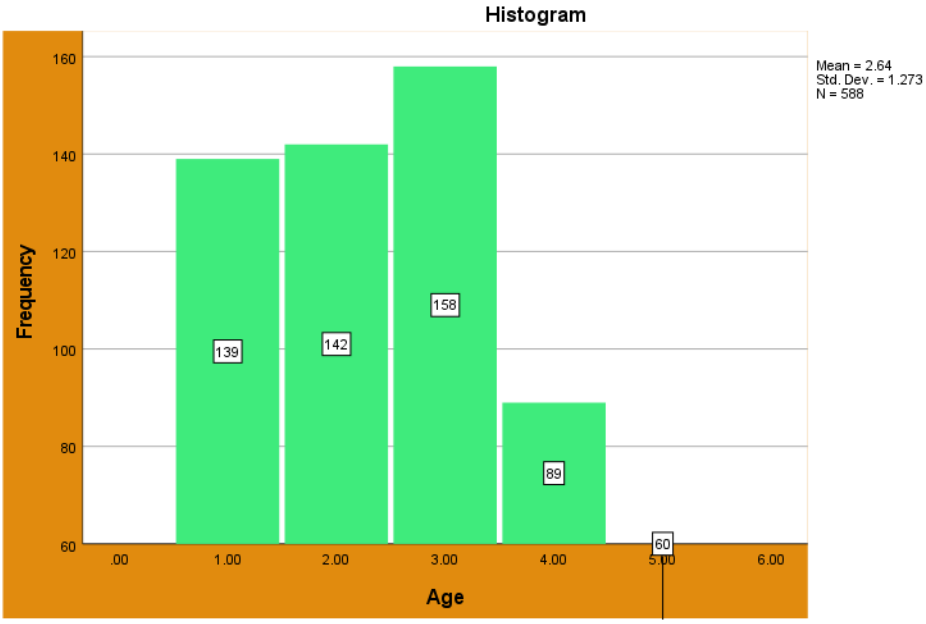


Figure 9: Age Histogram Frequency

Sources: SPSS Author Processing, 2025

According to Figure 10, this graph show Universitas Indonesia (UI) has the second-highest percentage (11.39%) after BINUS University (13.95%), indicating that these two universities have the most representatives in the dataset. North Sumatra University (USU) has a 9.35% rate, Hasanuddin University (UNHAS) has a 7.14% percentage, and Padjadjaran University (UNPAD) has an 8.16% proportion. Other universities with a sizable number of delegates include UGM (6.63%), IPB (6.63%), and ITB (5.78%). Conversely, Telkom University has the lowest rate (3.06%) among these universities. This graph's interpretation could point to some options. One is that compared to other universities, those with more significant percentages, like BINUS and UI, might have more alums interested in or qualified for particular programs or jobs. The number of students enrolled in those universities may also be reflected in it. This distribution can also determine the degree of representation of several universities within a field or institution.

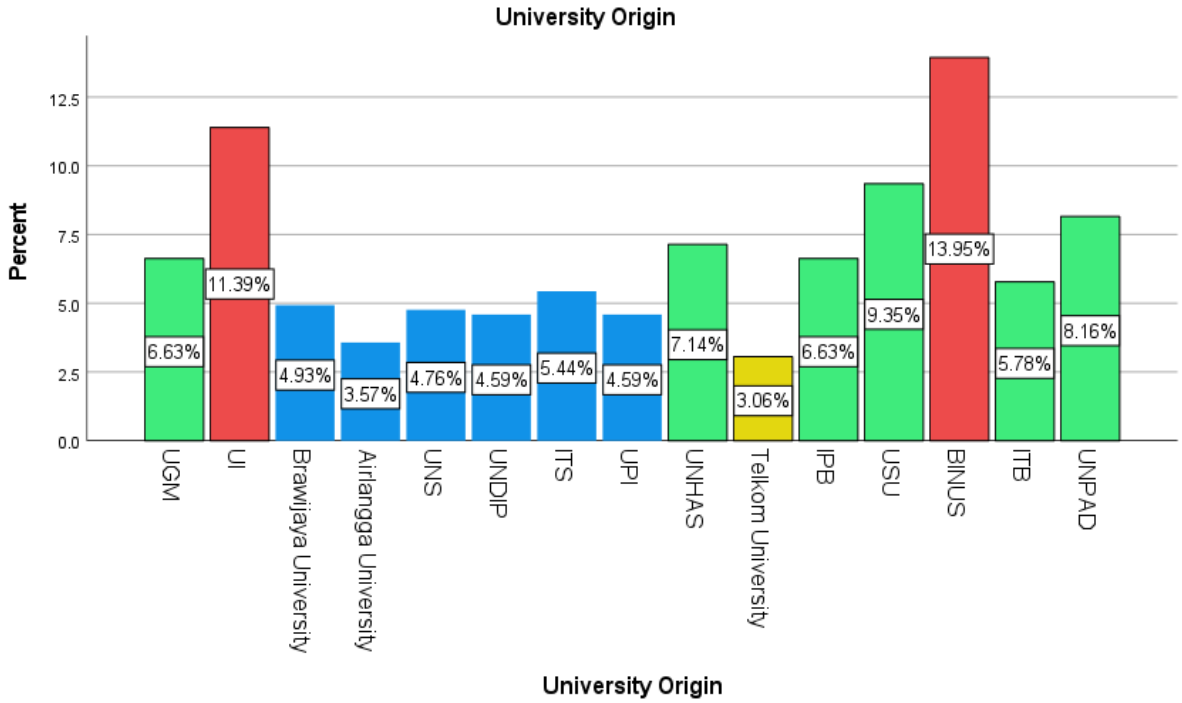


Figure 10: University Frequency

Sources: SPSS Author Processing, 2025

The distribution of 588 individuals by university status is displayed in Table 13. With 386 individuals (65.6%), PTN-BH (State University with Legal Entity) has the most, followed by PTN-Satker (128 individuals, 21.8%) and PTN-BLU (74 individuals, 12.6%). While the total includes all current university statuses, the cumulative percentage indicates that 78.2% of people fall into the first two categories.

Table 13: University Status Frequency

		Frequency	%	Valid Percent	Cumulative Percent
Valid	**PTN-BH**	386	65.6	65.6	65.6
	PTN-BLU	74	12.6	12.6	78.2
	PTN-Satker	128	21.8	21.8	100.0
	Total	588	100.0	100.0	

Sources: SPSS Author Processing, 2025

4.2.2. Validity and Reliability Test

Quantitative methods were used in this study to examine the influence of key variables on the sustainability of higher education in Indonesia using the Six-Sigma approach. The variables

analyzed include Six-Sigma implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, and stakeholder engagement which have been tested through a qualitative approach. This research uses Structural Equation Modeling (SEM) processed with the help of Smart PLS software to identify causal relationships and direct and indirect effects between variables. This approach allows researchers to comprehensively evaluate the contribution of each variable to the achievement of higher education sustainability in Indonesia.

The latent variable testing stage begins with an evaluation of the measurement model (outer model), which includes construct validity and reliability. Validity is tested through convergent validity, by assessing the loading factor value of each indicator (≥ 0.7) and the Average Variance Extracted (AVE) value (≥ 0.5) (Barcia et al., 2022). Meanwhile, reliability is tested through Composite Reliability (CR) and Cronbach's Alpha, both of which must have a value ≥ 0.7 (Hair, 2018). After the measurement model met the validity and reliability criteria, the research continued with the evaluation of the structural model (inner model). At this stage, the relationship between latent variables is analyzed to test the research hypothesis. The analysis was carried out by looking at the path coefficient value, t-statistics, and p-value obtained through bootstrapping with 588 samples. The R-squared (R^2) value is used to measure the ability of the model to explain the variability of the dependent variable, while the Q-squared (Q^2) assesses the predictive ability of the model. The results of this analysis provide an in-depth picture of the strength and direction of the relationship between latent variables as well as the contribution of each variable to the sustainability of higher education. Thus, this approach ensures that the recommendations are well-grounded and data-driven.

In this study, validity and reliability tests were conducted to ensure that the instruments used were able to measure variables accurately and consistently. The variables analyzed include Six-Sigma Implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, stakeholder engagement, and sustainability of higher education. Validity testing was conducted to assess the extent to which the indicators on each latent variable were able to represent the concept being measured. This includes convergent validity, which is seen from the loading factor value and Average Variance Extracted (AVE), and discriminant validity, which ensures that the latent variable is unique compared to other variables. Meanwhile, reliability is tested to evaluate the internal consistency of the instrument using Composite Reliability (CR) and Cronbach's Alpha, where the value considered eligible is above 0.7. The testing process was conducted using the

Structural Equation Modeling (SEM) approach with SMART PLS 4 software, which enables efficient and data-driven evaluation of latent variables.

Validity and reliability testing in this study play an important role in ensuring measurement accuracy, data consistency, increasing the credibility of research findings, reducing errors in decision making, and ensuring the feasibility of the SEM model used. Thus, validity and reliability testing is not only a technical step in the analysis, but also an important foundation for producing quality, reliable research, and has implications that can be applied in efforts to improve the sustainability of higher education in Indonesia. The analysis of convergent validity in this study aims to verify the ability of each indicator to accurately represent its respective latent variable. This evaluation is conducted by examining the loading factor values for the variables Six-Sigma implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, stakeholder engagement, and sustainability of higher education. A loading factor value of ≥ 0.7 is established as the benchmark to determine whether the indicators significantly contribute to their latent variables. As depicted in Figure 11, each latent variable meets this criterion, with all loading factor values exceeding the threshold of ≥ 0.7.

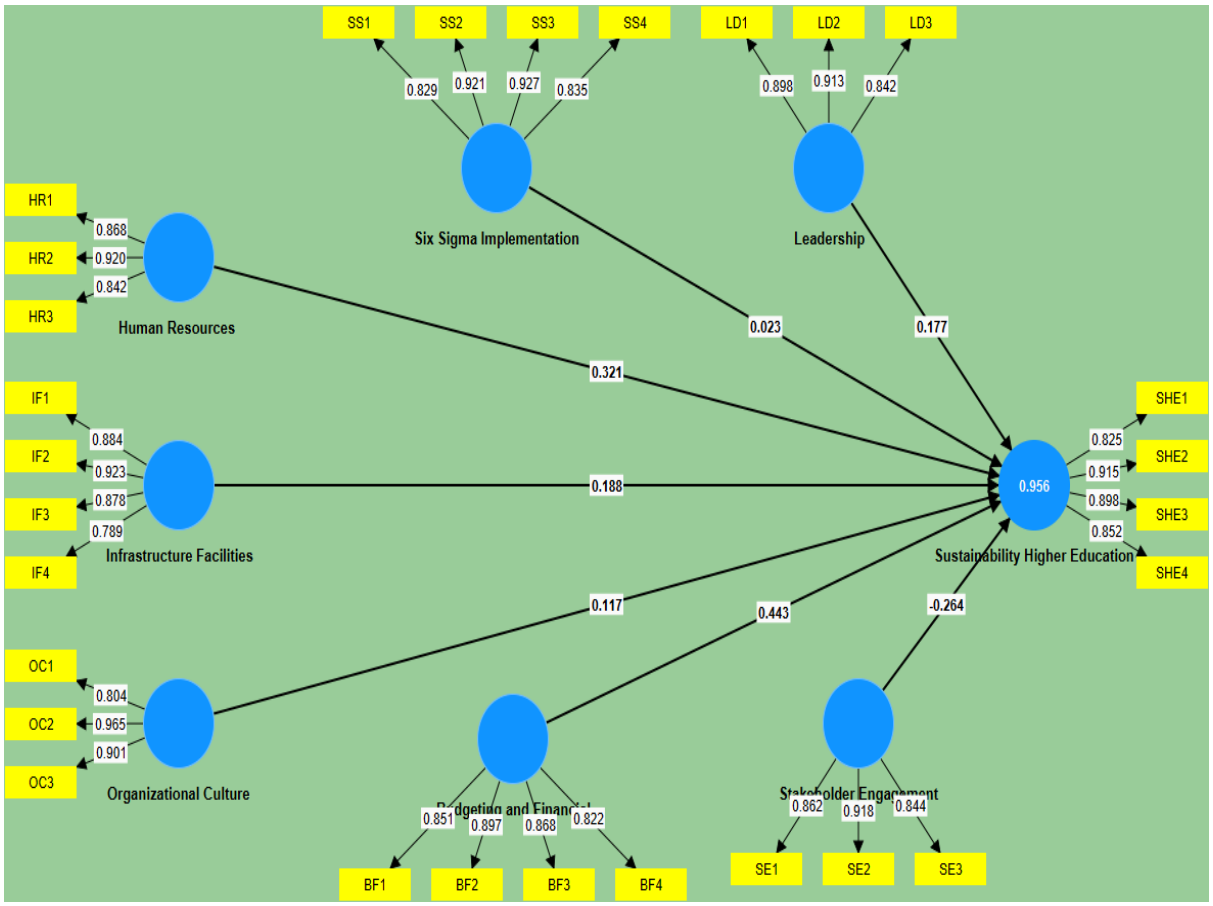


Figure 11: Loading Factor

Sources: Author Data Processing (Smart PLS.4) 2025

Upon completion of the convergent validity assessment, the subsequent critical step involves evaluating the reliability of the measurement model. The reliability analysis is essential to ensure that the indicators consistently and stably measure their corresponding latent variables over time. This evaluation is carried out by examining Composite Reliability (CR) and Cronbach's Alpha, with values exceeding 0.7 considered indicative of satisfactory internal consistency of the constructs. As shown in Table 14, each latent variable demonstrates a Cronbach's Alpha value greater than 0.7, thereby confirming that the measurement model meets the reliability criteria. The reliability threshold of 0.7 signifies that the indicators are sufficiently consistent in measuring the latent variables, ensuring that the results obtained from these measurements are stable and dependable across different contexts and over time. Thus, the constructs in this study exhibit a high degree of internal consistency, further validating the robustness of the measurement model.

Table 14: Construct Reliability and Validity

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Budgeting and Financial	0.882	0.882	0.919	0.739
Human Resources	0.850	0.851	0.909	0.770
Infrastructure Facilities	0.892	0.899	0.926	0.757
Leadership	0.861	0.868	0.915	0.783
Organizational Culture	0.870	0.883	0.921	0.797
Six-Sigma Implementation	0.901	0.903	0.931	0.773
Stake Holder Engagement	0.848	0.861	0.907	0.766
Sustainability Higher Education	0.895	0.897	0.927	0.762

Sources: Author Data Processing (Smart PLS.3) 2025

The assessment of Composite Reliability (CR) and Average Variance Extracted (AVE) for the latent variables of budgeting and financial resources, human resources, infrastructure facilities, leadership, organizational culture, Six-Sigma implementation, stakeholder engagement, and sustainability of higher education reveals that both indicators meet the

established criteria for validity and reliability. The Composite Reliability values for all latent variables surpass the 0.7 threshold, indicating a satisfactory level of internal consistency within the measurement model. Furthermore, the AVE values for each construct exceed the minimum acceptable threshold of 0.5, demonstrating that the indicators adequately explain the variance in their respective latent variables. These findings affirm both the validity and reliability of the measurement model, confirming that the constructs are well-defined and capable of providing stable and consistent measurements.

The regression model's R-square and Adjusted R-square values for the analysis of continuing higher education are displayed in Table 15. The model is excellent, as evidenced by the R-square (0.956), which can explain 95.6% of the variability in continuing higher education. After accounting for the number of predictors in the model, the Adjusted R-square (0.955) is marginally lower, but it still shows that 95.5% of the variability can be explained. While the Adjusted R-square corrects the R-square value if there are irrelevant variables in the model, a higher R-square value implies a high-quality model explaining the dependent variable.

Table 15: *R*-Square

	***R*-square**	**R-square adjusted**
Sustainability Higher Education	0.956	0.955

Sources: Smart PLS 4. Authors Processing, 2025

4.2.3. Outer Loading

In this study, the primary focus of the analysis is directed toward the evaluation of outer loading values rather than path coefficients, given that the study does not propose a hypothesis-based model testing causal relationships between variables. As such, greater emphasis is placed on the validity of the latent variable measurements, specifically through the assessment of outer loading, which indicates the degree to which the indicators effectively represent the latent constructs under examination. In contrast to testing inter-variable relationships via path coefficients, this approach prioritizes ensuring that each indicator accurately reflects its corresponding construct.

Within the framework of Structural Equation Modeling (SEM), particularly using the Partial Least Squares (PLS) method, outer loading quantifies the extent to which an indicator (or item) measures its associated latent variable. In other words, it reflects the strength of the relationship between the indicator and the latent construct it is intended to represent. A high

outer loading value, typically ≥ 0.7, signifies that the indicator significantly contributes to the construct, thereby ensuring the validity of the measurement. Conversely, a low outer loading value (e.g., < 0.4) suggests that the indicator may not adequately capture the construct, warranting potential removal from the model. Ultimately, outer loading serves as a key tool for assessing the quality and relevance of indicators in accurately measuring latent constructs, as illustrated in Table 16, thereby reinforcing the reliability and validity of the SEM model.

Table 16: Outer Loading

	BF	HR	IF	LD	OC	SE	SHE	SS
BF1	**0.851**							
BF2	**0.897**							
BF3	**0.868**							
BF4	**0.822**							
HR1		**0.868**						
HR2		**0.920**						
HR3		**0.842**						
IF1			**0.884**					
IF2			**0.923**					
IF3			**0.878**					
IF4			**0.789**					
LD1				**0.898**				
LD2				**0.913**				
LD3				**0.842**				
OC1					**0.804**			
OC2					**0.965**			
OC3					**0.901**			
SE1							**0.862**	
SE2							**0.918**	
SE3							**0.844**	
SHE1								**0.825**
SHE2								**0.915**
SHE3								**0.898**
SHE4								**0.852**
SS1						**0.829**		
SS2						**0.921**		
SS3						**0.927**		
SS4						**0.835**		

Sources: Author Data Processing (Smart PLS.3) 2025

The budgeting and financial resources variable shows significant outer loading, with indicator values exceeding the 0.7 threshold, indicating that these indicators accurately describe the management of funds in the context of sustainable higher education. Similarly, human

resources showed high outer loading values, with most indicators exceeding 0.7, reflecting the strong influence of the quality and skills of human resources on the sustainability of higher education and their ability to adapt to environmental changes. In the Infrastructure Facilities variable, the indicators used also show a strong relationship with the construct, with an outer loading value that meets the criteria (> 0.7), which indicates that physical and technological facilities support the achievement of higher education sustainability goals. The leadership variable also shows an outer loading value of more than 0.7, indicating that effective leadership plays an important role in creating an environment that supports the development and sustainability of educational institutions.

4.2.4. Bootstrapping

For bootstrapping analyses that focus on the outer model in Partial Least Squares Structural Equation Modeling (PLS-SEM), there are several criteria values that need to be met so that the relationship between indicators and latent variables can be considered significant. The qualified t-statistics value for the significance of the relationship between indicators and latent variables should generally be greater than 1.96 for a significance level of 5% (α = 0.05). That is, if the t-statistics are greater than 1.96, then the relationship is considered significant at the 5% level. The p-value indicates the probability that the result obtained is due to chance. A p-value smaller than 0.05 (α = 0.05) indicates a significant relationship between the indicator and the latent variable. If the p-value is smaller than 0.01, it indicates a higher level of significance otherwise if the p-value is greater than 0.05, the relationship between the indicator and the latent variable is not significant (Hair, 2018). If the t-statistics and p-value meet these criteria, it can be concluded that the indicators used in the outer model have a significant and valid relationship with the latent variable being measured.

A path map that depicts the connections between several elements leading to "Sustainable Higher Education" is shown in Figure 12. Blue circles depict several latent variables in this structural model diagram, while yellow boxes serve as indicators. "Human Resources," "Infrastructure Facilities," "Organizational Culture," "Six Sigma Implementation," "Leadership," "Budgeting and Financial," and "Stakeholder Engagement" are some of the aspects that are examined in this model. The intensity of each factor's influence on "Sustainable Higher Education" is indicated by a route with coefficient values along the relationship between the components. With a score of 0.733, "Leadership" is one example of a considerable influence, whereas "Human Resources" and "Six Sigma Implementation" have

zero values, indicating no, which probably shows how strongly or significantly the factors influencing it are related. This figure will likely be used in management analysis or scholarly studies to evaluate critical aspects of higher education sustainability.

Furthermore, with values of 0.037 and 0.070, respectively, this diagram indicates that several elements, including "Infrastructure Facilities" and "Organizational Culture," have a minor but noteworthy impact on "Sustainability Higher Education." As can be observed from the zero value on their relationship paths, the factors "Stakeholder Engagement" and "Budgeting and Financial" do not appear to have a substantial impact. This suggests that while other elements might need to be better refined to make a more significant contribution, the leadership component is crucial to attaining sustainable higher education. Higher education institutions can use this picture as a guide when deciding how to improve their sustainability plans.

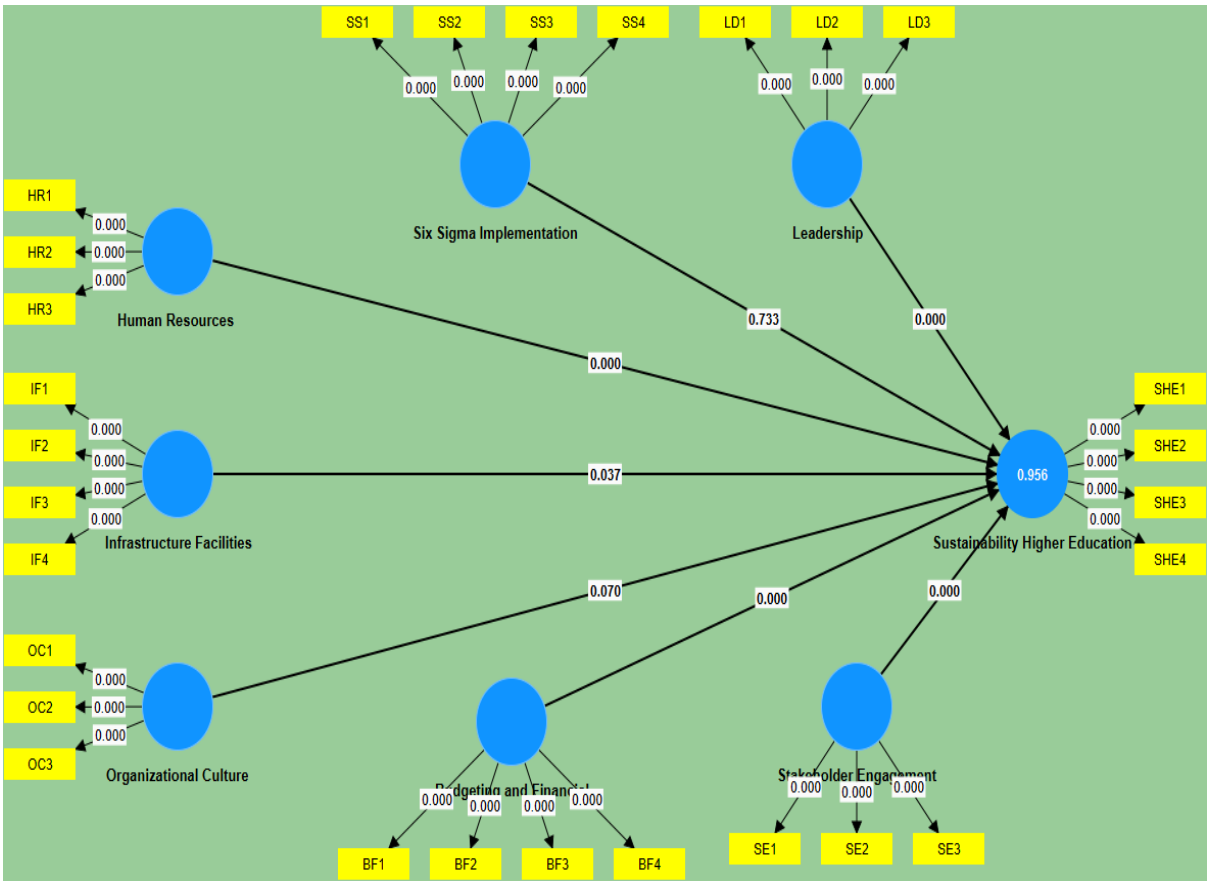


Figure 12: Bootstrapping Result

Sources: Smart PLS 4 Author Processing, 2025

The route coefficients that characterize the impact of several factors on sustainability in higher education are displayed in Table 17. This path coefficient indicates the contribution of each independent variable to the sustainability of higher education. With a coefficient of

0.443, budgeting and financial management have the most significant impact, suggesting that they are crucial to enhancing the sustainability of higher education. Infrastructure facilities (0.188) and human resources (0.321) are other essential characteristics that great impact to sustainability. With a coefficient of 0.177, leadership contributes favorably, whilst organizational culture has a lesser but noteworthy impact (0.117). However, with a value of -0.264, stakeholder engagement harms sustainability, suggesting that less-than-ideal stakeholder involvement may have unfavorable effects. In the meantime, Six Sigma Implementation displays a very low p-value (0.003) but has a very modest effect (0.023) and is not statistically significant. With a p-value of less than 0.05, most of the parameters examined demonstrated a substantial impact on the overall sustainability of higher education.

Table 17: Path Coefficient

	O	M	STDEV	(O/STDEV)	*P* values
Budgeting and Financial -> Sustainability Higher Education	0.443	0.447	0.060	7.402	0.000
Human Resources -> Sustainability Higher Education	0.321	0.318	0.048	6.725	0.000
Infrastructure Facilities -> Sustainability Higher Education	0.188	0.185	0.090	2.090	0.037
Leadership -> Sustainability Higher Education	0.177	0.180	0.037	4.729	0.000
Organizational Culture -> Sustainability Higher Education	0.117	0.123	0.065	1.810	0.028
Six Sigma Implementation -> Sustainability Higher Education	0.023	0.023	0.067	0.341	0.007
Stakeholder Engagement -> Sustainability Higher Education	-0.264	-0.271	0.070	3.777	0.000

Sources: Smart PLS 4. Authors Processing, 2025

In the context of this research, bootstrapping is applied to analyze the outer model that measures the relationship between indicators (observed variables) and latent variables such as budgeting and financial resources, human resources, infrastructure facilities, leadership, organizational culture, Six-Sigma implementation, stakeholder engagement, and sustainability of higher education. For each latent variable, bootstrapping is used to generate t-statistics and p-values that help determine whether the relationship between indicators and

latent variables is significant. By using a large sample size, bootstrapping allows for more stable parameter estimates while not relying on the assumption of a normal distribution, which is often a limitation of traditional estimation techniques. The results of the bootstrapping analysis on the outer model demonstrate a significant influence among the latent variables, including budgeting and financial resources, human resources, infrastructure facilities, leadership, organizational culture, Six-Sigma implementation, stakeholder engagement, and sustainability of higher education. This analysis offers a comprehensive understanding of the interrelationships between these dimensions within the context of performance enhancement and the sustainability of higher education. Specifically, the bootstrapping results for the outer model underscore the robustness and reliability of the indicators employed to measure these variables, as detailed in Table 18.

Table 18: Outer Model Bootstrapping

	Original Sample (O)	**Sample Mean (M)**	**Standard Deviation (STDEV)**	**T Statistics (O/STDEV)**	***P* Values**
BF1 <- Budgeting and Financial	0.851	0.849	0.019	45.220	0.000
BF2 <- Budgeting and Financial	0.897	0.894	0.013	67.904	0.000
BF3 <- Budgeting and Financial	0.868	0.866	0.015	58.638	0.000
BF4 <- Budgeting and Financial	0.822	0.820	0.017	49.290	0.000
HR1 <- Human Resources	0.868	0.865	0.015	57.829	0.000
HR2 <- Human Resources	0.920	0.920	0.007	129.413	0.000
HR3 <- Human Resources	0.842	0.840	0.018	46.949	0.000
IF1 <- Infrastructure Facilities	0.884	0.883	0.014	64.194	0.000
IF2 <- Infrastructure Facilities	0.923	0.922	0.008	112.305	0.000
IF3 <- Infrastructure Facilities	0.878	0.877	0.012	75.464	0.000
IF4 <- Infrastructure Facilities	0.789	0.785	0.026	29.935	0.000
LD1 <- Leadership	0.898	0.897	0.009	95.298	0.000
LD2 <- Leadership	0.913	0.911	0.009	99.863	0.000
LD3 <- Leadership	0.842	0.839	0.019	43.350	0.000
OC1 <- Organizational Culture	0.804	0.800	0.024	33.209	0.000
OC2 <- Organizational Culture	0.965	0.964	0.004	244.428	0.000
OC3 <- Organizational	0.901	0.900	0.010	91.851	0.000

Culture					
SE1 <- Stake Holder Engagement	0.862	0.861	0.012	72.274	0.000
SE2 <- Stake Holder Engagement	0.918	0.916	0.011	83.359	0.000
SE3 <- Stake Holder Engagement	0.844	0.841	0.021	40.596	0.000
SHE1 <- Sustainability Higher Education	0.825	0.821	0.022	37.283	0.000
SHE2 <- Sustainability Higher Education	0.915	0.914	0.010	88.382	0.000
SHE3 <- Sustainability Higher Education	0.898	0.896	0.010	88.747	0.000
SHE4 <- Sustainability Higher Education	0.852	0.850	0.016	53.191	0.000
SS1 <- Six-Sigma Implementation	0.829	0.826	0.022	37.953	0.000
SS2 <- Six-Sigma Implementation	0.921	0.920	0.008	119.223	0.000
SS3 <- Six-Sigma Implementation	0.927	0.927	0.008	119.356	0.000
SS4 <- Six-Sigma Implementation	0.835	0.833	0.018	45.327	0.000

Sources: Author Data Processing (Smart PLS.3) 2025

The fit between the estimated model and the saturated model using several model fit metrics is displayed in Table 19. Given that SRMR values below 0.08 are deemed sufficient, the 0.086 SRMR value for both models indicates a reasonable fit. Similarly, there is a slight discrepancy between the estimated and saturated models, as indicated by the values of d_ULS and d_G, which are 3.008 and 6.057, respectively. The NFI of 0.84 indicates a good match, as NFI values above 0.8 indicate a satisfactory fit. In contrast, the similar Chi-square value for both models (14284.189) shows that the estimated model is nearly identical to the saturated model. All things considered, these findings show that the estimated model matches the data quite well, suggesting that the model is trustworthy for additional research.

Table 19: Model Fit

	Saturated model	**Estimated model**
SRMR	0.086	0.086
d_ULS	3.008	3.008
d_G	6.057	6.057
Chi-square	14284.189	14284.189
NFI	0.84	0.84

Sources: Smart PLS 4. Authors Processing, 2025

Based on the frequency of occurrence of different effect values, Figure 13 shows the distribution of the overall impact of Six Sigma implementation on higher education

sustainability. According to this distribution, most of Six Sigma implementation's benefits fall into the small to medium positive range, suggesting that it generally impacts higher education's sustainability. The grey curve displays a normal distribution that matches the data, while the light blue histogram displays the empirical distribution of the overall effect in the sample under analysis. This aids in determining whether there are any deviations from the data's normal distribution. With peaks surrounding tiny positive values and a symmetrical spread on both sides, the distribution looks relatively near to a standard shape based on this graph.

The range of the overall effect values, which range from about -0.0220 to more than 0.1220, is displayed on the horizontal axis (X). Implementing Six Sigma may have a limited or negative impact in some situations, while it may have a more significant and favorable effect in others. In the meantime, the vertical axis (Y) displays how frequently specific effect values occur in the analysis sample. Most results reveal modest to moderate impacts, as shown by the maximum frequencies around effect values closer to zero or tiny positive.

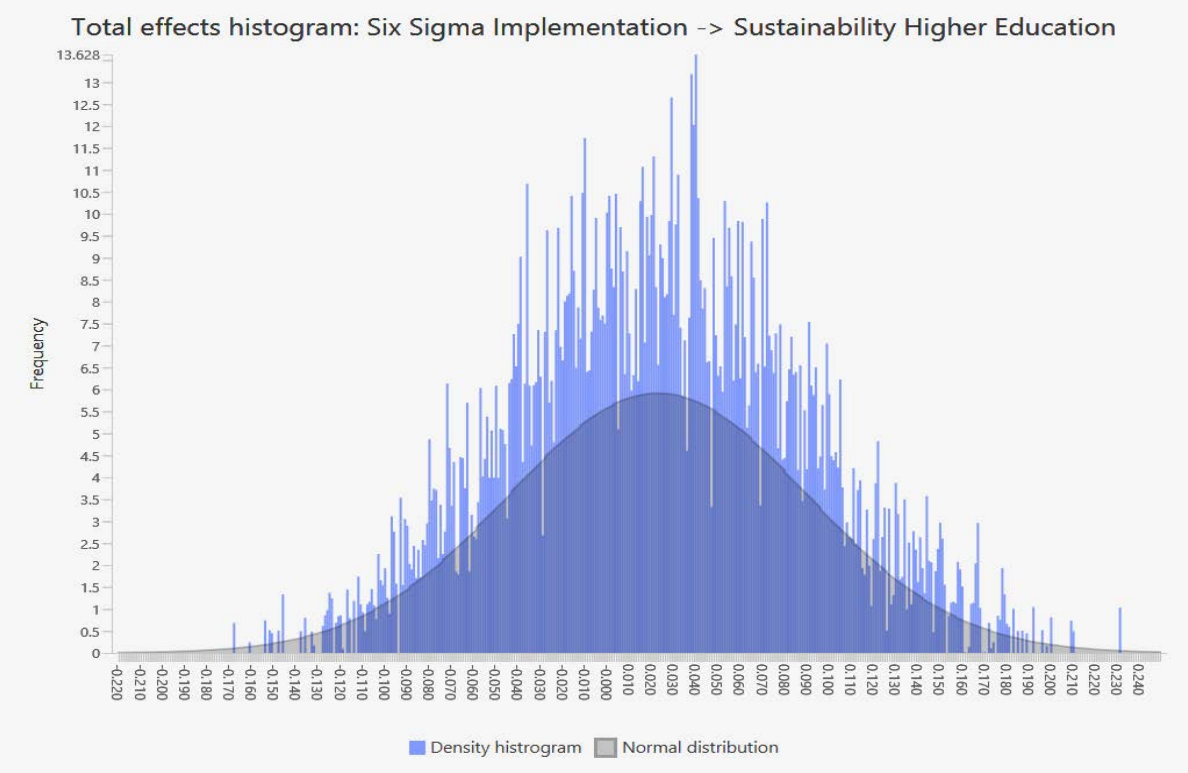


Figure 13: Histogram Distribution Data Result

Sources: Smart PLS 4 Author Processing, 2025

Overall, the results of the bootstrapping analysis on the outer model indicate a significant influence among the latent variables, namely budgeting and financial resources, human resources, infrastructure facilities, leadership, organizational culture, Six-Sigma implementation, stakeholder engagement, and sustainability of higher education. These findings offer valuable insights into the interrelationships between these dimensions within the context of performance enhancement and the sustainability of higher education. Furthermore, the analysis progresses with the integration of both qualitative and quantitative approaches, providing a more comprehensive understanding of how these factors interact and impact the sustainability and development of higher education institutions.

4.3. Integration Qualitative and Quantitative Analysis

As part of the effort to provide a comprehensive understanding of university sustainability in Indonesia, this research integrates the results of qualitative and quantitative analyses. This integrative approach aims to combine deep insights from a qualitative perspective with empirical evidence based on quantitative data, so as to provide a stronger foundation in formulating strategic recommendations based on the Six-Sigma approach. This integration allows for a more holistic identification of the key factors that influence sustainability, including aspects of resource management, organizational culture, stakeholder engagement, and implementation of Six-Sigma methodology. With this approach, the research not only explores the relationship between variables statistically, but also reveals in-depth dynamics and context, resulting in more relevant, applicable, and sustainable recommendations for Indonesian universities.

The results of this integration are expected to provide strategic guidance for university managers in designing policies that support operational efficiency, improve the quality of educational services, and strengthen institutional competitiveness. In addition, the findings of this research can also contribute to the development of an adaptive framework to face future challenges, such as limited resources, changing stakeholder needs, and the increasingly complex dynamics of the global environment. As such, this approach not only provides short-term solutions to current problems, but also builds a solid foundation for the long-term sustainability of higher education. The integration of qualitative and quantitative data enables more accurate evidence-based decision-making, which can be effectively implemented to create an inclusive, resilient and sustainability-oriented higher education system. In addition, the results of this study can also serve as a reference for stakeholders in strengthening

collaboration between the government, educational institutions, and the private sector to create an educational ecosystem that supports innovation and sustainability. By utilizing an integrated Six-Sigma approach, universities can be more responsive to the needs of society and the global market, while ensuring that policies and practices are aligned with the principles of efficiency, effectiveness, and social responsibility.

This integration begins with the use of the fishbone diagram to identify root causes of issues impacting sustainability in higher education, providing a clear understanding of the contributing factors across budgeting, human resources, infrastructure, leadership, and stakeholder engagement. Following this, the DMAIC framework is applied to systematically define problems, measure performance, analyze gaps, improve processes, and establish controls to ensure continuous improvement. Additionally, the SIPOC (Supplier, Input, Process, Output, Customer) analysis is utilized to map and refine key processes within the education ecosystem, ensuring alignment between inputs, processes, and desired outcomes. By combining these tools, the study offers a comprehensive roadmap for stakeholders to implement data-driven strategies that foster long-term sustainability and competitiveness in higher education.

4.3.1. Fishbone Diagram

Fishbone diagram, or commonly referred to as a cause-and-effect diagram or Ishikawa diagram, is a methodological tool employed to systematically and structurally identify the underlying causes of a particular issue (Shinde et al., 2018). To comprehensively understand the various factors influencing the sustainability of higher education in Indonesia, this study employs fishbone analysis as a primary tool for identifying the root causes of existing challenges. This method facilitates a systematic mapping of the relationships among key variables, including budgeting and financial resources, human resources, infrastructure facilities, leadership, organizational culture, Six-Sigma implementation, stakeholder engagement, and the sustainability of higher education.

The analysis seeks to uncover how these variables interact and collectively contribute to sustainability challenges. For instance, financial constraints and inefficiencies in human resource management may adversely affect infrastructure quality and leadership effectiveness. Simultaneously, an organizational culture that fails to promote innovation and collaboration can impede the successful implementation of Six-Sigma methodologies and weaken stakeholder engagement. By leveraging fishbone diagrams, this study strives to

pinpoint fundamental issues requiring resolution to establish a more efficient, adaptive, and sustainable framework for higher education in Indonesia. This approach is anticipated to yield profound insights that not only identify critical problems but also highlight opportunities for designing data-driven and contextually relevant improvement strategies. Such strategies aim to support the operational needs of higher education institutions while addressing the evolving demands of globalization and dynamic market conditions.

The initial stage of fishbone analysis involves clearly defining the primary problem that requires resolution. In the context of this study, the problem under investigation pertains to the various challenges faced by higher education institutions in Indonesia in achieving optimal sustainability. These challenges may encompass issues such as the misalignment between available resources and operational demands, inefficiencies in management practices, and insufficient stakeholder engagement in decision-making processes. Once the central issue is established, the next step involves identifying the primary categories or "bones" within the fishbone diagram, which will serve to map out the specific causes contributing to the problem. In this study, the key factors identified as potential contributors include budgeting and financial resources, human resources, infrastructure facilities, leadership, organizational culture, Six-Sigma implementation, stakeholder engagement, and the overall sustainability of higher education. Following the identification of these main categories, the next phase involves delving deeper into the specific sub-factors that contribute to the problems within each category. A thorough analysis will be conducted to uncover the detailed elements that represent the root causes of the issue at hand.

After the primary factors have been identified, the next phase involves investigating the more specific sub-factors that contribute to the issues within each category. A detailed analysis of each category will be conducted to uncover the underlying elements that serve as the root causes of the problems. For instance:

- Budgeting and Financial Resources:
    - Inaccurate budgeting and planning processes
    - Dependence on limited external funding sources
    - Inefficient management of financial resources
    - Overreliance on costly, non-renewable energy sources

- Human Resources:

    - Insufficient training and professional development for academic and administrative staff
    - High turnover rates among both academic and non-academic personnel
    - Challenges in recruiting staff with the necessary qualifications
- Infrastructure Facilities:
    - Constraints in physical facilities that support academic functions
    - Limited access to modern educational technologies and resources
    - Insufficient maintenance or deterioration of existing infrastructure
- Leadership:
    - Leadership that lacks a long-term strategic vision
    - Insufficient involvement of leadership in the planning and evaluation processes
    - Inadequate management of rapid educational changes
- Organizational Culture:
    - A culture that does not foster innovation or continuous improvement
    - Resistance to change from staff and management
    - Poor communication and coordination among various departments or units
    - Lack of initiatives to mitigate environmental impacts, such as waste management and carbon emissions
    - Inefficient energy utilization in campus operations
- Six-Sigma Implementation:
    - Insufficient understanding of Six-Sigma principles or inadequate training
    - Resource limitations in adopting Six-Sigma practices
    - Challenges in applying Six-Sigma for continuous process improvement
- Stakeholder Engagement:
    - Lack of involvement from students, faculty, and staff in strategic decision-making
    - Absence of clear communication channels with external stakeholders
    - Inadequate understanding of stakeholder needs and expectations

The subsequent step involves analyzing the interactions between each sub-factor and assessing their collective contribution to the overarching problem. For instance, limited financial resources may result in constrained infrastructure, which subsequently impacts the quality of education and the institution's sustainability. Similarly, an organizational culture

that resists change and innovation may impede the implementation of Six-Sigma, a methodology essential for enhancing operational efficiency and educational quality. Once the relationships between these factors are thoroughly analyzed, the next phase is to identify the root causes that have the most significant impact and require immediate attention. Through the use of a fishbone diagram, this analysis facilitates the prioritization of the most critical causes that must be addressed to achieve optimal outcomes. For example, if a lack of visionary leadership and budget constraints are determined to be the primary root causes, the initial actions should focus on enhancing leadership quality and improving budget planning efficiency. Based on this understanding of the root causes, the final step is to formulate targeted solutions and strategies for improvement. Each proposed solution will be designed to address the factors identified in the fishbone diagram, as illustrated in Figure 14. For instance, solutions for human resource challenges may include implementing continuous staff training and development, while infrastructure-related issues may be addressed through more efficient budget allocation aimed at upgrading existing facilities.

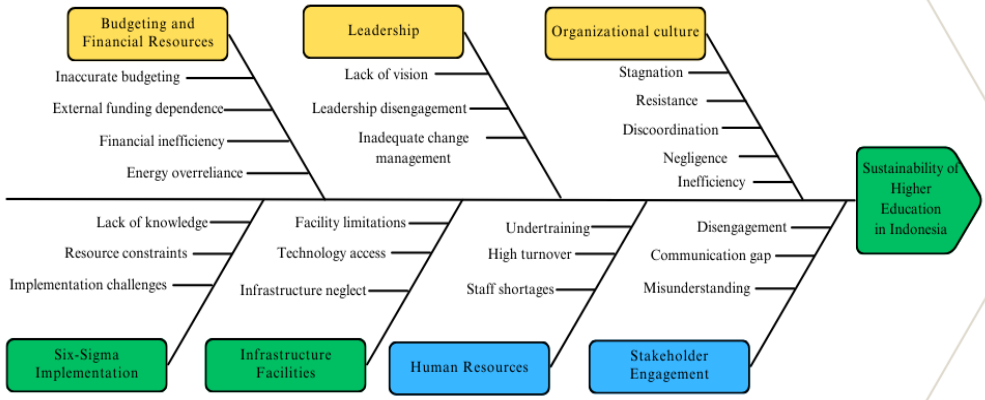


Figure 14: Fishbone Diagram of Sustainability Higher Education in Indonesia

Sources: Based own work, 2025

The factors of inaccurate budgeting, external funding dependence, financial inefficiency, and energy overreliance present significant challenges to the sustainability of higher education

institutions in Indonesia. Inaccurate budgeting occurs when financial plans fail to properly forecast the institution's needs, resulting in resource misallocation that hampers the ability to allocate funds effectively for critical areas such as infrastructure, academic programs, and staff development compromises long-term sustainability. Additionally, external funding dependence, such as reliance on government grants or donations, makes institutions vulnerable to financial instability, limiting their autonomy and decision-making flexibility as external funding is often subject to fluctuating political and economic conditions. Financial inefficiency further exacerbates these challenges, as poor resource allocation and wasteful spending reduce the available funds for essential activities like research and curriculum development. Finally, energy overreliance on costly, non-renewable sources increases operational expenses and contributes to environmental degradation, with institutions failing to transition to renewable energy or adopt energy-efficient practices. These factors collectively undermine the long-term sustainability of higher education institutions in Indonesia.

The factors of lack of vision, leadership disengagement, and inadequate change management represent critical challenges within the leadership domain of higher education institutions in Indonesia. A lack of vision, where leadership fails to provide a clear, long-term strategic direction, leads to fragmented efforts and missed opportunities for institutional growth and sustainability. Without a well-defined vision, decisions tend to be short-term, impeding the institution's ability to adapt to the evolving demands of education. Furthermore, leadership disengagement, characterized by insufficient involvement in decision-making, planning, and evaluation processes, creates disconnect between leadership and the operational needs of the institution. This disengagement weakens the effectiveness of institutional strategies and diminishes the capacity to respond to emerging challenges. Lastly, inadequate change management practices hinder the institution's ability to adapt to changing academic, technological, and societal conditions. Leaders who are unprepared to manage change often fail to guide the institution through necessary transformations, fostering resistance among staff and stakeholders and preventing the institution from meeting its sustainability objectives. The factors of stagnation, resistance, disco-ordination, negligence, and inefficiency serve as significant barriers within the organizational culture of higher education institutions in Indonesia. Stagnation, often driven by entrenched practices or reluctance to adopt new ideas, limits the institution's capacity to innovate and adapt to evolving educational demands. This stagnation is further exacerbated by resistance, where staff and

management resist change due to fear of the unknown, a lack of trust in leadership, or a preference for the status quo, preventing necessary institutional transformations. Additionally, disco-ordination, which stems from inadequate communication and collaboration across departments or units, hinders the alignment of institutional goals and resources, thereby reducing operational effectiveness. Negligence, characterized by the failure to address critical issues such as environmental concerns or operational inefficiencies, leads to missed opportunities for improvement and jeopardizes long-term sustainability. Finally, inefficiency arises when resources are not optimally utilized, resulting in waste or suboptimal performance, undermining the institution's ability to meet its goals and maintain its sustainability objectives.

The factors of lack of knowledge, resource constraints, and implementation challenges significantly hinder the effective implementation of Six-Sigma in higher education institutions in Indonesia. Lack of knowledge refers to the insufficient understanding of Six-Sigma principles and methodologies among institutional leaders and staff, making it difficult to apply Six-Sigma effectively to drive process improvements and enhance operational efficiency. In addition, resource constraints highlight the limitations in both financial and human resources required for Six-Sigma practices, where insufficient funding and a lack of skilled personnel restrict the institution’s ability to fully adopt and sustain Six-Sigma initiatives. Furthermore, implementation challenges arise from difficulties in applying Six-Sigma across various academic and administrative functions, including resistance to change, inadequate support from leadership, and a lack of infrastructure to facilitate the systematic application of Six-Sigma tools, all of which impede the successful integration of Six-Sigma within the institution.

Building on the challenges of Six-Sigma implementation, the factors of facility limitations, technology access, and infrastructure neglect further exacerbate the difficulties faced by higher education institutions in Indonesia. Facility limitations refer to the inadequacy of physical spaces required to support academic activities, restricting the institution’s ability to provide an optimal learning environment. Similarly, technology access underscores the lack of modern educational technologies, such as advanced teaching tools and digital resources, which are vital for enhancing educational quality and maintaining competitiveness in the evolving academic landscape. Moreover, infrastructure neglect pertains to the failure to properly maintain or upgrade existing facilities, leading to the deterioration of campus environments over time, which ultimately impacts the functionality, safety, and long-term

sustainability of the institution. Together, these infrastructure-related issues further hinder the ability of institutions to adapt and thrive in an increasingly dynamic educational landscape.

Following the discussion of technological infrastructure challenges, it is essential to also address the significant human resource challenges facing higher education institutions in Indonesia, namely undertraining, high turnover, and staff shortages. Undertraining pertains to the lack of sufficient professional development opportunities for both academic and administrative staff, which hinders their ability to perform effectively and keep pace with the evolving educational landscape. High turnover underscores the frequent departure of staff, driven by job dissatisfaction or better prospects elsewhere, resulting in institutional instability and a loss of valuable knowledge. Lastly, staff shortages refer to the ongoing difficulty in recruiting and retaining qualified personnel, which places additional strain on existing staff, disrupts academic and administrative functions, and limits the institution's ability to achieve its long-term objectives. Together, these human resource issues significantly hinder the ability of institutions to provide high-quality education and maintain efficient operations.

Following the analysis of challenges within the human resources domain, it is essential to address the significant barriers in stakeholder engagement that also hinder the overall sustainability and operational efficiency of higher education institutions in Indonesia. Among the key factors affecting stakeholder engagement are disengagement, communication gaps, and misunderstanding. Disengagement arises when key stakeholders, such as students, faculty, staff, and external partners, are not actively involved in decision-making processes. This lack of involvement leads to diminished ownership and motivation to support institutional objectives, which, in turn, disrupts collaboration and impedes the effective implementation of strategies. Often, disengagement stems from limited opportunities for participation, inadequate feedback systems, or a perception that stakeholders have no influence over critical decisions. Additionally, communication gaps further exacerbate the issue, resulting from inadequate communication channels or hierarchical barriers. These gaps prevent stakeholders from accessing timely, accurate, and relevant information, thus reducing their ability to align with institutional goals. The absence of transparent communication not only weakens trust but also hampers collective efforts to achieve the institution's mission and long-term objectives.

Finally, misunderstanding arises when stakeholders' expectations and needs are not clearly communicated or aligned. This misalignment leads to confusion or conflicting interpretations

of institutional priorities, which can create friction among groups and disrupt collaboration. Such misunderstandings are detrimental to the institution's ability to foster cooperation, address emerging challenges, and ultimately achieve sustainability. Simultaneously, these factors disengagement, communication gaps, and misunderstanding serve as critical obstacles to effective stakeholder engagement. Overcoming these barriers is essential for higher education institutions in Indonesia to establish a cohesive, collaborative environment that supports growth, innovation, and long-term sustainability.

The fishbone analysis provides a thorough examination of the key challenges impacting the sustainability of higher education institutions in Indonesia. It identifies critical factors across several domains that collectively hinder long-term effectiveness and growth. In terms of budgeting and financial resources, challenges such as inaccurate budgeting, dependence on external funding, financial inefficiency, and overreliance on non-renewable energy sources compromise resource allocation and operational stability, preventing investments in vital areas like infrastructure, human resources, and innovation. In the human resources domain, issues including undertraining, high turnover, and staff shortages limit the ability to develop a skilled and stable workforce, which is essential for maintaining quality education and efficient administration. Similarly, infrastructure facilities face limitations, such as inadequate spaces, lack of modern technology, and neglect of existing resources, preventing institutions from offering an optimal learning environment and keeping up with technological advancements. Leadership-related challenges, such as a lack of vision, disengagement, and poor change management, further impede the development of long-term strategies and adaptation to the changing educational landscape, leading to inefficiencies and missed growth opportunities. Moreover, organizational culture challenges like stagnation, resistance to change, and inefficiency complicate efforts to innovate and improve institutional practices. These issues are exacerbated by ineffective communication and lack of support for change, which disrupt institutional performance. Six-Sigma implementation also faces significant barriers, such as limited knowledge, resource constraints, and difficulties in applying systematic process improvements, preventing operational efficiency and educational enhancement. Finally, issues with stakeholder engagement, including disengagement, communication gaps, and misunderstandings, hinder collaboration among key stakeholders, reducing the institution's ability to address challenges and work towards common goals. In summary, these interconnected challenges across financial, human, infrastructural, leadership, organizational, and stakeholder domains necessitate a comprehensive and

strategic approach to ensure that higher education institutions in Indonesia can adapt, innovate, and remain sustainable in a rapidly evolving environment.

4.3.2. DMAIC

After conducting an analysis using Fishbone diagrams to identify the root causes of various challenges affecting higher education sustainability in Indonesia, the next step in this research is to apply the DMAIC (Define, Measure, Analyze, Improve, Control) approach as a framework to formulate systematic and data-driven solutions. Through DMAIC, this research will explore how continuous improvement can be applied to the identified variables, such as financial resources, infrastructure, teaching quality and stakeholder engagement, to achieve better and more effective higher education sustainability in Indonesia. The DMAIC approach will help optimize each stage in the process, starting with defining the problem clearly and measurably, then collecting relevant data to evaluate the extent to which the factors contribute to the challenge. In the analysis stage, the relationships between variables will be analyzed in depth to find the root causes that affect the quality and sustainability of higher education. After that, data-driven solutions will be implemented to improve sub-optimal aspects, with a focus on improving resource efficiency and education quality. Finally, the control step will ensure that the improvements made can be maintained in the long term, thus creating a sustainable and adaptive higher education system to the evolving changes. Through the implementation of DMAIC, it is hoped that higher education institutions in Indonesia can face the existing challenges and create a more advanced and sustainable future for higher education.

In addition, the application of DMAIC will facilitate continuous monitoring of the performance and impact of implemented improvements, enabling rapid adjustments to the changing needs and dynamics of the education environment. This data-driven approach will also strengthen collaboration between various stakeholders, including the government, private sector and society, in support of policies and strategies that support the sustainability of higher education. As such, this research will not only generate practical recommendations to improve the quality and efficiency of higher education in Indonesia, but also contribute to the development of a more holistic framework that is responsive to the long-term challenges faced by the education sector. It is hoped that, through the application of DMAIC, higher education in Indonesia can achieve a higher level of sustainability, both in terms of finance, teaching quality and resource management.

Furthermore, the implementation of DMAIC will enable more precise measurement of the achievement of sustainability goals, as well as provide useful feedback for continuous improvement in the management of higher education. It will also encourage the use of technology and innovation in the education process, which in turn can accelerate digital transformation in the education sector. With a more structured and efficient system in place, higher education institutions will be better able to adapt to rapid global changes, such as the need for a workforce based on digital and other global skills. As a result, higher education in Indonesia will not only be more responsive to future needs, but also more capable of creating greater value for society and the economy as a whole, thus supporting the achievement of sustainable development goals at the national and international levels.

The application of DMAIC will strengthen higher education institutions' ability to manage resources more efficiently, enabling them to improve the quality of education services without compromising financial sustainability. More efficient processes can also reduce waste and improve budget utilization, which is important in the face of increasingly complex education financing challenges. With a focus on improving quality and efficiency, DMAIC can help create a more inclusive and sustainable education ecosystem that provides access to quality education for all. Finally, by integrating this Six-Sigma approach, higher education in Indonesia can optimize the potential of existing resources, improve global competitiveness, and contribute to sustainable social and economic progress as shown in Figure 9. This approach allows higher education institutions to identify gaps in operational and management processes, so that solutions can be designed that are not only effective but also relevant to local and global needs. With improved efficiency, institutions can allocate resources more strategically, including for educational technology innovation, market-driven curriculum development, and faculty competency enhancement.

In addition, DMAIC provides a strong foundation for creating a transparent and accountable performance measurement mechanism, which can monitor the extent to which the institution is achieving its sustainability goals, from environmental, social and financial aspects. This is important to ensure that the changes implemented not only result in short-term improvements, but also support long-term sustainability.

By integrating DMAIC into higher education strategies, institutions can play a greater role in addressing development challenges, such as inequality in access to education, improving the quality of graduates relevant to industry needs, and contributing to the achievement of the

Sustainable Development Goals (SDGs). This approach can also strengthen collaboration between educational institutions and the government, private sector, and global community, creating greater synergy to achieve sustainable education transformation in Indonesia. Finally, DMAIC serves not only as a process improvement tool, but also as a strategic framework that enables higher education in Indonesia to face future challenges more confidently, resiliently, and adaptively to evolving global dynamics.

Moreover, DMAIC implementation can serve as a stimulant for innovation in research projects, curriculum design, and pedagogical approaches, guaranteeing that graduates possess the skills required to compete in a labor market that is becoming more and more competitive. Universities can close the skills gap and support workforce preparedness and national economic growth by coordinating educational programs with industry demands. likewise, the synergistic partnership created by DMAIC between academic institutions, governmental organizations, and the commercial sector will promote technical development and knowledge transfer, both of which are critical to the development of a knowledge-based economy. Through the education sector, this alignment helps Indonesia achieve sustainable growth and increase its competitiveness in the global market.

In the end, incorporating DMAIC into higher education initiatives guarantees adaptation to dynamic global issues, such as shifting labor market demands, technological disruption, and changing educational paradigms, in addition to enhancing institutional resilience. As shown in Figure 15, Indonesian higher education institutions can thus establish themselves as important forces behind sustainable development, giving the next generation the abilities, know-how, and creative attitudes required to successfully navigate and contribute to a changing world.

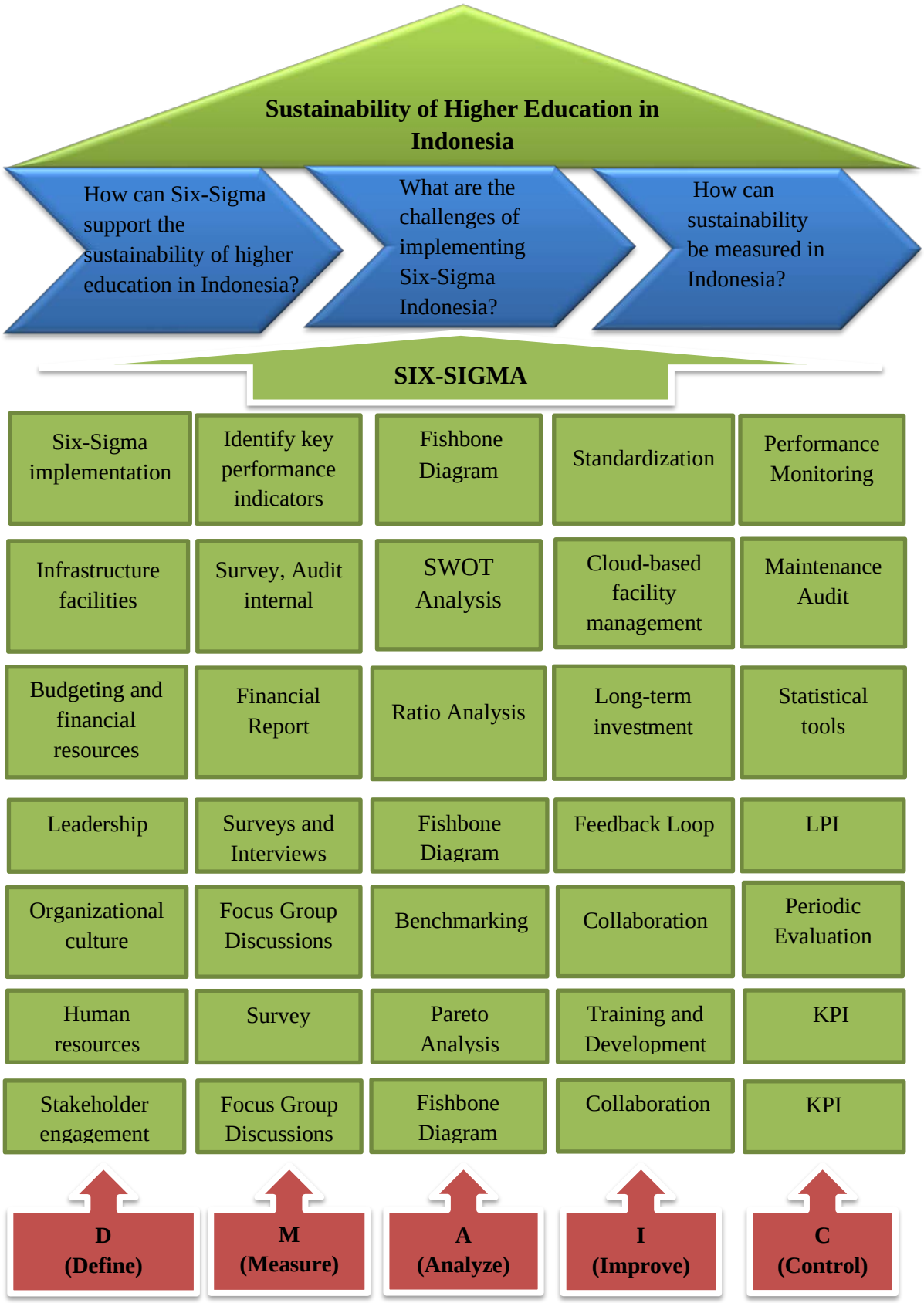


Figure 15: Proposed DMAIC Model

Sources: Based on own work, 2025

Based on DMAIC analysis involving indicators such as Six-Sigma implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, and stakeholder engagement, it can be concluded that this approach has great potential to improve the quality and efficiency of higher education in Indonesia, especially in supporting the implementation of the *Merdeka Belajar* program (KPI) described in Chapter 1. Six-Sigma implementation in higher education plays an important role in optimizing operations, reducing variability, and increasing process efficiency to ensure the sustainability of quality learning, in line with the competency-based learning principles of *Merdeka Belajar* Program.

In addition, efficient management of Human Resources through DMAIC contributes to the development of lecturers, which is increasingly necessary in implementing teaching models oriented towards skill development and self-directed learning. Infrastructure Facilities that support accessibility and learning quality are also improved through this approach, optimizing physical and technological facilities on campus to support the hybrid learning model promoted by *Merdeka Belajar* Program. Last but not least, an organizational culture that is adaptive and open to change is needed to create an innovative and flexible educational environment, which supports collaboration and academic freedom. Strong and visionary leadership is also a determining factor in the success of these programs, with DMAIC assisting leaders in assessing effectiveness and designing policies that are responsive to changing needs.

Budget and financial resources, as a major factor in the development of educational infrastructure, can be more efficiently managed through the implementation of DMAIC, ensuring the appropriate use of budget to support competency-based learning. Lastly, optimized stakeholder engagement through DMAIC allows stakeholders, including government, industry and the community, to collaborate in designing relevant education policies. Overall, the application of DMAIC to these indicators can help Indonesian higher education in facing challenges and optimizing the quality of learning in accordance with Merdeka Belajar Program KPIs, making a significant contribution to a more sustainable and adaptive education system to the times. Having discussed the application of the DMAIC approach in improving the sustainability of higher education in Indonesia, the next step is to conduct a SIPOC analysis to further explore and map the processes involved. By using SIPOC, we can identify in more detail the key elements in each stage of the higher education process, from the input providers, the steps performed in the education process, to the

expected outcomes and customers involved. This analysis will provide a clearer picture of the structure and dynamics of the higher education process, which is crucial for designing appropriate solutions to support more effective and efficient education sustainability in Indonesia.

4.3.3. SIPOC

As an integral part of implementing the Six-Sigma approach, SIPOC (Suppliers, Inputs, Processes, Outputs, and Customers) analysis provides a clear framework for understanding and identifying the key elements that affect the sustainability of higher education in Indonesia. By illustrating the relationships between suppliers, inputs, processes, outputs, and customers, SIPOC helps map existing workflows and provides strategic insights in improving the efficiency and effectiveness of the higher education system, which in turn contributes to the long-term sustainability of the sector. Through such mapping, SIPOC enables stakeholders to identify potential problems and areas that require improvement in the higher education value chain. This analysis also helps in setting priorities for improvement based on their impact on the quality of education services, student satisfaction, and the relevance of the curriculum to labor market needs. Thus, the application of SIPOC in the context of Six-Sigma not only improves operational performance, but also supports the achievement of higher education sustainability goals that are more inclusive, innovative, and adaptive to global change.

Furthermore, these analyses provide a solid basis for data-driven decision-making, which facilitates policy adjustments that are more responsive to social, economic, and technological dynamics. Within this framework, SIPOC serves as an important tool to integrate the perspectives of various stakeholders, ranging from institutional managers, lecturers, to students, in creating a sustainable and relevant education system. By fostering collaboration across these diverse groups, SIPOC aids in aligning institutional goals with broader societal needs, ensuring that higher education not only meets current expectations but also anticipates future challenges. This collaborative approach enhances the agility and resilience of the education system, enabling it to adapt more effectively to global trends such as digital transformation, demographic shifts, and evolving labor market requirements. Ultimately, the application of SIPOC within the Six-Sigma methodology contributes to a higher education system that is not only efficient but also capable of delivering long-term value to students, employers, and society at large.

Overall, the application of SIPOC within the Six-Sigma methodology contributes to a higher education system that is not only efficient but also capable of delivering long-term value to students, employers, and society at large. In the context of sustainability in higher education in Indonesia, the integration of key variables such as Six-Sigma implementation, human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, and stakeholder engagement becomes critical. Six-Sigma implementation provides a structured framework for continuous improvement, ensuring that resources - whether human, financial or infrastructure - are optimally utilized. Effective Human Resources management and leadership are critical in driving these improvements, fostering an organizational culture that embraces innovation, accountability and collaboration. Infrastructure facilities must be aligned with technological advances to meet the evolving needs of students and the labor market, while budgetary and financial resources must be strategically allocated to sustain long-term development. Stakeholder engagement, which includes students, lecturers and external partners, ensures that the education system remains responsive to the needs of its various constituencies, facilitating greater buy-in and ensuring the long-term sustainability of reforms as displayed by Figure 16. By utilizing these interconnected variables, Indonesia's higher education system can achieve a more sustainable and impactful trajectory, driving greater alignment between academic outcomes and the demands of a rapidly changing global environment.

In the context of SIPOC (Suppliers, Inputs, Process, Outputs, and Customers), we can group these variables based on the Input, Process, and Output categories as follows:

- Inputs are resources or elements needed to run a process. Based on the variables mentioned, some examples of inputs are:
    - Budgeting and financial resources (BF): Funds and financial resources needed to support activities.
    - Human resources (HR): The labor, skills, and abilities needed to carry out the process.
    - Infrastructure facilities (IF): Facilities and infrastructure required to support activities and operations.
    - Leadership (LD): Leadership that provides direction and decision-making.
    - Organizational culture (OC): Values, attitudes, and behaviors within the organization that influence the way members work and interact.

- Process. Process is a series of activities or steps performed to produce an output. Some examples of processes related to these variables are:
    - Six-Sigma implementation (SS): Six-Sigma implementation as a methodology to improve quality and efficiency.
    - Stakeholder engagement (SE): The process of involving and communicating with stakeholders in the decision-making process and management of activities.
- Output. Output is the result or product produced from the process. Variables related to output include:
    - Sustainability of higher education (SHE): Sustainability of higher education, which includes financial, social, and environmental aspects of educational institutions.
    - Using SIPOC, we can map each of these variables in the context of the process flow within the organization or larger system.

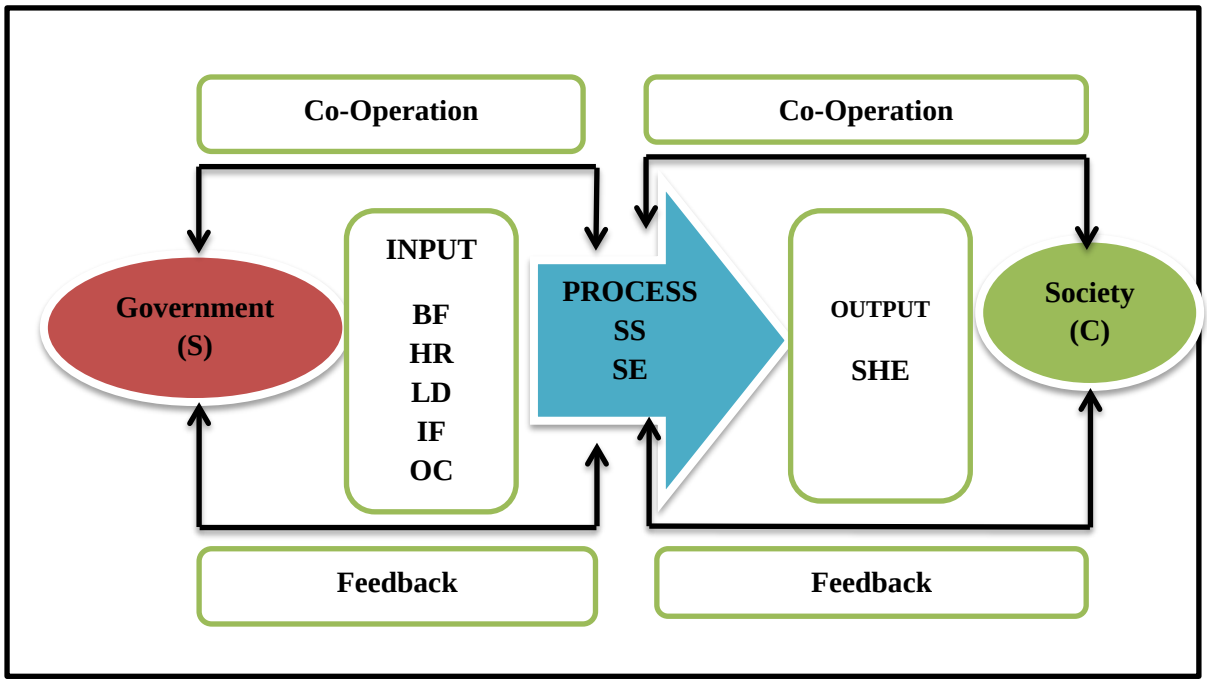


Figure 16: SIPOC Proposed Model

Sources: Author 2025

The government (S) acts as a supplier by providing policies, regulations, and financial support that facilitate the functioning of higher education institutions. This includes funding, subsidies, and policy frameworks that shape the educational landscape meanwhile Society (C) is a key consumer as the results of a sustainable higher education system contribute to the

well-being of the broader community. Graduates, research outcomes, and societal contributions from universities directly benefit society at large, including the economy, culture, and social development. In the context of SIPOC analysis, variables such as budgeting and financial resources (BF), provided by the government as a supplier, play an important role in ensuring the continuity of higher education operations. These funds support infrastructure facilities (IF), which are necessary to create an adequate learning environment, and also ensure sustainability in the provision of human resources (HR), both in terms of recruitment of qualified lecturers and ongoing training for teaching and administrative staff.

On the other hand, leadership (LD) and organizational culture (OC) in higher education institutions are key factors in driving and supporting change towards sustainability, by creating a culture of innovation and quality that focuses on long-term goals. Six-Sigma implementation (SS) serves to improve operational efficiency and quality of education, by improving existing processes through data-driven approaches and systematic problem solving. Stakeholder engagement (SE) is a crucial process in integrating inputs from various stakeholders, such as students, faculty, industry, and the community, in managing change and continuous improvement. All these elements support the achievement of sustainability of higher education (SHE), which is not only related to financial aspects, but also includes the social and environmental impacts of higher education institutions on society as a whole. By optimizing each variable in SIPOC, higher education can create a system that is more adaptive, efficient, and relevant to global needs, while maintaining long-term sustainability for future generations.

In conclusion to the SIPOC analysis, it can be concluded that the implementation of Six-Sigma in Indonesian higher education, involving variables such as financial resources, human resources, infrastructure facilities, leadership, organizational culture, and stakeholder engagement, has a key role in improving the sustainability of the sector. The qualitative analysis that has been conducted provides an in-depth understanding of the factors that influence Six-Sigma implementation, while the quantitative analysis enables objective measurement of the impact and effectiveness of these strategies. The integration of these two approaches allows us to not only understand the internal dynamics of higher education institutions, but also to evaluate the extent to which external factors, such as government policies and community responses, support or hinder the achievement of sustainability goals. Thus, this analysis provides a more comprehensive and holistic picture of efforts to improve the sustainability of higher education in Indonesia

5. CONCLUSION AND RECOMMENDATION

This dissertation will present an in-depth discussion of the findings obtained from research integrating the Six-Sigma approach to improve the sustainability of higher education in Indonesia. The discussion will analyze the results obtained through qualitative and quantitative analysis and relate them to relevant literature, existing theories, and the context of higher education in Indonesia and identify the practical and theoretical implications of the findings. In addition, this dissertation will provide strategic recommendations that can be implemented by higher education institutions to improve operational efficiency, service quality and overall sustainability. Thus, it is expected that this research will not only provide academic contributions through theory development, but also provide tangible benefits to stakeholders in the higher education sector in Indonesia.

Over the past decade, ‘Golden Indonesia 2045’ has become a slogan to mobilize the nation's potential, reflecting Indonesia's great hopes for 2045. This vision describes Indonesia's ambition to become a developed, modern country, and equal to the world's major powers, while creating better and more equitable welfare for the people, with improved quality of human resources. In addition, this vision aims to place Indonesia among the five largest economic powers in the world. This idea is in line with Indonesia's national vision, which is to realize an independent, united, sovereign, just and prosperous country. The achievement of the grand vision of ‘Golden Indonesia 2045,’ which has become a symbol of hope and mobilization of the nation's potential over the past decade, is highly dependent on the quality of human resources as the main foundation. In this context, the role of higher education becomes crucial as a catalyst to produce individuals who are competitive, innovative, and adaptive to global dynamics. This research, entitled ‘Enhancing Sustainability of Higher Education in Indonesia: Six-Sigma Approach,’ aims to contribute to realizing this vision through the development of sustainability in the higher education sector. By integrating the Six-Sigma approach, this research focuses on improving service quality and operational efficiency, which in turn can support the achievement of national strategic goals towards an advanced and competitive Indonesia in 2045.

To ensure a bright future for Indonesia's young generation, the government needs to base higher education policy on the latest data and trends. Investing in responsive, inclusive and sustainable education is a strategic step to ensure that Indonesia is not only able to keep up with global developments, but can also lead in innovation and development that suits the

needs and potential of the nation, especially in the context of the ongoing demographic bonus. In recent decades, the world has witnessed rapid advances in information technology, biotechnology and renewable energy. However, these developments are just the beginning of the transformation that will take place in the future. Amidst the ever-changing dynamics of globalization, the ability to anticipate and understand future knowledge, otherwise known as tapping future knowledge, is crucial. Identifying and following the direction of scientific development is not just an option, but an urgent need to prepare the next generation to remain relevant and competitive. Thus, the ability to predict and master future knowledge will be one of the key factors in determining the progress of a nation. To achieve the strategic role of higher education in producing excellent and resilient human resources, the Six-Sigma approach can be an effective framework in improving the quality and efficiency of the higher education system in Indonesia. Six-Sigma, which focuses on reducing variation and improving process consistency, can be applied to ensure that every stage in the education process-from curriculum to teaching to student services-is carried out to high quality standards.

By using Six-Sigma, higher education institutions can identify and eliminate bottlenecks or weaknesses in the system that hinders the achievement of graduate competencies. For example, the data-driven analysis at the core of Six-Sigma enables universities to deeply understand the needs of the labor market and align them with educational programs. This ensures that graduates not only master knowledge, but also possess relevant character, skills, and competencies, including critical thinking, innovation, and emotional intelligence. Furthermore, the continuous improvement principle of Six-Sigma encourages institutions to continuously improve their service quality, create a supportive learning environment, and integrate project-based learning and entrepreneurship training. Thus, Six-Sigma can be a strategic tool to produce graduates who are able to compete globally while pushing Indonesia out of the middle income trap.

5.1. Summary of Key Findings

The implementation of Six-Sigma in higher education cannot be separated from the role of various key variables that support its success. Variables such as human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, and stakeholder engagement have a significant contribution in creating an environment that supports the transformation of the education system.

- Human resources: Six-Sigma implementation requires faculty and staff who are competent, innovation-oriented, and skilled in analyzing data for evidence-based decision-making. By building human resource capacity through training and development, institutions can ensure that Six-Sigma processes are optimized. Looking at the current condition of Indonesia, one of the biggest challenges faced is the low quality of human resources. This is reflected in the data on the education level of the labour force, where 24.62% have the highest education at primary school level, 22.74% at junior high school level, and 30.22% at high school level. Meanwhile, only 10.15% have pursued higher education, and another 12.26% do not have a diploma (BPS, 2024). Qualified human resources (HR) play a key role in supporting Indonesia's progress. Excellent human resources can utilize the potential of natural resources to build the nation's glory, reduce dependence on imports, make Indonesia a strong producer country, and encourage sustainable economic growth and get out of the middle income trap. In addition, reliable human resources also contribute to global competitiveness, the development of future science and technology, and the sustainable management of megacity trends without ignoring natural preservation. In addition to having strong technical skills (hard skills), Indonesian human resources must master lifelong learning skills, which are an important asset in facing dynamic changes and rapid technological developments. Furthermore, Indonesian human resources also need to have noble morals, superior character, high fighting power, and uphold the values of morality, religion and national culture as the foundation of national character. Improving the quality of graduates is crucial to strengthening the nation's competitiveness. Educational institutions continue to produce graduates, while the business world and the environment continue to grow. This can lead to a long-term backlog of job seekers due to low labor absorption by the industry. Producing graduates who are ready to work is a form of public responsibility of higher education. A quality university always seeks to improve the education and learning process by referring to data on the absorption of graduates or their employability level. The existence of lecturers as one of the important elements in higher education human resources has a very vital role in producing superior and resilient human resources. In addition, lecturers also play a role in creating various innovations in the field of science and technology in the future, as well as following and developing learning strategies and academic leadership that are responsive to the challenges of higher education in the future. The mismatch between the field of study

and the competence of graduates with the needs of business and industry is one of the factors causing the low absorption of graduates. Therefore, universities need to periodically evaluate and update the curriculum so that the competencies of graduates produced are in accordance with industry needs. In addition, the curriculum must also consider future competency needs related to data literacy and digital literacy. It should be emphasized that the era of industrial revolution 4.0, also known as the era of disruption, has resulted in many changes in the order of life. Rapid changes, future uncertainty, and the increasing complexity of problems to be solved require universities to equip their graduates with inter- and trans disciplinary knowledge and skills. Six-Sigma teaches principles of rigor, problem-solving, and process management that can improve efficiency and quality in a variety of sectors. In addition, implementing Six-Sigma in organizations will help create a more systematic and data-driven culture, which requires individuals to continuously learn and adapt to change. In the long run, this approach can shape human resources who are not only technically skilled, but also have a strong character, can work in teams, and have the ability to continue to develop according to the demands of the times, thus contributing to the development of a more advanced and globally competitive Indonesia.

- Infrastructure facilities: adequate infrastructure, including supporting technology and modern learning facilities, is an important foundation to support Six-Sigma implementation. An environment equipped with high-quality facilities allows the teaching-learning process to run more efficiently and effectively. Higher education in Indonesia must seriously develop STEAM (Science, Technology, Engineering, Arts, and Mathematics) fields to catch up with other developing and developed countries. To support the strengthening of science and technology, the government needs to strengthen existing universities or open new institutes of technology, as well as provide adequate research facilities and human resources. The government also needs to encourage more in-country postgraduate scholarships for master's and doctoral programs, so that universities can focus more on their research missions, which in turn will accelerate the down streaming of Indonesia's natural resource potential. This effort is needed to address the shortage of human resources in science and engineering, which is caused by the limited number of exact studies programs that tend to be more expensive to organize compared to social studies programs. One strategy that can be implemented is to require universities to open at least one study program in mathematics and natural sciences every time they open a medical or social

science study program. The development of scholarship incentives or education credits for STEAM students should also be considered to attract interest. In addition, universities that organize exact study programs can be given incentives as rewards. In this context, the application of Six-Sigma can play a role in optimizing the higher education system in Indonesia, especially in the management of education and research processes. With Six-Sigma principles, universities can identify and reduce variability in learning and research processes, improve the quality of graduates, and manage limited resources more efficiently. Six-Sigma can also assist institutions in monitoring and evaluating the results of existing programs, to ensure that they produce graduates with competencies that are in line with industry needs and technological developments, supporting the development of quality human resources in the STEAM field. To drive the nation's progress and independence, national innovation capacity must be strengthened through the sustainability of higher education. Innovation is usually driven by creativity based on deep knowledge mastery, broad insight, freedom, and imagination in work, as well as partnerships across disciplines, expertise, and industries through competition, cooperation, collaboration, and coalition. Indonesia needs to immediately shift from an economic development model that relies on natural resources (resource-based economy) to a development model that focuses on knowledge resources (knowledge-based economy). The quality of human resources and mastery of science and technology will be the main determining factors in realizing this change.

- Organizational Culture: An organizational culture that supports innovation, collaboration, and continuous improvement is keys to Six-Sigma success. Institutions should promote values that encourage openness to change and quality orientation. As part of the organizational culture, universities need to develop a relevant and up-to-date curriculum, covering the knowledge and skills needed to meet industry demands. This curriculum development process should involve data collected from various sources; including the results of labor market needs analysis and feedback from alumni, which is aligned with Six-Sigma principles to continuously improve the quality of learning. In addition, an organizational culture that supports sustainability is also in line with the implementation of Six-Sigma, which encourages universities to integrate sustainability programs that include efficient management of natural resources, waste reduction, and promotion of environmental awareness as stipulated in the education policy enshrined in the constitution, especially as elaborated in the

National Education System Law (Law No. 20 of 2003) and other related regulations, such as the Teachers and Lecturers Law (Law 14/2005), the Education Legal Entity Law (Law 9/2009), and the Higher Education Law (Law 12/2012), providing a strong legal foundation for the development of education in Indonesia as an organization. This can be measured through clear and traceable performance indicators, in accordance with Six-Sigma's principle of measuring and improving performance continuously. In addition, to support green education policies, universities need to take concrete steps in reducing the carbon footprint and environmental impact oy universities activities. Six-Sigma can be applied to monitor and reduce energy consumption, waste management, and natural resource use on campus, by involving all elements of the organizational culture to create a more sustainable environment. By building an organizational culture that supports Six-Sigma implementation, universities can not only produce graduates who have relevant competencies, but also those who are committed to the principles of sustainability and social responsibility.

- Leadership: Visionary leadership capable of steering the organization towards sustainable transformation is an essential element. Leaders must facilitate Six-Sigma implementation by providing strategic guidance, motivation, and support in managing change. Where we want our higher education to go will be greatly influenced by the policies of the leaders that have been taken and decided in relation to higher education. Indonesia's Vision 2045 has been formulated to portray Indonesia as a developed, modern country that is on par with global superpowers. This vision aims to improve the welfare of the people through improving the quality of human resources (HR), significant economic growth, and equitable distribution of development. This vision is supported by five main targets, namely per capita income on par with developed countries, poverty and inequality reduction, increased competitiveness of human resources, a greater global role, and reduced greenhouse gas emissions towards Net Zero Emission. Indonesia is also projected to become one of the five largest economies in the world by 2050, with a GDP estimated at US$10.5 trillion. With a large demographic bonus, Indonesia has a great opportunity to achieve the Golden Indonesia of 2045, although major challenges remain, especially related to economic growth which is currently still limited to around 5%. To realize this vision, it requires strong and innovative human resources capable of supporting a higher rate of economic growth. Higher education plays an important role in producing graduates who can fulfill these needs. The application of Six-Sigma in higher education can be

an effective strategy to support the sustainability and achievement of Indonesia's vision 2045. With the principle of continuous improvement, Six-Sigma can help universities in improving the quality of curriculum, learning process, and resource management to produce competent and innovative graduates. In addition, Six-Sigma can be integrated to increase operational efficiency, reduce waste, and improve educational processes in a sustainable manner, which is in line with the goal to achieve higher and sustainable economic growth in Indonesia.

- Budget and Financial Resources: Sufficient financial resources are required to support the implementation of Six-Sigma programs, including training, infrastructure investment, and technology development. Budget efficiency must also be well managed to maximize the return on these investments. Education financing should be seen as a long-term investment that is as important as basic infrastructure development. The government needs to demonstrate a strong commitment to strengthening investment in the education sector, which includes supporting the expansion of scholarship programs, promoting culture, strengthening international universities, and developing research and innovation. As part of the effort to realize superior, innovative, integrity and competitive human resources for Golden Indonesia 2045, the government has allocated an education budget of IDR 660.8 trillion or 20 per cent of the 2024 State Budget. The allocation consists of central government spending of IDR 237.3 trillion, transfers to regions of IDR 346.6 trillion, and investment financing of IDR 77.0 trillion, which includes endowment funds for pesantren, research, universities, and culture. The education budget in 2024 shows and increase compared to 2023, which was recorded at IDR 612.2 trillion. However, the distribution of budget allocations for higher education needs to be adjusted to the mission of each institution to be in line with the assignments given by the government. Educational scholarships play an important role in increasing the number of qualified human resources. The government needs to increase the provision of educational assistance and scholarships for students from underprivileged families, affirmation areas, and outstanding children through the APBN and APBD. In addition, the government needs to encourage more domestic scholarships for master and doctoral programs, in addition to undergraduate programs, and provide incentives for universities to open study programs in exact fields to support the strengthening of STEAM. This can also strengthen applied research such as reverse engineering that aims to reduce dependence on imported products or components. In a fair and

effective manner, the education budget needs to be allocated to provide educational assistance and scholarships for undergraduate and postgraduate education, both through the APBN and APBD. Higher education budget management can be carried out more proportionally under the authority of the Ministry of Education, Culture, Research and Technology, allowing Ministry of higher education to play a more effective role in formulating policies and allocating funds for the higher education sector. In addition to increasing the number and accessibility of scholarships, Indonesians also need to realize the importance of investing in education. Parents who are aware of the importance of higher education will save money to provide proper education for their children. However, higher education is a right for everyone, so the government needs to design an education funding system that is more accessible to all members of society. The principle of accountability in higher education management can be strengthened through the implementation of the Six-Sigma approach, which focuses on continuous quality and efficiency improvement. By applying Six-Sigma, universities can evaluate and measure organizational performance based on objective data, thus ensuring that every resource-including infrastructure, human resources, and budget-is managed effectively and efficiently. This approach supports a structured management and quality assurance system, and ensures continuous monitoring in academic and non-academic areas. Six-Sigma can assist in identifying and reducing variability in processes, both in teaching and administrative activities, ultimately improving the quality of education. By using this method, universities can ensure that every program they run contributes to the achievement of the broader goal of producing high-quality graduates who are globally competitive. Furthermore, Six-Sigma implementation supports transparency and accountability, as every step and decision can be accounted for based on clear data. This, in turn, builds public trust in the quality of education provided.

- Stakeholder Engagement: Stakeholder engagement, including students, faculty, industry, and government, ensures that Six-Sigma implementation is aligned with labor market needs and socio-economic developments. This engagement also helps in receiving relevant feedback for continuous improvement. To achieve a “Golden Indonesia” 2045, it has been agreed that synergies are needed involving various parties that support sustainability. The approach used is no longer limited to the triple-helix model involving government, business, and higher education, but has evolved into a hexa-helix, which includes a wider range of stakeholders, including

government, business, higher education, NGOs (e.g. professional associations, THES, QSWorld, Webo, and others), mass media, and higher education-related communities (e.g. IKOMA). This is due to the fact that higher education accountability is not only determined by the government, especially the Ministry of Education, Culture and Research, but also by all the stakeholders mentioned above. Therefore, the higher education development strategy in order to achieve the Golden Indonesia 2045 needs to be supported by an ecosystem that involves all relevant parties. The government plays a vital role in the advancement of higher education in Indonesia. Therefore, the government needs to transform into a professional regulator, be consistent in supporting the development of higher education, provide autonomy to universities, and provide funding based on quality and results achieved. The synergy between the government, universities and industry cannot be realized in isolation. It requires the involvement of various stakeholders to create an innovation ecosystem in Indonesia. To build effective synergies, a common vision is needed between universities, industry, and society in developing a knowledge-based innovation ecosystem. In addition, good leadership skills on the part of universities, industry and government are also very important in building this synergy. Such cooperation should not only be limited to research and industrial applications, but also include the field of education, where students should be given wider access to learn about the application of the knowledge they acquire on campus. Indonesia needs to prepare its people to be able to adapt to various advances in technology and information in all fields, both with positive and negative impacts. The community acts as a key player and determines the direction in which these advances benefit people's lives. People must understand the importance of investing in education for the future, especially through higher education. The government's role includes managing education development through the establishment of regulations, increasing the effectiveness of the use of the education budget, and increasing the amount and allocation of the higher education budget to encourage innovation and competitiveness of the nation. Higher education governance and autonomy policies that support the development and independence of management based on output quality are very important. Responding to the issue of PTN Berbadan Hukum (PTNBH) and PTN Badan Layanan Umum (BLU), the government acts as a professional regulator in providing autonomy and authority policies to universities, especially in terms of funding based on output quality, and building academic leadership with good governance. In terms of increasing the role of

the government and other stakeholders, it can be seen from the development of higher education policies based on the context and ongoing trends, while still opening up opportunities to support the potential for innovation to be carried out. The implementation of Six-Sigma in this context can be an effective approach to improving the quality of higher education. Through the application of Six-Sigma principles, universities can optimize internal processes, ensure consistency of results, and identify and eliminate variability in the education system.

Looking at Indonesia's current condition, the journey towards a “Golden Indonesia” is still quite long and difficult to achieve. Stagnant economic growth at 5% makes achieving the desired level of prosperity seem difficult. To achieve this goal, excellent and innovative human resources (HR) are needed, who also have high morals and ethics. The role of higher education in producing quality, innovative, moral and ethical human resources is crucial. However, the conditions of higher education that are not fully supportive can be an obstacle in achieving these ideals.

To overcome these challenges, the application of Six-Sigma principles in higher education management can be an effective solution. Six-Sigma, with its focus on quality improvement and variability reduction, can help universities improve their educational processes, from curriculum planning to human resources and facilities management. By applying Six-Sigma methodology, universities can be more efficient in producing graduates who not only excel in technical skills, but also have high moral and ethical character. Through this approach, it is expected that the quality of higher education will improve, contribute significantly to the achievement of innovative and competitive human resources, and support more sustainable economic growth towards an “Golden Indonesia 2045”.

5.2. Interpretation of Findings in the Context of Theory and Literature

The discussion of the results of this study can be reviewed by referring to the existing literature, especially those related to higher education sustainability, Six-Sigma implementation, and quality management in the context of higher education. This research focuses on strengthening the sustainability of higher education through the Six-Sigma approach, which seeks to improve the quality of services and processes in the higher education system in Indonesia. The results of this study are in line with existing literature on the importance of higher education sustainability as an integral element in global and national education systems. Many previous studies have highlighted the role of higher education in

producing quality human resources and its contribution to social, economic and cultural development (Adina-Petruta & Roxana, 2014; Ameen Abdullah & Kavilal, 2022; Chroeder et al., 2008). Sustainability of higher education in this context is often associated with improving access, quality and relevance of the curriculum that can accommodate industry needs (Ratvasky & Furterer, 2024) and technological developments (O'Reilly et al., 2019; Sunder M, 2016; Svensson et al., 2015). This research adds a new dimension by using the Six-Sigma approach to improve efficiency and effectiveness in education process management, which is also seen as an important step in ensuring such sustainability (Antony, 2017; Clemons & Jance, 2024; Sharma, A.K et al., 2013;). Along with many studies linking educational sustainability to innovation and collaboration between various stakeholders (Budihardjo et al., 2021), the application of Six-Sigma can strengthen these efforts by providing a data-driven framework for continuous process analysis and improvement (Antony et al., 2012; Sunder M, 2016).

In terms of Six-Sigma theory, the results of this study support many existing findings regarding the benefits of implementing Six-Sigma in educational organizations. Six-Sigma, which focuses on variability reduction and process improvement, has been applied in various sectors, including higher education (Adina-Petruta & Roxana, 2014; Sunder M, 2016). The literacy in using Six-Sigma to improve quality in higher education has also been discussed in a number of literatures, which show that Six-Sigma can help identify areas that need improvement in the education management system, such as administrative management, teaching quality, and interaction between faculty and students (J. Li & Xue, 2022; Sunder M & Antony, 2018). This research confirms that this data-driven approach can facilitate better decision-making, as well as minimize errors that can affect the performance of universities in producing competitive graduates (Thomas et al., 2017). However, there are also some differences or challenges faced in applying Six-Sigma in the context of higher education, which have been previously pointed out by other studies. For example, in the existing literature, it is argued that the Six-Sigma approach, which is often applied in the industrial sector, is sometimes not fully compatible with the characteristics of education, which is more multidimensional and involves complex human interactions (Antony et al., 2012; Barcia et al., 2022; Cudney et al., 2020). In this regard, although this research supports the implementation of Six-Sigma in higher education, a key challenge is how to adapt Six-Sigma principles that are typically used in manufacturing or business environments, to be applied in

the more dynamic and diverse context of education (Antony et al., 2018; Lu et al., 2017; Sunder M & Antony, 2018; Svensson et al., 2015).

This research contributes to this discourse by adding Six-Sigma as an alternative or complement in order to strengthen higher education quality management systems. The Six-Sigma concept with its focus on measurement, analysis, improvement, and quality control is highly relevant to minimizing errors in the educational process and improving the outcomes achieved by students and faculty. Some previous studies may have placed more emphasis on utilizing quality models that are more based on overall quality management (such as TQM), which emphasizes the empowerment of all members of the organization and cross-divisional collaboration in improving overall quality. However, the application of Six-Sigma in this context puts a sharper focus on data-driven problem solving, as well as variability reduction that can improve efficiency and satisfaction of students and other stakeholders. This research also emphasizes the need for continuous improvement through the DMAIC cycle (Define, Measure, Analyze, Improve, Control), which is in line with principles that have been widely discussed in the quality management literature in higher education.

5.3. Theoretical and Practical Implications

Based on the above description, there are four main recommendations for higher education policy in Indonesia that are relevant to the findings of this research by considering the results of data-based qualitative and robust analysis (quantitative) such as Six-Sigma, Fishbone diagram, DMAIC cycle findings (Define, Measure, Analyze, Improve, Control), SIPOC diagram synergized with SEM approach by utilizing Six-Sigma methodology to elaborate and answer research questions.

- University Mission Differentiation in Indonesia. Higher education has a strategic role in facing challenges through higher education, by making significant contributions in three main aspects. First, producing superior and resilient human resources (HR) as graduates who are ready to face global dynamics. Second, developing competent lecturers and academic staff to produce various innovations in science and technology (IPTEK). Third, acting as a guardian of national and human values. These three roles are interconnected, where lecturers are not only a key element in producing quality human resources but also a driving force in producing superior innovations that support the noble values of humanity and nationality. The major challenges of higher education include the creation of resilient human resources, increasing national

innovation capacity, developing the nation's industrial and economic sectors, and preserving national and human values. To realize this, it is necessary to implement a mission differentiation policy for universities, which gives a specific mandate to each institution according to its role. With this approach, universities can focus more on carrying out their duties, both in strengthening human resources, developing innovation, improving the industrial, economic and health sectors, as well as in supporting the quality of primary and secondary education. This mission differentiation policy is expected to strengthen the contribution of higher education in various sectors of national development.

- Strengthening Science and Technology. To become a developed country with high innovation productivity, strengthening the STEAM (Science, Technology, Engineering, Arts, and Mathematics) field is a major capital that cannot be ignored. In order to realize this, the establishment of new technology institutes, including vocational education, as well as the strengthening of existing universities are strategic steps that need to be taken, especially in areas outside Java. This is important given Indonesia's vast territory, the potential for great natural wealth, the significant population, and the inequality of development between regions. New institutes of technology act as a guarantee of the availability of a high skill-labor force to support the strengthening of the industrial sector in the face of rapid changes in the business environment, as well as supporting a knowledge-based economy. Strengthening existing universities can be done through the opening of strategic study programs, construction of research laboratory facilities, and cooperation with the industrial sector to utilize the potential of regional natural resources.
- Equitable Education Funding. Equitable funding plays a vital role in the recruitment, development, and retention of qualified faculty and staff by allocating resources for capacity-building programs such as training and advanced studies, thereby enhancing human resource competence across all regions, including underserved areas, to bridge gaps in educational quality. Additionally, adequate infrastructure, as a cornerstone of quality education, benefits from equitable funding by ensuring sufficient investment in state-of-the-art laboratories, libraries, and digital learning tools, particularly for universities in remote or underdeveloped regions, fostering inclusive learning environments and driving regional innovation and development. Furthermore, building a robust organizational culture requires targeted funding initiatives to

promote collaboration, inclusivity, and continuous improvement, with alignment to Six-Sigma principles such as data-driven decision-making and quality enhancement, enabling operational excellence and addressing inequities in educational outcomes. Equitable funding also facilitates the development of strong leadership through well-funded training programs, equipping leaders with the skills to manage resources effectively and adapt to challenges such as regional disparities and evolving stakeholder expectations. Moreover, equitable funding ensures meaningful stakeholder engagement by providing institutions with resources to build partnerships with governments, industries, communities, and international actors, thereby enhancing educational relevance, bridging funding gaps, and supporting sustainable innovation. Through the structured methodology of Six-Sigma, funding allocation is optimized to reduce variability and inefficiencies, ensuring resources are distributed effectively to address disparities and improve educational outcomes, ultimately supporting the vision of a sustainable, inclusive, and competitive higher education system in Indonesia.

- Autonomous Higher Education Policies. The concept of Autonomous Higher Education Policies, as explored in the study "Enhancing Sustainable Higher Education in Indonesia: Six-Sigma Approach," emphasizes the importance of granting universities greater flexibility in managing their resources, governance, and academic programs. This autonomy is recognized as a pivotal mechanism for fostering innovation, enhancing efficiency, and achieving long-term educational sustainability. The study integrates Six-Sigma principles to assess how autonomy interacts with key indicators, including human resources, infrastructure facilities, organizational culture, leadership, stakeholder engagement, and budgeting, thereby shaping a more robust and sustainable higher education ecosystem. By allowing institutions to implement tailored policies for human resources, such as recruitment, professional development, and retention, autonomy facilitates the creation of a skilled workforce aligned with institutional goals, with Six-Sigma ensuring data-driven improvements. In terms of infrastructure facilities, autonomous policies enable institutions to prioritize investments in critical areas like laboratories, libraries, and digital platforms, addressing regional disparities in access to quality education. Furthermore, autonomy promotes a strong organizational culture, fostering collaboration, inclusivity, and continuous improvement, in line with Six-Sigma's principles. It also empowers leadership, allowing university leaders to craft strategic visions, manage resources

efficiently, and make decisions responsive to institutional challenges, all while ensuring operational excellence through Six-Sigma methodologies. Additionally, autonomy enhances stakeholder engagement, enabling universities to form impactful partnerships with governments, industries, and local communities, furthering innovation and educational relevance. Lastly, budgeting is optimized under autonomous policies, enabling institutions to allocate financial resources effectively to support areas that will have the most significant impact. Ultimately, the integration of Six-Sigma in the context of autonomous higher education policies provides a structured approach that enables institutions to achieve sustainability, address regional disparities, and enhance their global competitiveness, creating a more equitable and effective higher education system in Indonesia.

Overall, this study concludes that the application of Six-Sigma principles can significantly support the sustainability of higher education in Indonesia. The research findings show that Six-Sigma not only improves the efficiency and effectiveness of higher education management, but also affects various important aspects, such as human resources, infrastructure facilities, organizational culture, leadership, budget and financial resources, and stakeholder engagement. In particular, Six-Sigma plays a role in strengthening Human Resources management through data-driven policies for recruitment and development, which in turn improves the competence of lecturers and staff. The implementation of Six-Sigma also ensures a more efficient allocation of infrastructure resources, enabling colleges, especially in remote areas, to access better educational facilities and technology. In addition, Six-Sigma-based policies encourage the creation of an organizational culture that prioritizes collaboration, innovation and continuous improvement, ultimately improving college performance. Well-trained and effective leadership is key in ensuring the successful implementation of the policy. With more efficient budget allocation based on data analysis, Six-Sigma contributes to the financial sustainability of higher education. In addition, increased Stakeholder Engagement with industry, government, and local communities strengthens the relevance of higher education to market needs and technological developments. Overall, the findings confirm that Six-Sigma implementation helps Indonesian higher education institutions achieve greater sustainability, both through improving the quality and access of education, as well as by optimizing the use of resources and increasing stakeholder participation. The research emphasizes that to create a sustainable higher education system, it is imperative to integrate data-driven management approaches that focus

on efficiency, effectiveness and quality across all aspects of higher education operations and management.

To achieve optimal results, all of the above recommendations need to be implemented in their entirety and with care, rather than a choice of one over the other. However, implementing all of these recommendations requires attention and time. Therefore, it is necessary to priorities their implementation so that the impact can be felt in a shorter period of time. This prioritization can be based on an analysis of the needs and current conditions of each university, as well as the readiness of each institution in applying Six-Sigma principles. The urgent first step is to focus on strengthening human resources and infrastructure, which are the main foundations for the sustainability of higher education in Indonesia. Then, strengthening organizational culture, leadership, and stakeholder engagement need to be done in parallel, as these aspects support each other to create a more efficient and sustainable higher education ecosystem. In addition, more efficient management of budget and financial Resources should also be a top priority to support the financial sustainability of higher education. With a focused and data-driven approach, implementing these recommendations will have a significant impact in improving the quality and access of higher education in Indonesia, as well as preparing universities to face global challenges.

5.4. Research Limitations and Future Research Directions

The study titled "Enhancing Sustainability of Higher Education in Indonesia: Six-Sigma Approach" has several limitations that should be considered when interpreting its results.

- First, although this research employs a mixed-methods approach (qualitative and quantitative), the data used is limited to specific higher education institutions in Indonesia, meaning the findings may not be fully representative of the entire higher education sector in the country. Additionally, geographical limitations may influence the findings, as the majority of the data was collected from universities in certain regions, and other areas with different characteristics may face greater challenges in implementing Six-Sigma.
- Second, while the Six-Sigma approach focuses on efficiency and data-driven management, the challenges of adopting these principles across universities in Indonesia, particularly those with limited resources, remain an issue that requires time and a lengthy process. Furthermore, the implementation of Six-Sigma demands a level of organizational readiness and culture that may not yet be fully developed in

many institutions. Third, this study does not explore in-depth the role of external factors, such as government policies or global economic dynamics, which may influence the sustainability of higher education in Indonesia.

Future research could expand the scope by involving more universities from various regions across Indonesia, including those in remote areas, to provide a more comprehensive view of the challenges and opportunities in implementing Six-Sigma. Furthermore, future studies could conduct longitudinal analyses to evaluate the long-term impact of Six-Sigma implementation on the sustainability of higher education, as well as identify the factors influencing its success and barriers to its implementation. Additionally, further research could delve deeper into the influence of government policies on the implementation of Six-Sigma in higher education institutions, particularly regarding budget allocation and the development of policies that support the sustainability of higher education. Developing a more adaptive and responsive policy model tailored to the specific conditions of each institution could be a key focus for future studies. Future research could also explore how technology and digitalization can be further leveraged in Six-Sigma implementation to enhance efficiency in higher education management. Moreover, further analysis on the impact of increased stakeholder engagement, including industry and government, in the planning and management of higher education should be considered to identify ways to better align higher education with market needs and technological advancements.

6. MAIN CONCLUSION AND NOVELTY FINDINGS

6.1. Main Conclusion

Sustainable higher education is one of the crucial aspects in supporting human resource development and improving the nation's competitiveness. In the Indonesian context, the sustainability of higher education faces various challenges, including the quality of management, operational efficiency, and the demands of improving academic standards amid limited resources. This dissertation focuses on the application of the Six Sigma approach in improving the sustainability of higher education in Indonesia. Through a Define, Measure, Analyze, Improve, and Control (DMAIC)-based methodology, this research explores how quality improvement strategies can be implemented systematically to overcome the various obstacles faced by higher education institutions. The findings demonstrate that by locating and removing the causes of inefficiencies and inconsistencies in academic and administrative procedures, the Six Sigma methodology can be a useful instrument for enhancing the sustainability of higher education. Higher education institutions can create data-driven plans to lower academic service error rates, raise student satisfaction, and more effectively allocate resources by implementing Six Sigma techniques. Furthermore, this study discovered that Six Sigma adoption fosters a continuous improvement culture in the academic setting in addition to having an impact on operational elements.

Furthermore, this study indicates that the effective adoption of Six Sigma in higher education is strongly dependent on the support of institutional leadership, involvement of all stakeholders, and preparedness to adopt data and technology-based approaches. Without the commitment of the management and active participation of lecturers and education staff, Six Sigma-based transformation is difficult to obtain optimal results. Therefore, in order to fully reap the benefits of Six Sigma, its adoption requires a well-developed organizational change strategy, ongoing training, and an open evaluation system.

The study's conclusions demonstrate that the Six Sigma methodology may be a useful framework for raising the standard and effectiveness of Indonesian higher education. When implemented correctly, educational institutions can increase decision-making accuracy, decrease academic process variability, and establish a more efficient and flexible learning environment. This study also demonstrates that managerial considerations, regulations, and technology advancements that promote greater operational efficiency all have an impact on

the sustainability of higher education in addition to academic concerns. This dissertation recommends that Indonesian higher education institutions start implementing Six Sigma concepts more extensively in quality control and strategic planning. In order to establish a more sustainable higher education system, emphasis should be placed on developing human resources, incorporating technology into academic procedures, and putting in place a data-driven performance monitoring system. Furthermore, it is imperative to reinforce policies that foster innovation and cross-sector cooperation to guarantee that Indonesian higher education can compete both domestically and internationally. All things considered, this dissertation significantly advances the field of higher education management both theoretically and practically. This study provides new information about how educational institutions can implement quality-based methods to increase their sustainability and competitiveness by demonstrating the efficacy of the Six Sigma methodology. It is anticipated that the results of this study will serve as the foundation for the creation of more creative and empirically supported educational strategies, which will ultimately improve the administration of higher education in Indonesia.

6.2. Novelty Findings

This research makes a significant academic contribution by innovatively adapting Six Sigma methodologies typically used in manufacturing and service industries to the higher education sector, aiming to improve the sustainability and long-term viability of higher education institutions in Indonesia. By applying a systematic, data-driven approach to quality improvement, this research addresses a critical gap in the existing literature by demonstrating how Six Sigma principles can be effectively used to optimize academic quality, operational efficiency, and institutional governance in the higher education landscape from sustainability standpoint and environmental, economic and government (ESG) as well. The main novelty of this research lies in its comprehensive and in-depth analysis of Six Sigma's potential role in driving sustainable educational practices, which differentiates it from previous studies that emphasize more on general quality improvement in education. Unlike conventional research that focuses on broader educational reforms, this research provides a targeted examination of Six Sigma as a structured framework for continuous quality improvement, supported by empirical evidence and contextualized to the specific challenges faced by Indonesian higher education institutions. In addition, this research offers a nuanced exploration of the barriers and opportunities associated with implementing Six Sigma in academic settings, an area that remains under-explored in scholarly discourse. By integrating key principles from quality

management, higher education reform, and sustainability studies, this research contributes to the advancement of interdisciplinary scholarship in education management. Beyond its academic significance, this research carries important practical implications for policymakers, university administrators, and stakeholders seeking to improve institutional resilience and global competitiveness. The findings from this research have the potential to serve as a strategic foundation in driving national economic development, in line with Indonesia's long-term vision of a Golden Indonesia 2045. Through the enhancement of human capital capabilities and the establishment of strong and sustainable educational institutions, this research underscores the critical role of higher education in positioning Indonesia as a leading global economy in the future.

This research not only contributes to scholarly discourse but also gives higher education institutions practical insights for successfully implementing Six Sigma methodology by offering an organized and evidence-based framework for quality enhancement. Universities can reduce inefficiencies, improve student satisfaction, and make sure that institutional aims are in line with national development goals by implementing Six Sigma into academic operations. Furthermore, this study emphasizes how crucial faculty involvement, institutional flexibility, and leadership commitment are to effectively integrating Six Sigma methods into academic settings. Additionally, by highlighting the necessity of ongoing evaluation and iterative improvement procedures, this study emphasizes the relationship between data-driven decision-making and sustainable educational progress. Through the use of empirical data, this study provides policymakers in higher education with specific recommendations, including the implementation of performance indicators based on Six Sigma to improve curriculum relevance, promote institutional responsibility, and fortify research and innovation ecosystems. By doing thus, it contributes to the larger global conversation on quality assurance in higher education by offering a reproducible model that may be modified for use in various educational environments outside of Indonesia. Broadly speaking, this novelty also answers the research question, which is part of the hypothesis in this study as mention in chapter 1 show by Table 12.

Table 12: Summary of Research Novelty

Six-Sigma's Contribution to Higher Education Sustainability	• Integrating Six Sigma (SS) to enhance operational efficiency and resource optimization in Indonesian higher education. • Utilizing DMAIC methodology to improve human resources management (HR), infrastructure facilities

	utilization (IF), and budgeting and financial (BF) efficiency for long-term sustainability. • Strengthening leadership (LD) and stakeholder engagement (SE) strategies through data-driven decision-making in sustainability initiatives.
Challenges in Implementing Six-Sigma in Higher Education	• Human resource (HR) constraints include resistance to change and lack of Six Sigma expertise. • Infrastructure (IF) and organizational challenges (OC) include outdated systems and limited integration of Six Sigma practices in academic and administrative processes. • Budgeting and financial (BF) constraints impacting the feasibility of Six-Sigma training and implementation. • Leadership (LD) and governance barriers, where organizational culture (OC) may hinder structured quality improvement efforts.
Measuring Sustainability Using Design for Six-Sigma (DFSS)	• Developing qualitative and quantitative metrics for sustainability (SHE) performance in higher education using DMAIC principles required. • Assessing human resources (HR) engagement, infrastructure facilities efficiency (IF), budgeting and financial (BF) sustainability, stakeholder engagement (SE) and leadership (LD) effectiveness through Six-Sigma-based evaluation models. • Creating a predictive framework to forecast the long-term impact of sustainability (SHE) initiatives in higher education.

Sources: Based on own works, 2025

SUMMARY

The foundation of this study is the significance of enhancing competitive advantage by raising the excellence of Indonesian human resources, which is inextricably linked to the function of higher education. Lifelong learning encompasses a range of social, economic, and environmental topics.

Chapter one examines the research's primary goal: how using the Six Sigma methodology affects higher education institutions' ability to remain sustainable. This research aims to determine how Six Sigma can enhance operational effectiveness, cut waste, and raise the standard of educational services. This study will likely offer strategic recommendations for higher education institutions in Indonesia to successfully and sustainably implement Six Sigma by comprehending the existing opportunities and difficulties. According to the research gap, one of the biggest challenges facing higher education is the poor caliber of teachers, which affects Indonesia's low Human Development Index (HDI). Six Sigma's methodology, which emphasises quality control and continuous improvement, may offer a solution. Universities can detect important issues in the educational system, such as poor teacher motivation, lack of training, and material that is not updated frequently, by using DMAIC techniques (Define, Measure, Analyse, Improve, and Control).

Higher education, sustainability, Six Sigma techniques, and their analytical tools are some of the ideas reviewed in Chapter Two that support this research. Economic, social and environmental factors are all included in higher education sustainability, which emphasises the operational efficiency and long-term development contributions of academic institutions. Six Sigma methodology, a quality management technique that focuses on reducing process variation to improve efficiency and customer satisfaction, can help higher education address several issues, including management effectiveness, teaching quality, and accessibility. Lean Six Sigma (LSS), which integrates Lean Manufacturing concepts to reduce waste and improve productivity in higher education operations, is one of the emerging methodologies. To implement Six Sigma, tools such as SIPOC (Supplier, Input, Process, Output, and Customer) are used to map the flow of academic and administrative activities, and DMAIC (Define, Measure, Analyse, Improve, Control) techniques are used to systematically identify and fix problems. Furthermore, Fishbone (Ishikawa) diagrams are used to examine the underlying reasons for problems in education, including curriculum, infrastructure and teacher quality.

To examine Six Sigma implementation in higher education related to sustainability, Chapter Three outlines how to combine qualitative and quantitative methodologies. Through case studies and interviews, qualitative data analysis helps understand the perspectives, difficulties and possibilities associated with Six Sigma implementation. In contrast, quantitative data analysis uses statistical data to measure its efficacy. Root causes are discovered, and academic processes are mapped using diagram analysis techniques such as Fishbone and SIPOC. To create a more successful improvement plan, the study also correlated the results with the Six Sigma Framework, specifically at the DMAIC level. Surveys, observations, and document analyses were used to gather information to thoroughly understand how Six Sigma is applied to improve the sustainability of Indonesian higher education.

Thus, chapter four evaluates the application of Six Sigma in higher education by combining qualitative and quantitative analysis to identify the study's findings. A qualitative analysis was conducted using NVivo 15, employing data coding and thematic analysis to find important patterns in the interviews and observations. Descriptive statistics, validity and reliability testing, and outer loading and bootstrapping procedures were employed in quantitative analysis using SMART PLS 4 and SPSS 28 to guarantee data accuracy. Fishbone Diagrams for root cause analysis, DMAIC for process improvement, and SIPOC for workflow mapping reinforce the integration of these two methodologies, offering a thorough picture of how well Six Sigma works to enhance the sustainability of higher education.

Furthermore, the key conclusions about approaching the Six Sigma methodology in higher education are summed up in chapter five. The study suggests this approach can raise academic service quality, cut waste, and increase operational efficiency. The findings' interpretation in light of theory and literature demonstrates the importance of DMAIC, SIPOC, and Fishbone Diagrams in locating and removing obstacles in the higher education system. While practical implications include suggestions for higher education institutions to implement Six Sigma, theoretical implications successfully include contributions to the growth of quality management literature in the education sector. Limitations of this study include possible bias in data collection and restricted sample coverage. As a result, future research is advised to broaden the analysis using a wider range of methodologies and investigate the use of Lean Six Sigma in diverse educational settings.

Finally, chapter six of this study found that Six Sigma implementation plays an important role in driving the sustainability of higher education in Indonesia, particularly through

optimizing resources and improving operational efficiency through the DMAIC approach. To achieve long-term sustainability in higher education institutions, this approach has been proven to improve infrastructure usage efficiency (SSP), budget and financial optimization (BH), and human resource management (HRM). Combining Six Sigma with sustainability methods in higher education, which are more commonly used in the manufacturing and service sectors, makes this research novel. In addition, by integrating DMAIC, Design for Six Sigma (DFSS), and qualitative and quantitative evaluation models, this research provides a more thorough and data-driven method for assessing Six Sigma success in academic settings.

Implementing Six Sigma in higher education is not without its difficulties, though, including a lack of knowledge, experience, and opposition to change in the academic setting. Stakeholder involvement (SE) and leadership factors (LD) are important elements that affect how well Six Sigma is implemented. Additional limitations that affect the durability of training and the application of this approach are financial limitations (BF) and organisational system inadequacies (OC). This study used a DFSS approach to assess the efficacy and impact of Six Sigma sustainability by creating qualitative and quantitative indicators based on DMAIC. This includes evaluating several important components in a structured model, including HR, IF, BF, SE, and LD. The study also provides a new predictive paradigm for examining the long-term impact of various sustainability measures in higher education. Using this data-driven approach, academic institutions can make more effective policies to improve their operational sustainability and competitiveness in the face of changing global dynamics.

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List of Abbreviation

Abbreviation	Full Form
AVE	Average Variance Extracted
BINUS	Bina Nusantara University
BPS	Statistic Indonesia Bureau
BF	Budgeting and financial
CR	Composite Reliability
CSR	Corporate Social Responsibility
DFSS	Design for Six-Sigma
DMADV	Define, Measure, Analyze, Design, and Verify
DMAIC	Define, Measure, Analyze, Improve, and Control
DUDI	Business and Industrial Sectors
GE	General Electric
HE	Higher Education
HEIs	Higher Education Institutions
HDI	Human Development Index
HR	Human Resources
IF	Infrastructure Facilities
IPB	Bogor Agricultural University
ITB	Institute of Technology Bandung
KKN	Community Engagement Program
KPI	Key Performance Indicator
LD	Leadership
LPDP	Indonesia Endowment Fund for Education
LSS	Lean Six Sigma
NFI	Normed Fix Index
RMSEA	Root Mean Square Error of Approximation
SE	Stakeholder Engagement
SEM	Structural Equation Modeling
SDGs	Sustainable Development Goals
SHE	Sustainability Higher Education
SIPOC	Suppliers, Inputs, Processes, Outputs, and Customers
SS	Six Sigma
SPC	Statistical Process Control
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TA	Thematic Analysis
OC	Organizational Culture
UI	University of Indonesia
UGM	Gadjah Mada University
UNDIP	Diponegoro University
UNS	Sebelas Maret University
USU	University of North Sumatra
UPI	Indonesia University of Education
UNPAD	Padjadjaran University
UNHAS	Hasanuddin University
QFD	Quality Function Deployment

APPENDIX

Research Questioner

ENHANCING THE SUSTAINABILITY OF HIGHER EDUCATION IN INDONESIA: A SIX-SIGMA APPROACH

This research aims to explore and understand how Six Sigma methods can be applied to improve sustainability in higher education institutions in Indonesia.

Sustainability has become a major focus in various sectors, including higher education. With increasingly complex environmental challenges, higher education institutions have an important role in promoting sustainable practices. Six Sigma, a methodology that focuses on process improvement and reducing variability, offers a systematic and measurable framework to achieve this goal. Purpose of this questionnaire is designed to gather views, understandings, and experiences from various stakeholders in higher education institutions regarding the application of Six Sigma in sustainability efforts. The results of this quiz will help in identifying areas that need improvement, potential benefits, and challenges that may be faced in implementing Six Sigma for sustainability purposes.

Thank you for your participation. We appreciate your time and contribution to this research. If you have any questions or need further additions, please do not hesitate to contact us.

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Please give your information data below before moving to next part.

Part 1: Demographic Information

- Gender
  □ Male □ Female
- Ages
  □ < 30 years old □ 30 – 40 years old □ 40– 50 years old □ 50 – 60 years old □ > 60 years old
- Origin of university:……..
- Scientific rank
  □ Lector
  □ Assistant Professor- Lower
  □ Assistant Professor- Upper
  □ Associate Professor
  □ Professor
- Structural positions:…….

- Academic Title

  □ Master
  □ Doctor
  □ Full Professor
- University Status:
  □ PTN-BH (State University with Legal Entity)
  □ PTN-BLU (State Universities with Public Service Agency)
  □ PTN-Satker (State Universities as Ministry Work Units)
- Field of Study or Department
  □ Science
  □ Engineering
  □ Business
  □ Arts and Humanities
  □ Social Sciences
  □ Healthy Sciences
  □ Law
  □ Other : (please specify)

Please tick (√) for each statement below

Please indicate your level of agreement with each of the following statements by selecting the appropriate number on the scale where: 1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Part 2: Six-Sigma Implementation

INDICATOR	STATEMENTS	**SCALE**				
		1	2	3	4	5
Six-Sigma Implementation	The University/Institution has implemented DMAIC (Define, Measure, Analyze, Improve, and Control) measures to improve work processes in the field of education.					
	Key Performance Indicators (KPIs) of Merdeka Belajar programs are defined and monitored in your institution?'					
	Standard Operating Procedures (SOPs) related to education and sustainability policies are effectively implemented in your institution?					

	Industry involvement as a partner is very active in the development of curriculum and training programs at your institution					

Part 3: Human Resources

INDICATOR	STATEMENTS	**SCALE**				
		1	2	3	4	5
Human Resources	Human resource management (e.g., distribution of tasks, work schedules, and allocation of teaching staff) is well established in your institution.					
	The role of human resources has great potential in developing a curriculum that is relevant and in accordance with the educational needs of your institution.					
	The institution regularly provides training and professional development for faculty and other staff					

Part 4: Infrastructure Facilities

INDICATOR	STATEMENTS	**SCALE**				
		1	2	3	4	5
Infrastructure Facilities	The information systems and technology available in your institution are sufficient to support the smooth operation and learning process.					
	Your institution actively engages stakeholders in the planning and management of infrastructure facilities.					
	The security and safety systems in your institution are adequate to ensure a safe environment for all.					
	Infrastructure facilities at your institution support environmental sustainability through green policies and technologies					

Part 5: Organizational culture

INDICATOR	STATEMENTS	SCALE				
		1	2	3	4	5
Organizational culture	The curriculum and teaching materials implemented at your institution are relevant to the latest developments and industry needs.					
	Your institution has a sustainability programs that is integrated on campus and consistently applied in daily activities.					
	Your institution actively reduces the carbon footprint and environmental impact of campus activities through green policies and practices.					

Part 6: Leadership

INDICATOR	STATEMENTS	SCALE				
		1	2	3	4	5
Leadership	Leaders in your institution have a clear vision and can steer the organization towards long-term sustainable goals.					
	Leaders in your institution inspire and drive significant positive change in organizational culture and staff performance.					
	Leaders in your organization always act with integrity and promote high ethical values in every aspect of operations					

Part 7: Budget and Financial Resources

INDICATOR	STATEMENTS	SCALE				
		1	2	3	4	5
Budget and Financial	Your institution has a well-thought-out financial plan and efficient budget					

Resources	allocation to support programs.					
	Your institution has an effective strategy to generate income and diversify sources of funds for financial sustainability.					
	Your organization ensures accountability and transparency in financial management, and publicly reports on budget utilization.					
	Your institution implements a policy of cost efficiency and resource optimization to maximize results without wastage.					

Part 8: Stakeholder Engagement

INDICATOR	STATEMENTS	**SCALE**				
		1	2	3	4	5
Stakeholder Engagement	Your institution actively involves students and alumni in decision-making regarding brand-affecting policies and programs.					
	Your organization involves the community in the development and implementation of sustainability policies that impact the local environment.					
	Your institution has effective partnerships with government in formulating policies and programs that support educational and social sustainability.					

Part 9: Sustainability of Higher Education

INDICATOR	STATEMENTS	**SCALE**				
		1	2	3	4	5
Sustainability of Higher Education						
	Your institution actively implements environmentally friendly policies and practices in operations and teaching to					

	support environmental sustainability.					
	Your institution has an effective long-term strategy to ensure economic sustainability through diversification of income sources and prudent budget management.					
	Your institution supports social sustainability by promoting inclusivity, equity and justice within the campus environment and through social programs.					
	Your institution develops infrastructure and technology that supports the sustainability of education and supports efficient and sustainable learning processes.					

Part 10: Current State of Sustainability in Higher Education in Indonesia

1. How would you rate the current sustainability practices in your institution?
    - o Excellent
    - o Good
    - o Fair
    - o Poor
    - o Very Poor
2. Which areas do you believe need the most improvement to enhance sustainability in your institution? (Select all that apply)
    - o Energy efficiency
    - o Waste management
    - o Water conservation
    - o Curriculum development
    - o Research initiatives
    - o Community engagement
    - o Others (please specify)……..
3. What challenges does your institution face in implementing sustainable practices? (Select all that apply)
    - o Lack of funding
    - o Insufficient knowledge/training
    - o Resistance to change
    - o Limited resources
    - o Others (please specify)……

Part 11: Potential of Six Sigma in Enhancing Sustainability

4. In your opinion, which of the following Six Sigma tools could be most effective in enhancing sustainability in higher education? (Select all that apply)
    - o DMAIC (Define, Measure, Analyze, Improve, Control)

- DMADV (Define, Measure, Analyze, Design, Verify)
- SIPOC (Suppliers, Inputs, Process, Outputs, Customers)
- FMEA (Failure Modes and Effects Analysis)
- Control Charts
- Others (please specify)

5. How likely are you to support the implementation of Six Sigma projects aimed at improving sustainability in your institution?
    - Very likely
    - Likely
    - Neutral
    - Unlikely
    - Very unlikely
6. What resources or support would you need to effectively implement Six Sigma for sustainability initiatives? (Select all that apply)
    - Training programs
    - Financial support
    - Technical expertise
    - Leadership commitment
    - Collaboration with external experts
    - Others (please specify)

Part 12: Perceived Impact and Outcomes

7. What positive outcomes do you anticipate from applying Six Sigma to sustainability efforts in your institution? (Select all that apply)
    - Cost savings
    - Enhanced reputation
    - Improved environmental impact
    - Increased efficiency
    - Better stakeholder engagement
    - Others (please specify)
8. How do you think students can be involved in Six Sigma sustainability projects? (Select all that apply)
    - Participating in workshops/training
    - Engaging in research projects
    - Leading sustainability initiatives
    - Collaborating with faculty
    - Others (please specify)
9. What metrics should be used to measure the success of Six Sigma sustainability projects in higher education? (Select all that apply)
    - Reduction in energy consumption
    - Decrease in waste production
    - Water usage reduction
    - Financial savings
    - Improvement in sustainability awareness
    - Others (please specify)

Part 13: Open-ended Questions

10. In your view, what are the main barriers to enhancing sustainability in higher education in Indonesia?
11. Can you provide examples of successful sustainability initiatives in higher education that you are aware of?

12. How do you envision the role of Six Sigma in the future of sustainable higher education in Indonesia?
13. Do you have any additional comments or suggestions regarding the implementation of Six Sigma for sustainability in higher education?
14. To what extent does the implementation of Six Sigma in your institution contribute to the development of human resource competence and effectiveness in supporting the sustainability of higher education?
15. How does the existing facility infrastructure in your institution support Six Sigma implementation in achieving higher education sustainability goals?
16. To what extent does the organizational culture in your institution support the application of Six Sigma principles in creating more efficient and sustainable processes?
17. What is the role of leadership, budget management and stakeholder engagement in ensuring that Six Sigma is effectively applied to support financial and operational sustainability in your higher education institution?

List of Publications

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List of publications related to the dissertation

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