Tümay Avcı ANALYZING ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT GOALS THROUGH VOLUNTARY NATIONAL REVIEW REPORTS AGU 2024

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A THESIS
SUBMITTED TO ABDULLAH GÜL UNIVERSITY
SOCIAL SCIENCES INSTITUTE
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF ARTS

By
Tümay Avcı
December, 2024
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SCIENTIFIC ETHICS COMPLIANCE

I hereby declare that all information in this document has been obtained in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

Name-Surname: Tümay Avcı
Signature :

REGULATORY COMPLIANCE

M.A. thesis titled Analyzing Achievement of Sustainable Development Goals Through Voluntary National Review Reports has been prepared in accordance with the Graduate Thesis Preparation Guidelines of the Abdullah Gül University, Social Sciences Institute.

Prepared By	Advisor
Tümay Avcı	Assoc. Prof. Fatma Selen Madenoğlu
Signature	Signature

Head of the Data Science for Business and Economics Program

Assoc. Prof. Umut Türk

Signature

ACCEPTANCE AND APPROVAL

M.A. thesis titled Analyzing Achievement of Sustainable Development Goals Through Voluntary National Review Reports and prepared by Tümay Avcı has been accepted by the jury in the Data Science Graduate Program at Abdullah Gül University, Social Sciences Institute.

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(Thesis Defense Exam Date)

JURY:

Advisor: Assoc. Prof. Fatma Selen Madenoğlu

Member: Assoc. Prof. Umut Türk ..…… .....

Member: Prof. Dr. Sinem Kulluk…… .....

APPROVAL:

The acceptance of this M.A. thesis has been approved by the decision of the Abdullah Gül University, Social Sciences Institute, Management Board dated ….. /….. / …….. and numbered ……..……. .

…….. /…….. / ……..

(Date)

Director of Social Sciences Institute

Name Surname : Tümay Avcı
Program : Data Science (Master of Arts)
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ABSTRACT

The 2030 Agenda for Sustainable Development sets 17 Sustainable Development Goals (SDGs) to address critical global challenges such as poverty, inequality and climate change. To monitor progress towards these goals, countries submit Voluntary National Reviews (VNRs) that qualitatively and quantitatively assess their SDG implementation. This study comprehensively analyses the VNR reports submitted in 2023 and 2024 and examines the extent to which these reports reflect progress towards the SDGs. Using a multi-layered text classification model supported by advanced machine learning algorithms, the alignment of VNR reports with specific SDGs is categorized and assessed. The study provides data-driven recommendations on regional differences, performance by goal, and the development of reporting frameworks. The findings show that SDG 5 (Gender Equality) and SDG 13 (Climate Action) are prioritized in VNR reports in many countries, while SDG17 (Partnerships for the Goals) is underrepresented in VNR reports. In addition, positive and negative relationships between the goals have been addressed in VNR reports. With these results, recommendations for more effective policy development, international cooperation and data-driven decision-making processes are presented for decision-makers.

Keywords: Sustainable Development Goals, Voluntary National Reviews, Machine Learning, Natural Language Processing

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ÖZET

2030 Sürdürülebilir Kalkınma Gündemi yoksulluk, eşitsizlik ve iklim değişikliği gibi kritik küresel sorunları ele almak üzere 17 Sürdürülebilir Kalkınma Hedefi (SKH) belirlemiştir. Bu hedeflere yönelik ilerlemeyi izlemek için ülkeler, SKH uygulamalarını niteliksel ve niceliksel olarak değerlendiren Gönüllü Ulusal Değerlendirme (VNR) raporu sunmaktadır. Bu çalışma, 2023 ve 2024 yıllarında sunulan VNR raporlarını kapsamlı bir şekilde analiz etmekte ve bu raporların SKH'lere yönelik ilerlemeyi ne ölçüde yansıttığını incelemektedir. Gelişmiş makine öğrenimi algoritmalarıyla desteklenen çok katmanlı bir metin sınıflandırma modeli kullanılarak, VNR raporlarının belirli SKH'larla uyumu kategorize edilmiş ve değerlendirilmiştir. Çalışma, bölgesel farklılıklar, hedefe göre performans ve raporlama çerçevelerinin geliştirilmesi hakkında veriye dayalı öneriler sunmaktadır. Bulgular, SKH 5 (Toplumsal Cinsiyet Eşitliği) ve SKH 13'ün (İklim Eylemi) birçok ülkede VNR raporlarında önceliklendirildiğini, SKH 17'nin (Hedefler için Ortaklıklar) ise VNR raporlarında yeterince temsil edilmediğini göstermektedir. Bununla birlikte, VNR raporlarında hedefler arasındaki olumlu ve olumsuz ilişkiler ele alınmıştır. Bu sonuçlarla, karar alıcılar için daha etkili politika geliştirme, uluslararası işbirliği ve veri odaklı karar alma süreçlerine yönelik öneriler sunulmaktadır.

Anahtar kelimeler: Sürdürülebilir Kalkınma Hedefleri, Gönüllü Ulusal Değerlendirme, Makine Öğrenimi, Doğal Dil İşleme

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LIST OF ABBREVIATIONS

BERT	Bidirectional Encoder Representations from Transformers
COVID-19	Corona Virus Disease
CSV	Comma Separated Values
G20	The Group of 20
IDF	Inverse Document Frequency
IP	Intellectual Property
MDG	Millenium Development Goals
ML	Machine Learning
ML-RSD	Machine Learning – Regional Sustainable Development
NLP	Natural Language Processing
NLTK	Natural Language Toolkit
OSDG	Open Sustainable Development Goals
PCA	Principal Component Analysis
PCDS	Policy Coherence for Sustainable Development
PDF	Portable Document Format
SDG	Sustainable Development Goals
SMOTE	Synthetic Minority Oversampling Technique
SVM	Support Vector Machine
TF	Term Frequency
TF-IDF	Term Frequency- Inverse Document Frequency

UN	United Nations
VNR	Voluntary National Review
WHO	World Health Organization

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1. INTRODUCTION

1.1 Background Information

Throughout history, humanity has been seeking solutions to social, economic and environmental problems. The sustainability of these solutions is one of the most significant debates of the last century. The Sustainable Development Goals, developed by the United Nations in 2015 aims to resolve this challenge, have been adopted by countries all over the world to ensure that necessary actions are taken. Thanks to these common goals, the way has been made possible for various problems to be solved in a more sustainable manner.

The Sustainable Development Goals (SDGs), which were adopted by the Member States of the United Nations on 1 January 2016, comprise 17 main goals and 169 specific targets. (United Nations, 2015) The action plan, developed under the 2030 Agenda, was based on the Millennium Development Goals, previously established by the United Nations as an initiative to achieve these objectives (Hickmann et al., 2023). Each initiative proposed by the United Nations provides a common language for countries to express their sustainability capabilities.

The MDGs aimed to achieve succession with following 8 goals: poverty, hunger, gender inequality, child mortality, diseases, basic education, environmental sustainability and global partnerships (United Nations, 2000).

SDG 1 in other words “No Poverty”, is the actions taken for extreme poverty conditions that is defined as living under $1.90 daily. The aim is to eliminate the conditions that possibly effects poverty and reducing the number of people who is affected by this conditions (United Nations, 2015). This goal prioritizes the need for an access to economic resources, social protection systems and resilience to environmental and economic impacts. Achieving this goal requires targeted actions in vulnerable communities, promoting inclusive economic growth and addressing systemic inequalities (Allen et al., 2016).

SDG 2 advocates the resolution of hunger, the ensuring of food security, and the advancement in sustainable agriculture. Moreover, it highlights fair food distribution, environmentally friendly agricultural techniques, and the development of agricultural technologies that can fight and recover from challenges (United Nations, 2015).

The SDG3, "Good Health and Well-Being," has focused on providing comprehensive health and well-being for everybody. This includes the removing of maternal and child mortality, the fight against communicable and non-communicable diseases, and the achievement of universal health coverage. Moreover, the SDG 3 focuses on mental health, substance abuse prevention (United Nations, 2015).

SDG 4 aims to provide inclusive and equal access to quality education and lifelong learning opportunities for all. The objective is to facilitate universal access to primary and secondary education, early childhood development, vocational training, and gender parity. Furthermore, the SDG 4 framework gives particular emphasis to the improvement of curricula, teacher training and infrastructure (United Nations, 2015)

SDG 5 stand for gender equality. It represents one of the fundamental element of the SDG framework, which fight against the discrimination, violence, and harmful practices towards to women and girls. This goals include the creation of equal opportunities in leadership also underline the unpaid care work. It also defend the guaranteeing of reproductive rights, and remove of child marriage and female genital mutilation (United Nations, 2015).

SDG 6, Clean Water and Sanitation, is concerned with ensuring the availability and management of water and sanitation for everybody. Its outline covers water quality, wastewater management, and water scarcity. (United Nations, 2015).

SDG 7, Affordable and Clean Energy, underline the importance of accessibility of affordable and clean energy. The main target regarding this goal is including facilitating the transition to renewable and green energy. (United Nations, 2015).

SDG 8, Decent Work and Economic Growth, is mostly focusing on the presentation of sustainable, inclusive economic growth, and of course decent work for all individuals. It addresses the issues of youth unemployment, forced labor, and safe working conditions (United Nations, 2015).

SDG 9, also known as Industry, Innovation, and Infrastructure, aims to enhance resilient infrastructure, inclusive industrialization, and innovation. It places an emphasis on developing infrastructure in underserved regions and advancing sustainable industrial processes (Le Blanc, 2015; United Nations, 2015).

SDG 10, or Reduced Inequalities, is concerned with the reduction of inequalities within and among countries. It does so by focusing on three key areas: income equality, social protection and the inclusion of marginalized groups (Biermann et al., 2022).

SDG 11, or Sustainable Cities and Communities, has the objective of making cities inclusive, safe, resilient, and sustainable. It ask for fair urban planning and affordable housing, sustainable transportation for everyone (United Nations, 2015).

SDG 12 consider responsible consumption and production which proposes for the sustainable consumption and production steps. This goal involves getting rid of waste, the enhancement of resource efficiency, and the encouragement of sustainable business practices. (United Nations, 2015).

SDG 13 Climate Action has the objective of eliminating climate change and its consequences by building resilience and adaptive capacity. Integrating climate measures into policies, strengthening global partnerships and aligning with the Paris Agreement on climate change are main points of this goal (Sachs et al., 2019; United Nations, 2015).

SDG 14 is focuses on the conservation and sustainable usage of marine resources. It is concerned with the issues of marine pollution, overfishing and habitat destruction (Le Blanc, 2015; Wulff et al., 2018).

SDG 15 is concerned with the protection and promotion of the sustainable use of terrestrial ecosystems. It addresses issues such as deforestation, desertification, and biodiversity loss, while emphasizing forest conservation and sustainable land management (Nilsson et al., 2016; United Nations, 2015).

The objective of SDG 16 is to create peaceful societies, access to justice, and accountable institutions. SDG16 aims to reduce violence, corruption, and bribery in communities and institutions while present participation in decision-making and providing legal identity for all (United Nations, 2015).

SDG 17 underline the importance of international coordination and cooperation to achieve Sustainable Development Goals. It suggests on sharing and mobilizing resources and increasing the capacity-building. (United Nations, 2015) It also promote trade and technology transfer. Breuer et al (2019) state that data monitoring and accountability on this regard is also crucial for this SDG.

Each country that are members of United Nations has committed to fulfilling the goals defined. However, there is a need for monitoring the progress of SDGs, such as understanding to which extent these goals are being achieved at the country level, how each country is adapting to these goals in its own context. In this case, Voluntary National Reviews (VNRs) created to track the progress of SDGs achieved by the countries. It is an effective tool for countries to share their sustainable development policies and practices internationally. In High-Level Political Forum, these official documents are being presented to the members of the United Nations which provides a transparent image for several countries about how they deliver their goals in sustainability. Furthermore, these reports allow for cross-national comparative analyses, which makes them a critical resource for measuring progress towards the SDGs.

The Handbook for the Preparation of Voluntary National Reviews sets up a structure for countries to plan, prepare, and deliver their VNRs (UN DESA, 2024). The handbook emphasizes fundamental themes such as evidence-based analysis, stakeholder participation, and SDG alignment with national policy. While this study does not directly rely on the handbook's techniques, it recognizes the handbook's emphasis on standardized reporting practices across

countries. This ensures that VNRs have a consistent structure, making cross-country comparisons easier. For this study, the handbook's advice on focusing on inclusive and participatory review processes provides context for how countries match their reports with the SDGs.

According to Handbook for the Preparation of Voluntary National Reviews, creating the VNR report has a complicated process (UN DESA, 2024). It is expected that there is a multi-stakeholder partnership and their participation is crucial for organizing the reports. Besides that, additional proactive participation of commercial sector, academic, and civil society organizations are expected. (Smith et al., 2024) The accuracy is high when reports have qualitative and quantitative research methodology in particularly in data collection phase (European Sustainable Development Network, 2022). It is required that reports have a careful selection of indicators at local, regional and natal side. For instance, indicators should be determined in accordance with regional dynamics as well as at the national level, per United Nations standards (United Nations, 2020). The challenges faced in the preparation process include the lack and inconsistency of data. These challenges can be mitigated by strengthening national statistical systems and enhancing communication between stakeholders (European Sustainable Development Network, 2022). In addition, conducting VNR reports in a disciplined timeline and present the findings in the international communities ensure the effectiveness of report. (United Nations, 2020).

As a conclusion, preparation of VNR report is a dynamic process where all contributor create a theoretical framework. Participatory approaches and methodological depth increase the impact of these reports in achieving sustainable development goals while academic and practical efforts strengthens the succession of the process. (Smith et al., 2024; United Nations, 2020).

1.1.1 *Türkiye's VNR Reports*

As part of the United Nations, Türkiye took an important step when the SDGs were first put on the agenda and smoothly managed the transition period from the MDGs to the SDGs. As one of the first countries to share a VNR report in 2016, the year the SDGs were first adopted, Türkiye has made efforts to address the targets set with sensitivity. As stated in this report, the main focus is on SDG 3, SDG 9, and SDG 11. In summary, it can be stated that this report focuses on

eliminating regional inequalities, improving urban infrastructure and increasing environmental sustainability.

Türkiye prepared its second report in 2019 and in this report, Türkiye explained in detail how the process of harmonization with the targets has continued since the previous report and the steps taken for SDG 1, SDG 4, and SDG 5. The report states that achieving the SDG targets depends on reducing rural/urban inequalities, increasing women's participation in the labor force and reducing the gender gap in education.

According to the 2016 and 2019 reports, significant progress has been made towards the SDGs, but some structural problems still remain. Based on observations from the two reports, it can be said that the SDGs have been integrated into national policies and a high level of political ownership (e.g. through the presidency) has been achieved. Despite that, Türkiye has not published a VNR report since 2019, and information on the latest status of Türkiye in achieving the 2030 Agenda targets can be obtained by accessing TURKSTAT website, which was created for the measurement of SDG indicators across Türkiye.

1.2 Motivation

SDGs present a comprehensive framework to encourage sustainable development globally and to build a fair future for the humanity. However, to check the active application of these goals has a critical significance. The success of SDGs is dependent on how countries adapt these goals into their national context and to applicable strategies. In this case, VNR reports is a valuable tool to evaluate the countries' sustainable development strategies. Nevertheless, current analysis processes are usually limited to manual methodologies that reviews the reports superficially (Matsui et al., 2022; Hacıhasanoğlu, Ünlüsoy & Madenoğlu, 2024).

The analysis of VNR reports is a complex process because of the size and diversity of the data. These reports require to be reviewed deeper in order to understand the alignment levels. Yet, traditional manual analysis methods are inadequate to effectively process the big data and

objectively show the differences between countries. Thus, advanced technologies are required to perform the analysis process effectively, comprehensively, and systematically. In this regard, technologies like machine learning and NLP presents promising tools to detailly and objectively analyze the reports.

Machine learning algorithms have the capacity to swiftly analyze large amounts of data. This technology is stands out as a innovative method in terms of evaluation of the alignment of VNR reports to SDGs. Especially using text classification and multi layer analysis models enable to investigate in detail and to make comparison between countries. The motivation of this study is to make analysis process more efficient for VNR report, to better understand the achievement status in the global level and to contribute with a new methodology in this topic.

1.3 Research Problem and Objectives

Most of the time VNR reports are found to be limited and selective while analyzing the improvements of the countries towards SDGs. This case can possibly make the holistically monitoring process and achieving comparable results more challenging. This paper aims to investigate if 2023 and 2024 VNR reports are more aligned with one of the SDGs, and if only one SDG is extremely emphasized in the reports. The research statement of this thesis is "Do VNR reports prepared to be more aligned for specific SDGs and do these reports emphasize specific SDGs more than the others?" In this framework, the research will be shaped by the following hypotheses and sub-question.

1.3.1 *Hypotheses*

In this section, the hypotheses developed to answer the study's primary research questions are discussed. These hypotheses have been formulated to provide an understanding of the information to be obtained as a result of analyzing the existing findings and reports in the literature.

H0: All SDGs are present in the VNR reports.

H1: VNR reports demonstrate a stronger alignment and emphasis on certain SDGs, particularly SDG 5 (Gender Equality) and SDG 13 (Climate Action), compared to other SDGs.
H2: There are significant differences on VNR reports to focus towards SDGs between developed, developing, and underdeveloped countries.
H3: Environment related SDGs (SDG 13 Climate Action, SDG 15 Life on Land) are positively correlated.

1.3.2 *Research questions:*

The research questions for this study are outlined as part of an exploration into the distribution and prominence of SDGs in VNR reports from 2023 and 2024. In this case, the following questions are considered to be investigated throughout this report:

- How VNR reports published in 2023 and 2024 are distributed SDGs?
- Which SDGs are more prominent in the reports?
- Does VNR reports differ according to the countries' national priorities?
- Is there any inconsistencies on emphasis of SDGs among the developed, developing and underdeveloped countries?
- Have certain SDGs and specifically SDG 5 and SDG 13 been addressed more than others?

According to the Handbook for the Preparation of Voluntary National Reviews (UN DESA, 2024), the VNR reports are suggested to be submitted at regular intervals focusing on progress since their last submission. However, this study limits its scope to VNRs that are submitted in the same year, specifically review of VNR reports of 2023 and 2024 and comparisons between countries. In this case, there are no country with more that one submission of VNR report in the period of 2023 and 2024, meaning that there is no overlapping submission from the same country. In particular, the focus on certain SDGs throughout the reports will be analyzed with multi layer text classification and natural language processing techniques.

As a result, this thesis will objectively report the alignment of SDGs in the VNR reports and develop a new methodological approach to understand strategic priorities in the reports. The

findings will present suggestions for enhancing cross-country cooperation and policy coherence to support more effective implementation of the SDGs.

2. LITERATURE REVIEW

Sarwar and Nicolai (2018) conducted a study to assess the effectiveness of voluntary national review reports in implementing the sustainable development goals. The focus of the study was on the principle of “leaving no one behind”. Researchers examined VNRs submitted between 2016 and 2017 to assess political commitments, institutionalization efforts and SDG coverage. Findings show that all countries has strong political commitment to the SDG targets, however, there was less detail on how the 'leave no one behind' principle would be integrated into practice. The requirement highlighted in the study is concretely acting, mainly in terms of inclusion and policy implementation for disadvantaged groups. To address this, the researchers recommended the development of standardized guidelines for future VNR reports. These guidelines would provide more detailed information on these principles and thus increase the effectiveness of VNRs in achieving the SDGs.

Okitasari et al. (2019) evaluate the management mechanism for the national side of the application of the SDG 2030 Agenda. The study shows that nations create management structures to integrate the SDG into national policies. However, multi-stakeholder partnerships are limited. Even though European countries use Policy Coherence for Sustainable Development (PCDS) frequently, other countries are less active in these mechanisms. Authors present base suggestions like SDGs should connect to the local mechanism of national local budget integration and monitoring process.

Elder and Bartalini (2019) have assessed the actions reported by G20 countries in the context of implementing the SDGs, as published in their VNRs in the period 2016-2018. In this study, the level to which specific policy measures and financial allocations were reported is illustrated. The main finding is that G20 countries have reported a critical efforts, including wide range policies and considerable budget allocations. Yet, it is found difficult to express the difference between existing from new initiatives, and therefore, not easy to evaluate the overall importance or effectiveness of such efforts. It shows that some countries underreport existing SDG-related

policies and budgets. The authors underline the importance of continuing to measure efforts related to SDGs and note that the effectiveness of these efforts warrants further research.

Sebestyén, Domokos and Abonyi (2020) explored the primary areas of focus within sustainable development strategies through the utilization of text mining techniques on 75 VNRs to identify shared characteristics between nations. In order to assess similarities between nations, the study adopted text mining methodologies in order to convert VNRs into keyword networks. The analysis revealed that gender equality (SDG 5) and decent work and economic growth (SDG 8) were the most discussed goals, while no poverty (SDG 1) and reduced inequalities (SDG 10) were less emphasized. The study demonstrates how well text mining-based techniques may discover important topic areas of sustainable development and reveal opportunities for international cooperation.

Bickler, Morton and Menne (2020) examined the links between health and sustainable development by analyzing the VNR reports of 20 countries in Europe. The study assessed the extent to which the nine key areas of the WHO Europe's 2030 Agenda Roadmap are reflected in these reports. According to the results, countries with strong proof in areas like governance, monitoring, collaboration, and "leave no one behind", but also have gaps in areas like health, healthy environments, and health literacy. Additionally, the co-benefits between sustainability and health are underemphasized. The study also proves that the health sector is mostly not included in strategic decision-making processes.

Hajikhani and Suominen (2021) developed a machine-learning model for analyzing SDGs among publications and patents. Research uses an NLP approach for detecting the context of SDGs among scientific publications and patents. The study develops a model for automatically classifying the alignment of patents with SDGs by transforming SDGs definitions into a lexical database. It was found that SDG 1 and SDG 16 are the most highlighted subjects by getting data from the European Patent Office. The study states that this methodology would be helpful for policy makers and corporations to align their IP strategy with SDG.

Matsui et al. (2022), develop a model that uses NLP techniques for supporting SDG. Firstly, this model makes a semantic matching for SDG-related problems and actions. Secondly, it visualizes the connection among SDGs. And lastly, it provides matching functions between local problems and initiatives that can provide solutions to these problems. Research achieves the SDGs' semantic mapping by optimizing a pre-trained Japanese BERT model for multistage classification. Findings present a platform that could accelerate SDG applications by making easier between policies and stakeholder relationships easier. The authors emphasized that this model is a strong tool for understanding SDG more.

In 2021 VNR reports are examined by Okitasari and Kandpal (2022) in terms of how integrated SDG is in these reports. The study shows that 31 countries used SDG tagging systems to allocate their budget to the SDGs and some nations integrate SDG targets into their budget programs. The study emphasizes that SDG budgeting efforts facilitate the monitoring of budget performance and enhance accountability for effective policy implementation. The report also underline that the COVID-19 pandemic reveal that there is a need of stronger integration of SDG budgeting.

Oda (2023) make an examination on his report of how a gender perspective might be incorporated into the 2030 Agenda for SDG implementation process. In this study, VNRs of gender equality and women's empowerment were discussed in 13 nations. According to the results, gender is mainly related in VNR reports about SDG 5 and it is not linked with another domain such as environment. The Japan has not incorporated this finding even though it has legislative and regulatory frameworks on gender equality. The author made also six crucial policy that is also including the gender equality integration into all goals.

Elder and Newman (2023) examine policy and budget reports regarding the efficacy of Sustainable Development Goals in Voluntary National Reviews filed from 2016 to 2021. The research has shown that these reports created more than 4100 policies with a budget of 2.7 billion dollars has been recorded. The results show that the reported policies were established by comprehensive initiatives such as broad national strategies, regulations, and programs, not limited to small-scale projects or awareness campaigns. Yet, there are budget data under-reporting and fragmentation in areas corresponding to the environmental SDGs. They particularly underscore that the failure to

make adequate progress with the SDGs cannot be attributed to merely a lack of policies; further research is recommended also in terms of assessing policies' effectiveness. The research similarly presents a database and basis for monitoring the number of policies.

Chen (2024) proposed utilizing machine learning for modeling sustainable regional growth in order to improve decision support systems for the reuse of contaminated areas. Based on the SDGs, the study proposes a model (ML-RSD) that predicts regional development levels in various Taiwanese regions by combining the Principal Component Analysis (PCA) and Support Vector Machine (SVM) techniques. The study indicated that efficient reuse practices might have positive impacts on regional development, but the activities involved in removal of pollution do not impact sustainable development significantly in the region. Having an accuracy rate of above 80%, the ML-RSD model has been reported to produce more general and unbiased results as compared to conventional expert-oriented techniques.

Hacıhasanoğlu, Ünlüsoy ve Madenoğlu (2024) developed a system for analyzing companies' contributions to the SDGs using annual reports. The study employs a multilabel text classification approach to examine the annual reports of BIST30 enterprises in Türkiye and determine their level of commitment to the SDGs. The research defines which SDGs are prioritized, how they are covered in annual reports, and how much they are integrated into business operations. This approach optimizes the process of correlating information to the SDGs through the XGBoost algorithm, allowing for more immediate and credible analysis.

Martins and Paes-Sousa (2024) examined how VNRs are used to report health-related indicators for the SDGs of the 2030 Agenda. The study looked at 60 health indicators in 195 VNRs submitted between 2016 and 2020, assessing the degree of alignment between the indicators and the global methodology framework and strategic objectives of states. Study shows that the health indicators often focus on diseases like infectious and also maternal and child health is on focus point, while important issues such as universal health coverage and health systems are neglected. Authors said that, this is a complex result of both policy choices and statistical capabilities. On the other side, this study indicates that selectively reporting of the health data threatens the wholesome management paradigm of the 2030 Agenda.

Chisika and Yeom (2024) represents the key findings on the SDG application of VNR reports throughout the East Africa. The analysis is done on the reports belonging to Burundi, Kenya, Ruanda, South Sudan, Tanzania, and Uganda while investigating the integration of SDGs with the national policies and strategies. Findings show that considerable progress have been made in several areas, including poverty reduction, access to basic services, environmental protection, and support for economic growth and promotion of gender equality. On the other hand, it is emphasized that reaching the SDGs will be harder because of social, economic, and environmental obstacles. Authors provide using technology more efficiently for the development of SDG applications, raising awareness, and promoting accountability and collaboration as solutions.

2.1 Research Gaps

Most current studies done on evaluation of alignment of SDGs with the VNR reports are limited analyses based on textual data (Sarwar & Nicolai, 2018; Sebestyén et al., 2020). These studies, usually focus on certain SDGs (e.g. SDG 5: Gender Equality [Oda, 2023], SDG 3: Good Health and Well-being [Bickler, Morton & Menne, 2020] or SDG 13: Climate Action [Chisika & Yeom, 2024]) and instead of covering the content of the report integrally only review main titles of the reports. In particular, in-depth studies on how VNR reports are prepared, which SDGs are more prominent between countries, and the level of consideration of the regional differences on the reports remain limited (Okitasari & Kandpal, 2022; Elder & Bartalini, 2022; Elder & Bartalini, 2022). Furthermore, it is difficult to conduct a comprehensive comparison since current analyses mostly depends on manual methods. This highlights the requirement for a more systematic and objective approach to analyze VNR reports detailly (Matsui et al., 2022; Hacıhasanoğlu, Ünlüsoy & Madenoğlu, 2024).

While studies assessing differences between SDGs across the countries generally considers the economical and political context of the countries (Okitasari et al., 2019; Chisika & Yeom, 2024), they are insufficient to examine the methodologies used in the preparation of VNR reports (Elder & Newman, 2023). For instance, it has been observed that some VNR reports have relatively more emphasis on certain SDGs (e.g. gender equality or climate action) while others are relatively less

addressed (Sarwar & Nicolai, 2018; Oda, 2023). Besides, the reasons or consequences of this tendency are not explained well enough in the literature. Additionally, there is a need of systematically analyze on how prioritized political fields of the countries are reflected and how to address the challenges on SDG integration (Bickler et al., 2020; Martins & Paes-Sousa, 2024).

Finally, it is considered that inconsistencies and insufficiency of the data is a crucial problem (Elder & Bartalini, 2019; Elder & Newman, 2023). In the literature, it is indicated that these deficiencies negatively affect the comparability and reliability of the reports (Chen, 2024; Hajikhani & Suominen, 2021). Especially, the differences of the data collection process and diversity of the indicators that are used by the countries make it difficult to effectively evaluate the alignment of the SDGs (Matsui et al., 2022; Hacıhasanoğlu et al., 2024). This situation shows that there is a need of more comprehensive and unifying approaches that are in accordance with international standards. In this context, how to use machine learning and natural language processing (NLP) techniques while overcoming such data problems is standing out as an important gap in the literature (Sebestyén et al., 2020; Hajikhani & Suominen, 2021).

3. METHODOLOGY

In this section, research design, data sources and preprocessing techniques information have given. In the way of machine learning algorithm usage for multi-label classification methodological framework has been selected carefully. This research uses advance techniques for reflecting which VNR reports prepared in terms of global and national SDG commitment. The adoption of machine learning methods in analyzing VNR reports offers a new contribution to the area of sustainable development studies.

Text mining and natural language processing (NLP) methods form the basis of the study. Initially, VNR reports as unstructured text data are collected and examined. Application of machine learning model optimized for identifying alignment degrees of SDG categories with the way of multi-label category method.

The choice of quantitative techniques provides a strong methodological basis that makes it possible to analyze large data sets. Each VNR report automatically evaluated with the most appropriate SDG goals by machine learning methods. As a conclusion, with this research higher precision and objectivity can be achieved. In this context, for the data preprocessing and analytical techniques Python language is selected.

Strengths of this study design include the capacity to process large amounts of textual data and to assess SDG compliance in an unbiased way. In this context, any manual reader-oriented work that may be inaccurate or time-consuming can be avoided. Furthermore, the unstructured nature of the textual data and differences in the content quality of VNR reports are unexpected drawbacks. To overcome these challenges, the data was cleaned and optimized for the ML model during the preprocessing phase.

3.1 Data Collection

This part of the study provides detailed descriptions of the data sources. Data sets were carefully selected from community-driven projects and publicly available VNR reports to measure alignment with the SDGs. VNR reports are part of the methodological approach. There are 3 separate data sources in this study. The first is the OSDG Community dataset. The second is a GitHub repository (GitHub "SDG-s-classification" Project, 2022). Finally, VNR reports published in English between 2023 and 2024 are used as our dataset as third. OSDG and Github Repository were used to test and train the ML algorithm.

3.1.1 *First Dataset*

The OSDG Community Database is publicly available and consists of a large corpus endorsed by 110 countries and 1000 volunteers. The texts in the dataset include public documents, studies, policy papers, public summaries and studies specifically for the SDGs. In total, 32431 texts are included in the corpus, with 217147 tags assigned to each text. On average, each text is 90 words long and approximately 6 sentences long. Volunteers make decisions about the texts using a single SDG tag. At least 3 volunteers made a decision for each text. However, in order to increase the

reliability in the study, texts with an agreed score of 70% and above were used to train the ML algorithm. After calculating the rejection and acceptance rates using the formula below, the texts are assigned to the agreed SDG. The limitation of this dataset is that it includes data on the first 16 SDG targets but not SDG 17.

$$agreement = \frac{\left|labels_{positive} - labels_{negative}\right|}{labels_{positive} + labels_{negative}}$$

The dataset consists of the following headings:

text_id: Create a unique ID number for each text.
text: Refers to the analyzed text.
sdg: Refers to the SDG label assigned to the respective texts.
labels_positive and labels_negative: Refers to the values indicating that the volunteers agree with the same SDG label on the texts.
agreement: Refers to the overall agreement score of the SDGs on the text.

3.1.2 *Second Dataset*

To overcome the limitation of the first dataset, a GitHub SDG Classification Project Repository published in 2022 was used as the second dataset for this study. This dataset consists of 22631 texts in total, with each text previously assigned to the relevant SDG. This dataset consists of the following parts.

Description: Refers to the texts in which the relevant assignment will be made
SDG 1 – SDG 17: The text belongs to which SDG in binary way.

3.1.3 *Third Dataset*

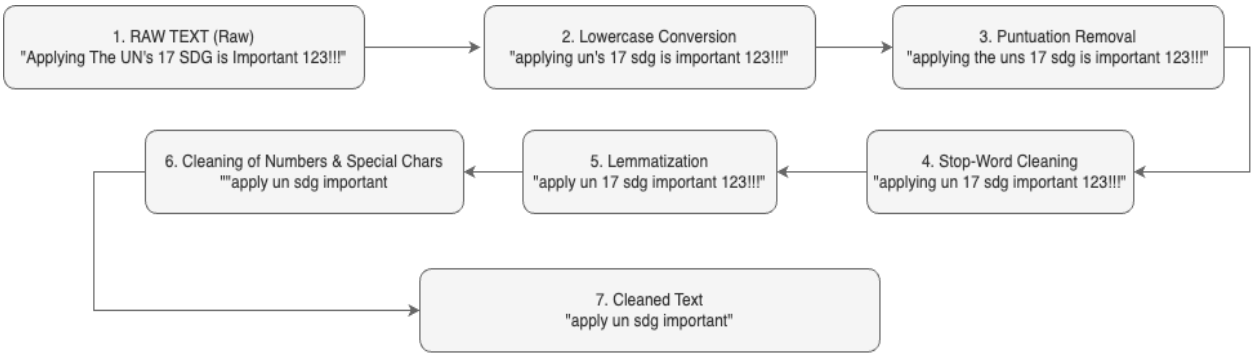
VNR reports were used as the third data set. Specifically, this study evaluates VNR reports produced by 51 different nations in both years of 2023 and 2024, written only in English. The

countries are Armenia, Austria, Azerbaijan, Bahrain, Barbados, Belgium, Belize, Bosnia and Herzegovina, Brunei, Cambodia, Canada, Croatia, Eritrea, EU, Fiji, Georgia, Guyana, Iceland, Ireland, Kenya, Kuwait, Laos, Liechtenstein, Lithuania, Maldives, Mauritius, Mongolia, Namibia, Nepal, Palau, Poland, Portugal, Romania, Romania, Rwanda, Saint Kitts and Nevis, Samoa, Saudi Arabia, Sierra Leone, Singapore, Slovakia, Solomon Islands, South Sudan, Tajikistan, Tanzania, Timor Leste, Turkmenistan, Uganda, Uzbekistan, Vanuatu, Vietnam, and Zimbabwe. Voluntary National Reports are retrieved from the UN High Level Political Forum on Sustainable Development platform (Voluntary National Reviews, High-Level Political Forum, n.d.).

Careful integration of OSDG and VNR data has been done to enhance the analysis procedures and increase the efficacy of the models. The integration is explained in the Data Preprocessing part.

3.2 Data Preprocessing

Figure 3.2.1 Steps of Data Preprocessing



Data preprocessing is a two-step process that involves cleaning and vectorization of the data. Data cleaning prepares the texts for semantic analysis. In this context, it consists of changing all texts to lowercase, removing punctuation, cleaning stop-words, lemmatization, and cleaning numbers and special characters.

3.2.1 *Lowercase Conversion*

All characters in the text are converted to lowercase. The process is called "Case Folding" and it tries to get rid of the case difference in text analysis. For example, "Sustainability" and "sustainability" were treated as the same term.

3.2.2 *Removal of Punctuation*

The punctuation marks were removed as they do not contribute anything to the semantic analysis of the texts. This was done with the use of regex, regular expressions in Python.

3.2.3 *Stop Word Cleaning*

Words that are commonly used in languages such as English and have limited semantic contribution such as, “and”, “or” were removed from the texts. Stop-word lists were obtained from tools such as NLTK (Natural Language Toolkit) in Python. This process ensured that the texts were focused on key words that carry meaning.

3.2.4 *Lemmatization*

Words are reduced to the root form. For example, the word “running” is reduced to “run”. has been converted to its root. Lemmatization was implemented using libraries such as SpaCy in Python.

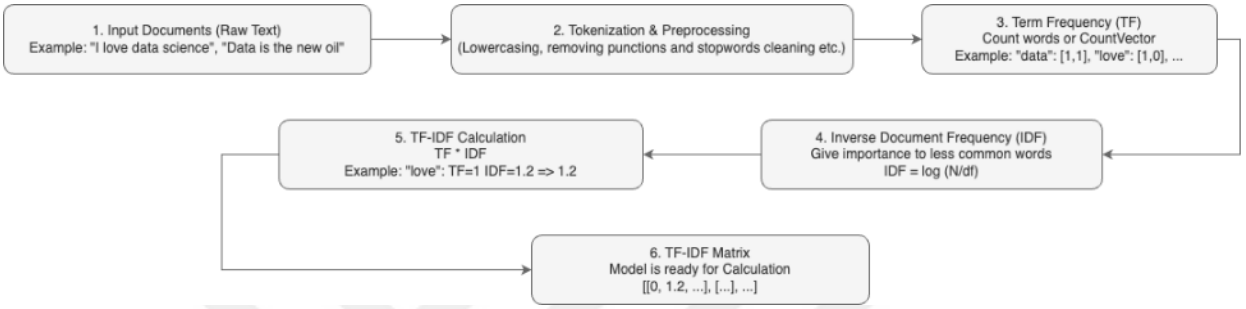
3.2.5 *Cleaning of Numbers and Special Characters*

Numbers and special characters that do not contribute to semantic analysis are removed, like page numbers.

In the study, both datasets were cleaned, and after cleaning the data, the Vectorization phase was started by assuring cleanliness. This phase of vectorization has enabled the texts to get converted into a digital format suitable for machine learning algorithms. In this study, TF-IDF method, calculating importance of words in documents with the help of their frequency, was preferred. This is because TF-IDF calculates the relative importance of terms within the text and measures the impact of each word on text analysis in a more objective way. The method creates a data structure suitable for multi-dimensional analysis by preserving unique features between texts. In particular, this is a necessary step for the analysis of categorical tags such as SDGs.

3.2.6 *Term Frequency-Inverse Document Frequency Method*

Figure 3.2.6.1 Application Steps of TF-IDF



The formula of TF-IDF basically contains two major combined parts for the calculation of the importance of a term in a document. These are known as Term Frequency and Inverse Document Frequency. Mathematically, TF-IDF would be expressed as follows:

$$TF - IDF(t,d) = TF(t,d) \times IDF(t)$$

3.2.6.1. *Term Frequency (TF)*

Measures the frequency of a term in a document. TF is defined as the ratio of the number of repetitions of a term in a document to the total number of terms in the document:

$f_{t,d}$: Number of repetitions of term t in document d.
$\sum_k f_{k,d}$: Number of all terms in document d

$$TF(t,d) = \frac{f_{t,d}}{\sum_k f_{k,d}}$$

3.2.6.2. *Inverse Document Frequency (IDF)*

Measures the rarity of a term in the collection. Reduces the importance of common terms:

N: Total number of documents in the collection

n_t: Number of documents in which term t occurs.

1: A correction coefficient used to avoid zero division error.

$$IDF(t) = \log \frac{N}{1 + n_t}$$

3.2.6.3. *Combined TF-IDF Formula*

TF and IDF are multiplied to find the importance of a term in a document:

$$TF - IDF(t, d) = \left(\frac{f_{t,d}}{\sum_k f_{k,d}} \right) \times \log \frac{N}{1 + n_t}$$

Thanks to this formula, the relative importance of a term in the document (TF) and its rarity in the collection (IDF) are evaluated together.

3.3 Analytical Techniques

After the data collection and data preprocessing steps, the data is ready to be analyzed by the analytical techniques that will be explained in detail. Firstly, the data split is conducted for machine learning model to be trained by the 80% of the data. According to the evaluation with the indicators such as accuracy of the model, the level of performance of SDG classes will be analyzed and if necessary, a rebalancing method will be applied to generate higher accuracy rates. After the expected indicator levels are achieved, the final model will deliver results.

3.3.1 *Machine Learning Model*

The VNR reports alignment with the SDGs will be analyzed using a machine learning algorithm. The choice of Support Vector Machine, the reason for choosing it, and how this aligns with the objectives of the study are described in the analytical framework.

3.3.1.1. *Support Vector Machine*

It is one of the most powerful supervised learning techniques with a higher degree of accuracy and generalization ability. Support Vector Machine can be applied in classification. The objective of SVM is to create a hyperplane with the maximum margin between classes. A hyperplane, which is represented as below, is a plane that divides the data into two classes:

$$f(x) = w^T x + b$$

Where:

w: Weight vector (determines the orientation of the hyperplane),
x: Input features (data point),
b: Deviation term (adjusts the position of the hyperplane).

Decision margins and bounds are set in order to divide the two classes. The margin bounds are specified by the support vectors, those data points falling closest to the hyperplane. The primary objective of SVM is to maximize this margin between the decision boundary and the support vectors. This minimum probability of misclassification would thereby be reduced. This optimization problem could be mathematically presented as below:

$$min\frac{1}{2}\|w\|^2 \quad \text{on condition} \quad y_i(w^T x_i + b) \geq 1, \forall i$$

Where:
y_i: The class label of the data (+1 or -1),
x_i: Data point.

3.3.1.2. *Validation of the Model*

In the study, the data sets that were subjected to data processing and cleaning processes were divided into test and training parts using the SVM algorithm. Here, 20% is used as test data while 80% is used to train the model. In addition, “stratify=y_res” was marked as yes in order to train the model homogeneously from all SDGs.

The performance of the model was measured by Classification Report. The Classification Report provides us with crucial parameters and metrics that show how accurate and precise the model predicts. Classification report consists of the following components:

1. **Precision**: Shows how many of the samples predicted as positive are actually positive.

$$\frac{\text{true positives} + \text{false positives}}{\text{true positives}}$$

2. Recall: Shows how many of the examples that are actually positive you guessed correctly.

$$\frac{\text{true positives}}{\text{true positives} + \text{false positives}}$$

3. f1-score: Harmonic mean of Precision and Recall. Used as a balancing metric.

$$2 \times \frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}}$$

4. Accuracy: The proportion of instances that the model correctly predicts, over all classes and individually over each SDG.

5. Macro Average: It calculates the average of precision, recall and f1-score, giving equal weight to each of the classes.

6. **Weighted Average:** Calculates averages weighted according to the support rates of the classes.

Rebalancing is additional SMOTE or differential oversampling (or undersampling) that helps to better select classes of unbalanced size in the dataset or to better analyze classes with low performance (Fernández, et al., 2018). Based on the initial results of the model, SMOTE was applied to the overall dataset to bring the representation of each SDG class closer together. Thus, the model had the chance to learn the classes where there is an imbalance. After retraining the model, some classes were still underperforming. At this stage, SMOTE was applied again, targeting these poor performing classes. By increasing the number (sample size) of those classes a bit more, it is tried to help the model to better learn the classes that "make the most mistakes" or "are the most underrepresented". The accuracy or other metrics of low-performing classes increased significantly. Some classes that already have high accuracy or are well represented may see small decreases, but this was a trade-off.

3.3.2 *Output Generation*

This was applied using a previously trained and saved SVM model along with a TF-IDF vectorizer, whereby text from new PDF documents were assigned to their corresponding classes of SDG. Basically, this is based on the approach whereby prediction is made directly with regard to VNR PDF documents; hence, it skips retraining the already pre-prepared and stored model by means of the Support Vector Machine-SVM and TF-IDF vectorizer. This will enable the fast, automated mapping of vast amounts of data or even unknown text sources to the respective classes.

First in Python, the joblib library is used to load the model of SVM: svm_model.pkl and TF-IDF vectorizer: tfidf_vectorizer.pkl because these models are saved, since the training phase may be time-consuming or even require a particular infrastructure. Therefore, no retraining will be necessary, and the model can be used immediately after loading. Similarly, the TF-IDF vectorizer is set in a way that it would behave consistently on any given input; therefore, it takes the same parameters and vocabulary to transform text into numerical vectors.

The VNR reports were downloaded as PDFs from the target dataset source. Using the PyPDF2 library, every page of the PDF files inside the target folder was systematically read, page by page, and merged into one coherent text. This raw text constitutes the full content of the report but is unprocessed. During this stage, the extracted text from the PDF might have structural errors or extra spaces. These are sure to be corrected in further steps involved in the process.

The raw text was extracted from PDFs in a stepwise cleaning way: lowercasing, removal of punctuation, numeric characters, and superfluous spaces. Then, with the help of the stop-word list from NLTK, frequently used words like "the," "is," "and," etc., which do not carry any meaning in English, were removed. Finally, each word was reduced to its root or basic form (lemma) using the WordNetLemmatizer from NLTK. These steps will have the model learn content-oriented learning without meaningless variations in the text.

Further, preprocessed text will be transformed into a numerical vector by an installed tfidf_vectorizer based on TF-IDF (Term Frequency-Inverse Document Frequency). In other words, applying, to new texts with the same approach, the vocabulary and frequency information onto which the TF-IDF vectorizer was previously trained.

The resulting vector then gets input to the pre-trained SVM model, which will make a class prediction showing which class it falls into. It selects the most suitable class for SDG and gives a label.

It will for each PDF store the predicted SDG tag with a name of the PDF file. It gets aggregated into the list of python dictionaries which get converted to pandas DataFrame whose contents get saved and stored in ".csv" format-thematic output of information on which pdf is assigned to which SDG.

4. RESULTS

The objective of results chapter is to present primary findings of machine learning model and to investigate the relationship between SDGs and VNR reports.

The machine learning performance metrics are obtained by SVM (Support Vector Machine) classification report. These metrics are used to evaluate the reliability and effectiveness of the model. The SVM has a high accuracy rate in the extant literature particularly for classification problems. In this study range, each SDG is assign into a specific VNR report. Moreover, the margin maximization principle of SVM reduces the risk of overfitting by increasing the generalization ability of the model. The model performance is as follows:

Table 4.1 Support Vector Machine Classification Report of 2023 & 2024 VNR Reports

Accuracy	Precision	Recall	F1 Score
0.9039	0.9034	0.9036	0.9032

Notes: *1) The classification used the dataset that contains reports from 2023 and 2024.*

The Support Vector Machine classification report results in Table 4.1. outlines the performance of the machine learning model developed to analyze VNR reports submitted in 2023 and 2024. This model was employed to classify and assess the alignment of these reports with the SDGs.

The results show that the SVM model works effectively for this specific classification problem and the model performance is significantly improved, especially by rebalancing. Overall, the model's 90.39% accuracy rate is supported by high F1 scores in various SDG classes. This shows that the model provides consistent results both in terms of overall performance and class-wise. Additionally, it is important to highlighted that accuracy scores get to the peak for each SDGs after rebalancing. Results are as follows.

Table 4.2 SDG Accuracy Comparison by SMOTE Method

SDGs	Before SMOTE Rebalancing Accuracy Score	After SMOTE Rebalancing Accuracy Score
SDG 1 No Poverty	0.8580	0.9028
SDG 2 Zero Hunger	0.8744	0.9038
SDG 3 Good Health and well-being	0.8744	0.9205
SDG 4 Quality Education	0.8319	0.8987
SDG 5 Gender Equality	0.7892	0.8887
SDG 6 Clean Water and Sanitation	0.9008	0.9509
SDG 7 Affordable and Clean Energy	0.8883	0.9520
SDG 8 Decent Work and Economic Growth	0.8381	0.8635
SDG 9 Industry, Innovation and Infrastructure	0.8932	0.9643
SDG 10 Reduced Inequalities	0.8882	0.9704
SDG 11 Sustainable Cities and Communication	0.8858	0.9542
SDG 12 Responsible Consumption and Production	0.9259	0.9565
SDG 13 Climate Action	0.8808	0.9364
SDG 14 Life Below Water	0.9472	0.9791
SDG 15 Life on Land	0.9359	0.9682
SDG 16 Peace, Justice and Strong Institutions	0.9209	0.9673
SDG 17 Partnership for The Goals	0.9749	0.9933

According to the SDG accuracy comparison by SMOTE method presented in Table 4.2; SDG 17, 14, 10 have the highest consistency accuracy rate with more that 97%, while SDG 8, 5, 4 have the lowest accuracy rate more that 86%. In addition, the accuracy rates increased after the rebalancing

operations performed on classes with initially lower performance, such as SDG 5 (78% to 88%), proves that SMOTE technique effectively solve the class imbalance problem.

The SVM model was trained to assign the given VNR reports to the most appropriate SDG classes. The predicted SDG label and associated probability scores were calculated for each report. The following table shows the SDGs to which specific VNR reports were assigned, as well as the probability scores obtained for these classes.

Table 4.3 Assigned SDG Labels for Countries (Part 1 of 3)

Country Report	Assigned SDG Label
Armenia	13
Austria	5
Azerbaijan	13
Bahrain	8
Barbados	13
Belgium	13
Belize	5
Bosnia and Herzegovina	9
Brunei	13
Cambodia	9
Canada	13
Croatia	11
Eritrea	5
EU	13
Fiji	13
Georgia	5
Guyana	9

Table 4.4 Assigned SDG Labels for Countries (Part 2 of 3 – Continued from Page 38)

Country Report	Assigned SDG Label
Iceland	5
Ireland	5
Kenya	5
Kuwait	5
Laos	5
Liechtenstein	5
Lithuania	5
Maldives	5
Mauritius	9
Mongolia	5
Namibia	2
Nepal	5
Palau	5
Poland	13
Portugal	9
Romania	6
Rwanda	5
Saint Kitts and Nevis	13
Samoa	13
Saudi Arabia	9
Sierra Leone	16
Singapore	13
Slovakia	11
Solomon Islands	13
South Sudan	5
Tajikistan	13

Table 4.5 Assigned SDG Labels for Countries (Part 3 of 3 – Continued from Page 39)

Country Report	Assigned SDG Label
Tanzania	8
Timor Leste	5
Turkmenistan	13
Uganda	5
Uzbekistan	6
Vanuatu	5
Vietnam	9
Zimbabwe	2

Table 4.3, 4.4, and 4.5 illustrates the distribution of SDG labels assigned to individual countries as part of the analysis of VNR reports submitted in 2023 and 2024. This table is part of a comprehensive breakdown of SDG alignment across countries, showcasing how different nations prioritize various goals in their VNR submissions.

Among sustainable development goals SDG 5 has the most alignment score with 20 reports among 51 countries. This finding shows that social gender equality has a central place in the development agenda of many countries. SDG 13, another crucial target that stood out in 15 out of 51 countries. The highest alignment rate of this goal is observed in countries like Armenia, Azerbaijan, Samoa and Solomon Islands. SDG 9 goal is specifically observed in countries like Mauritius and Saudi Arabia. These countries may be making significant progress in modernizing industrial infrastructure and promoting innovative technologies.

SDG 2 and SDG 16 goals are stand out in certain countries like Namibia and Zimbabwe. These countries may intense effort on improving food security and ending the hunger with applying agricultural reforms and enhancing local production capacities. In line with SDG 16, Sierra Leone ensure peace and security may give priorities in terms of justice system and social reforms. In these countries works, It emphasizes that meeting basic human needs and enabling societies to develop peacefully are critical to sustainable development.

Figure 4.1 VNR Reports (2023 & 2024) and SDG Relationships Sankey Diagram

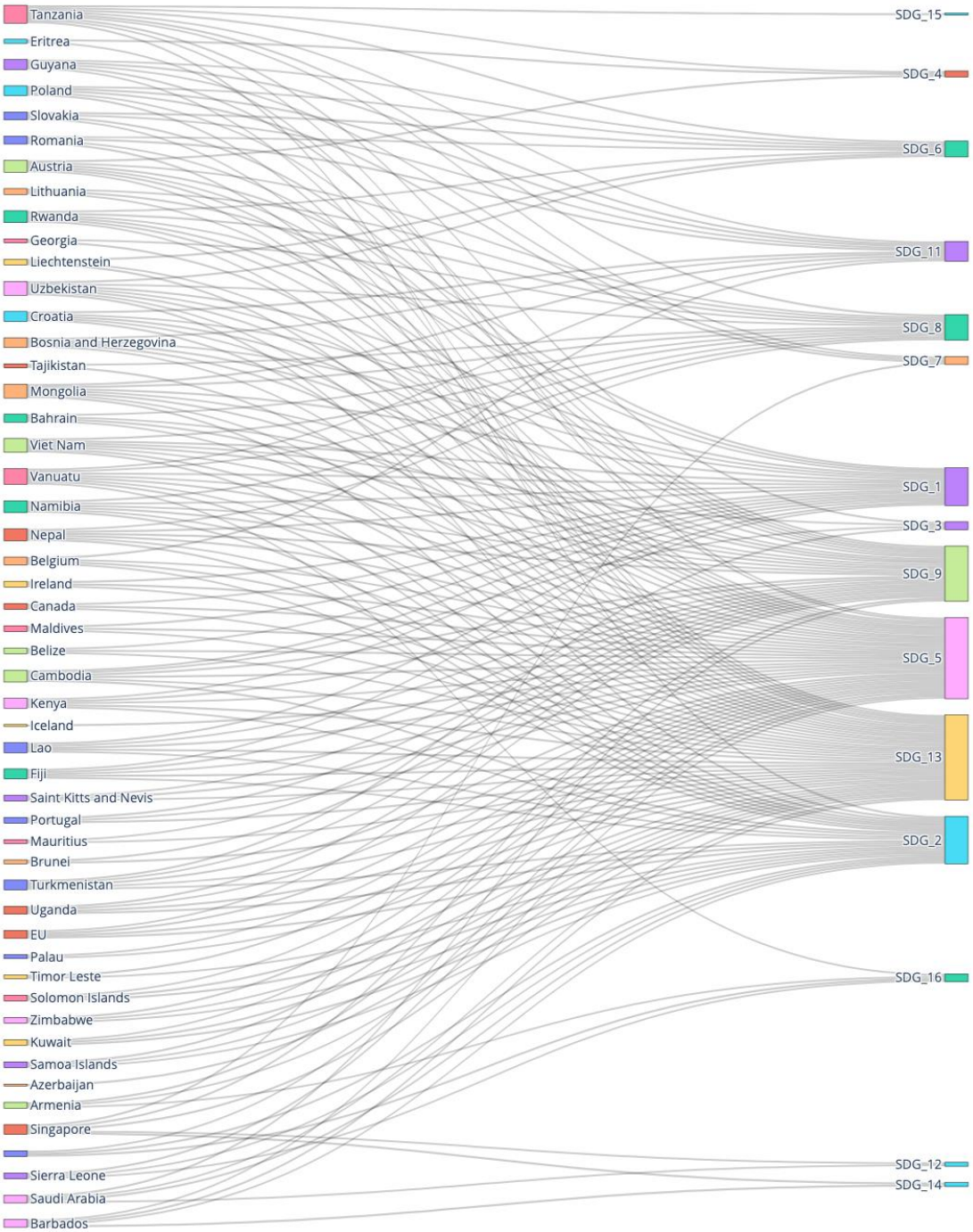


Figure 4.1 VNR Reports and SDG Relationships Sankey Diagram represents how countries matches with different SDGs. This diagram is instrumental in illustrating the flow of focus from the national priorities highlighted in VNR reports to specific SDGs.

The Sankey diagram demonstrates how countries allocate attention across different SDGs, offering insights into the relative emphasis placed on each goal. For instance, the diagram highlights strong linkages to SDG 5 (Gender Equality) and SDG 13 (Climate Action), reflecting global concerns about gender equity and environmental sustainability. Moreover, it identifies weaker connections to certain SDGs, such as SDG 17 (Partnership for the Goals), which are less frequently addressed in the reviewed reports.

This visualization underscores the disparities in SDG focus between developed, developing, and underdeveloped countries. The thicker flows in the diagram correspond to higher attention to specific SDGs, providing a clear indication of which goals are prioritized globally. Additionally, the year-based comparison embedded in the diagram reveals trends, such as increasing or declining focus on particular SDGs between 2023 and 2024.

4.1 Detail Analysis of SDG Alignment Scores

This analysis is made based on Appendix 1 which involves the SDG alignment score for each country analyzed. In this context, SDG 5 was by far the most represented goal and ranked first in 24 reports, indicating the highest level of alignment. With an average value of 28,4%, SDG 5 shows that it is strongly addressed by countries and supported by policies. The maximum alignment observed in SDG 5 is 84,6%.

Besides this, SDG 13 achieved a maximum alignment rate of 90,5% in the Azerbaijan Report, which has pointed out strong progress in environmental sustainability. SDG 9 with 52,0% underlines the importance of industrialization and innovation in Saudi Arabia Report. SDG 8 and SDG 11 showed high performance with 31.4% and 31.3% respectively.

The least represented goal was SDG 17. This rate attracts attention with having the lowest alignment level among 42 reports and only achieved a very low value of 0,12%. The maximum alignment level of SDG 17 is 0,91%. This reveals that international cooperation and partnerships still have serious shortcomings. Likewise, SDG 15 with 36% and SDG 10 with 0,51% are other targets with low compliance rates.

Moreover, data reveals that there is a big difference between minimum and maximum alignment levels. For example, for SDG 6, the minimum alignment was recorded as 0.069% while the maximum value was 48.2%. So it could be said that applying clean water and sanitation policies in Timor Leste and Romania. SDG 14 with 0,008% has the lowest minimum alignment level in the Azerbaijan Report.

These findings reveal that policies towards SDGs are quite heterogeneous. While great progress has been made on some targets, there are serious shortcomings on others. Specifically for SDG 17, there is a need for stronger global coalitions, based on international cooperation goals and comprehensive strategic planning.

4.2 Analysis of Correlation Heatmap

Figure 4.2.1 Correlation Heatmap of SDG Scores from 2023 and 2024 VNR Reports

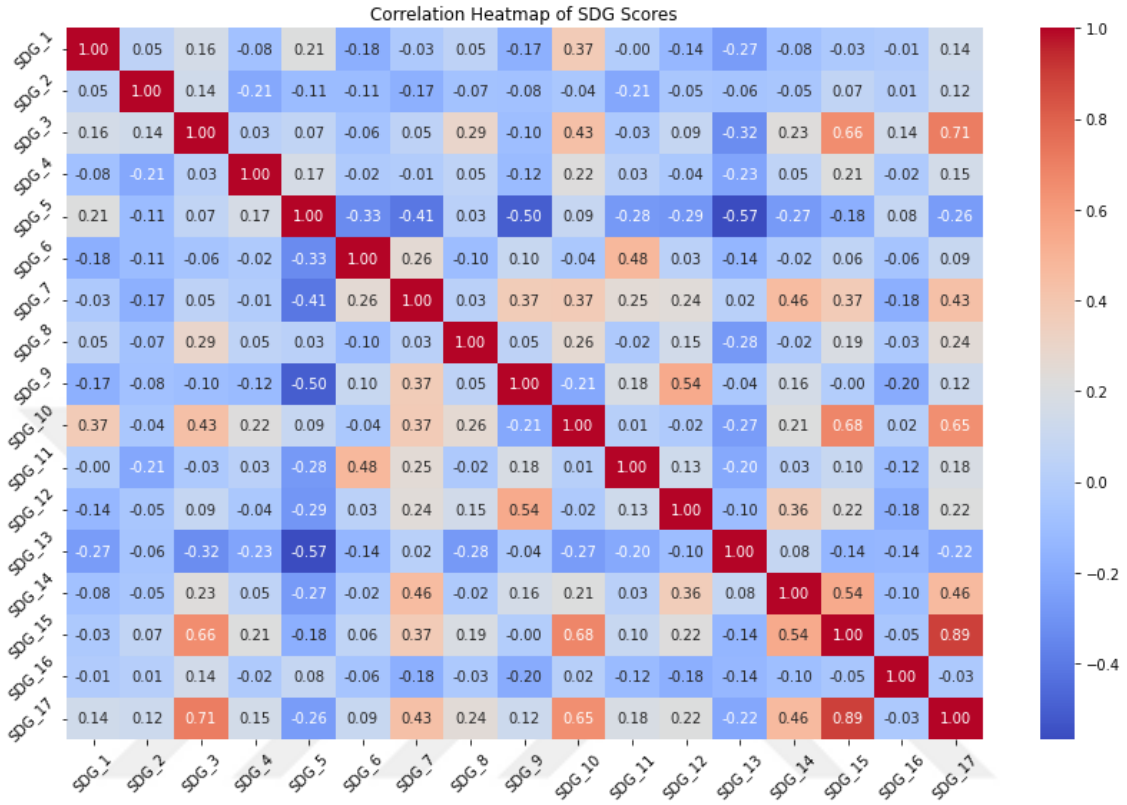


Figure 4.2.1 presents the detailed relations among SDGs. In general, there is strong correlation among some of the SDG while has negative or low correlation. For instance, among SDG3 and SDG 17 have high positive correlation with 0.71. This result may shows that improving health systems is directly related to strengthening international cooperation and partnerships. Similarly SDG 15 and SDG 17 has high correlation with 0.89. This may point out that conservation of natural ecosystems is possible through joint efforts.

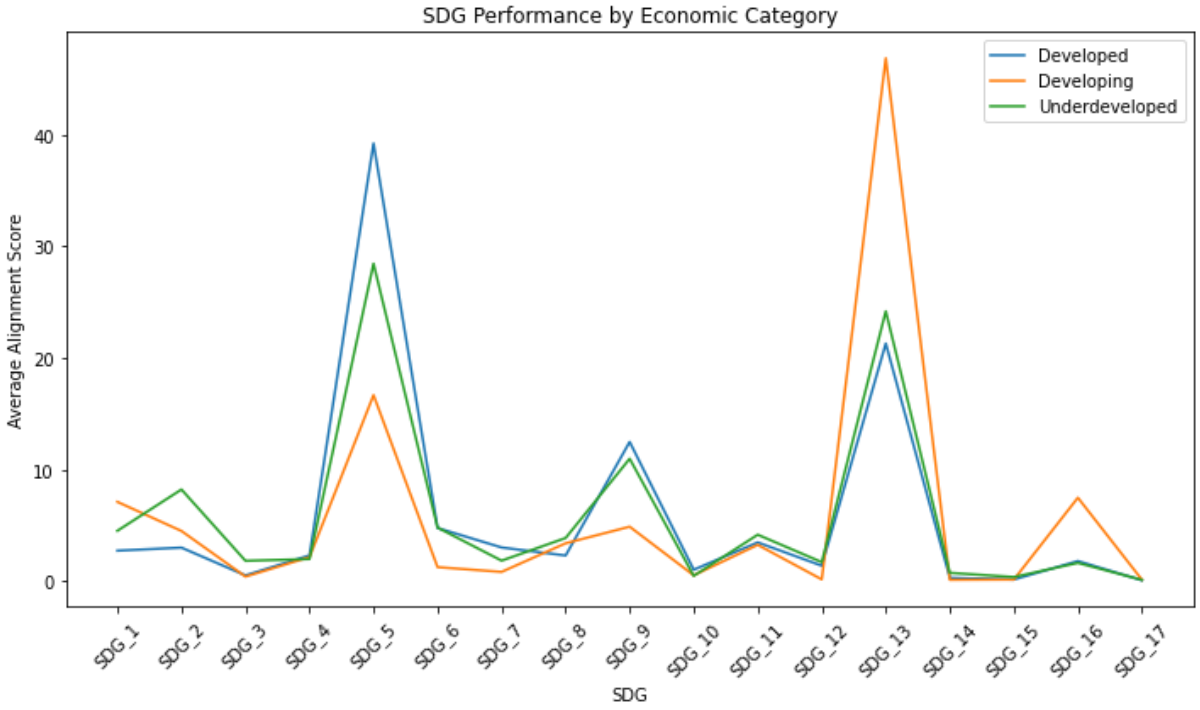
There are notable negative correlations among some SDGs. For instance, with -0.57 rate, negative correlation observed between SDG 13 and SDG 5. This findings may show climate actions policies are not integrate enough with social gender equalities. Moreover, SDG 13 has low or negative correlation values with many other targets. This reveals that climate actions are considered independently of other development goals. On the other hand, industry and infrastructure projects are not fully compatible with environmental sustainability principles with the low rate of -0.04.

SDG 7 and SDG 15 has 0.37 positive relations this highlights the positive impact of clean energy policies on the preservation of natural habitats. Moreover, among SDG 12 and SDG 14 have 0.36 positive correlation. This demonstrates the importance of responsible production and consumption habits in protecting marine resources.

These findings reveal that in order to effectively implement SDG, interactions between goals must be carefully evaluated. While positive relations point out the areas that can create synergy, negative correlation and low relation highlights the need for policy alignment and strategic planning. In this way, even in national and international level, developing more integrated approaches, will contribute to the more effective realization of the SDGs.

4.3 Performance of SDGs by Economical Growth

Figure 4.3.1 SDG Performance by Economic Category from 2023 and 2024 VNR Reports



The Figure 4.3.1 explains the average alignment score for each SDG according to the level of development of the countries. Moreover, Appendix 3 further contains data about in which areas it remains strong or weak and how concentrated each economic group is in certain SDGs. Below, each group leading SDG scores with current condition and possible improvement areas have been addressed.

In developed economies, Gender Equality has taken the lead and presents a high performance of 39,22%. These countries' leadership position in this area is visible when compared with the other economic categories. Moreover, 12,49% SDG 9 emphasizes the importance of innovation, technology, and infrastructure. Climate Action is taking a strong role with 21,30%. This rate shows the effect of countries' environmentally focused policies. However, 0,16% in SDG 15 and 0.09% in SDG 17 indicate significant deficiencies in these areas. SDG 17's score especially shows that developed countries need to make more efforts to establish collaborations and partnerships.

The SDG 13 with 46,85% performs the highest score among all economic categories. This rate reveals that there is a strong intention to combat climate change. SDG 16 with 7,49% shows that these counties are making efforts to develop their administrative reforms and institutional capacity. Nevertheless, SDG 7 with 0,84%, and SDG 10 with 0.54% can be considered as a very low SDG performance. These rates reveal that there is a need for more resources and policies to address the challenges of achieving energy and eliminating socioeconomic inequalities.

Underdeveloped economies are taking the front with their performances to meet basic human needs. SDG 2 with 8.22% and SDG 6 with 4,81% are performed higher than developing economies. These countries underline their vulnerability to climate action with a score of 24,19% in SDG 13. However, SDG 17 with 0.13%, and SDG 10 with 0,49% have the lowest performance. This situation shows that there is insufficient global cooperation and it is a big issue that there are inequalities in these countries.

As a result, each economic category has its priorities and has different SDG performances that reflect the points where it falls short. While developed countries have more focus on social gender

equality and innovation-based development, developing economies give more priority to climate action and institutional reform. However, while underdeveloped economies are sensitive to basic survival needs and climate action, there is a need for fighting inequalities and more comprehensive global cooperation. In this way, international cooperation efforts and related policies could accelerate the achieving sustainable development goals for each economic category.

5. DISCUSSION

This research presents an innovative methodological framework for evaluating the level of alignment of VNR reports to SDGs. The study addresses the need for a more objective assessment of strategic alignment towards the SDGs, in particular by proposing a comprehensive solution to the current situation where VNR reports are analyzed in a limited way using traditional methods. Results obtained show that VNR reports emphasize certain SDGs in parallel with the motivation of the study and this condition has a critical role to understand both national and international strategical priorities.

The results of the 2023 VNR reports highlight a significant focus on SDG 5 (Gender Equality) and SDG 13 (Climate Action), reflecting national strategies prioritizing these goals. Additionally, SDG 9 (Industry, Innovation, and Infrastructure) also received considerable attention, particularly in countries with growing economies or infrastructure needs. However, certain goals, such as SDG 2 (Zero Hunger) and SDG 16 (Peace, Justice, and Strong Institutions), were either minimally represented or absent, pointing to a lack of comprehensive action across all SDGs in the reviewed reports. This uneven distribution indicates gaps in addressing critical areas like food security and institutional stability.

In 2024, SDG 5 (Gender Equality) and SDG 13 (Climate Action) continued to dominate the agenda, reaffirming their position as global priorities. However, SDG 16 (Peace, Justice, and Strong Institutions) emerged more prominently, with countries like Sierra Leone reporting on this goal. Additionally, there was a noticeable emphasis on SDG 2 (Zero Hunger), suggesting heightened awareness of food security challenges. Despite these improvements, the 2024 reports

still highlighted gaps in addressing SDG 17 (Partnership for the Goals), underlining persistent challenges in fostering global collaborations.

A comparative analysis of the 2023 and 2024 VNR reports reveals both continuity and evolution in SDG priorities. Both years showed a consistent focus on SDG 5 (Gender Equality) and SDG 13 (Climate Action), but the distribution of focus slightly shifted. For instance, while SDG 9 (Industry, Innovation, and Infrastructure) was more prominent in 2023, SDG 2 (Zero Hunger) and SDG 16 (Peace, Justice, and Strong Institutions) gained more attention in 2024. This suggests that countries are gradually diversifying their focus areas based on emerging national and global challenges. However, the lack of substantial progress on SDG 17 (Partnership for the Goals) over the two years highlights a persistent gap in international cooperation and resource mobilization, emphasizing the need for stronger global governance mechanisms.

This comparative evaluation supports the hypothesis that while SDG priorities may remain consistent across years, shifts in focus reflect evolving national and international contexts.

Findings demonstrates that some goals such as SDG 5 (Gender Equality) and SDG 13 (Climate Action) has been distinctly addressed in the reports for many countries. This situation verifies H1 hypothesis and highlights that particular SDGs are more likely to be priority for countries. Besides, some SDGs (e.g. SDG 17 Partnership for the Goals) are reported with a low emphasize level. This illustrates that there are some insufficiency with the goals that requires international co-operation and these areas needs more political coherence and resource allocation.

In the context of H2 hypothesis, the results demonstrate that there are significant differences between developed, developing and underdeveloped countries. While the focus of developed countries is usually on gender equality and innovative development areas, developing countries mostly interested in climate action and institutional reforms. Underdeveloped countries exhibits a higher performance on fulfilling basic human needs and fighting climate change. This finding indicates that strategies specific to economical growth of the countries should be developed for the implementation of the SDGs

Detection of the positive correlation between SDG 13 (Climate Action) and SDG 15 (Life on Land) supports the H3 hypothesis. This finding indicates that environmental SDGs can be implemented through mutually supportive policies. Nevertheless, the weak and negative correlation of SDG 13 with social goals (e.g. SDG 5) demonstrates that climate policies should have a more integrative approach.

In response to the research questions, there is a quite heterogeneous distribution of SDGs throughout the VNR reports published in 2023 and 2024. The stronger emphasis on specific targets (e.g. SDG 5 and SDG 13) reveals how national priorities are reflected in the reports. Additionally, significant inconsistencies has been identified across countries which shows both reporting standards and data collection processes needs to be enhanced.

In light of these findings, several steps are recommended to make more effective strategies for decision-makers on SDGs. Initially, the adoption of more standardized indicators and data collection processes is required in the preparation of VNR reports. This will enable more comparable and reliable results across countries. Secondly, policy-makers should recognize system dynamics and integrated planning approaches to better understand the relationships between SDGs. For instance, climate action policies (SDG 13) can be more adapted to social and economic goals like gender equality (SDG 5), and decent work and economic growth (SDG 8). Finally, especially in context of SDG 17, multi-stakeholder mechanisms should be formed in order to empower international cooperation and partnerships. Such mechanisms will increase the knowledge share between countries which leads to the acceleration of the achievement of SDGs at the global level.

As a result, this thesis contributes to a more systematic and objective analysis of the VNR reports using machine learning and natural language processing techniques. The findings provide a foundation for policy development and international partnership strategies for SDGs to be implemented more effectively. Moreover, the elimination of the gaps in the reporting phase and enhancement of policy harmonization across countries will contribute positively to the achievement of the SDGs at the global level.

6. CONCLUSION

While presenting an improved methodology with this study, the machine learning and NLP methods provided a systematic, objective and thorough analysis overcoming the limitations of the traditional methods in the literature. Despite this, the study has some limitations. Firstly, the scope of the study is only limited with 2023 and 2024 VNR reports, meaning that the analysis involving more extended time span can provide with a more in depth results. Secondly, the differences of the data collection and reporting methodology across different countries limit the direct comparison of the results. Moreover, the performance of the machine learning models depends on the algorithms and data preprocessing techniques used which likely caused some SDG classes to have lower performance. The researches in the future can address these limitations with larger datasets and improved analysis techniques.

In contrast, this study provides some important contributions to the literature. Initially, a framework with machine learning and NLP basis is developed to analyze VNR reports. Secondly, new insights about the relationship between SDGs is presented and synergies and conflicts between certain goals are analyzed in detail. This offers a valuable guide for policy makers in order to develop more integrated and coherent strategies. Lastly, this study creates an impact on academic and applied levels by making solid suggestions on standardization of the indicators used in reporting and improvement of the data collection methods.

As a conclusion, this research provides a comprehensive analysis method on the better application of SDGs on a national and global level and proposes strategies for policy makers. Future research could potentially extend the methodology within geographical and temporal contexts and provide deeper insights into achievement of SDGs. Moreover, the integration of interdisciplinary approaches may accelerate the implementation of SDGs in a more effective way.

7. APPENDICES

7.1 Appendix 1: SDG Alignment Scores from 2023 and 2024 VNR Reports

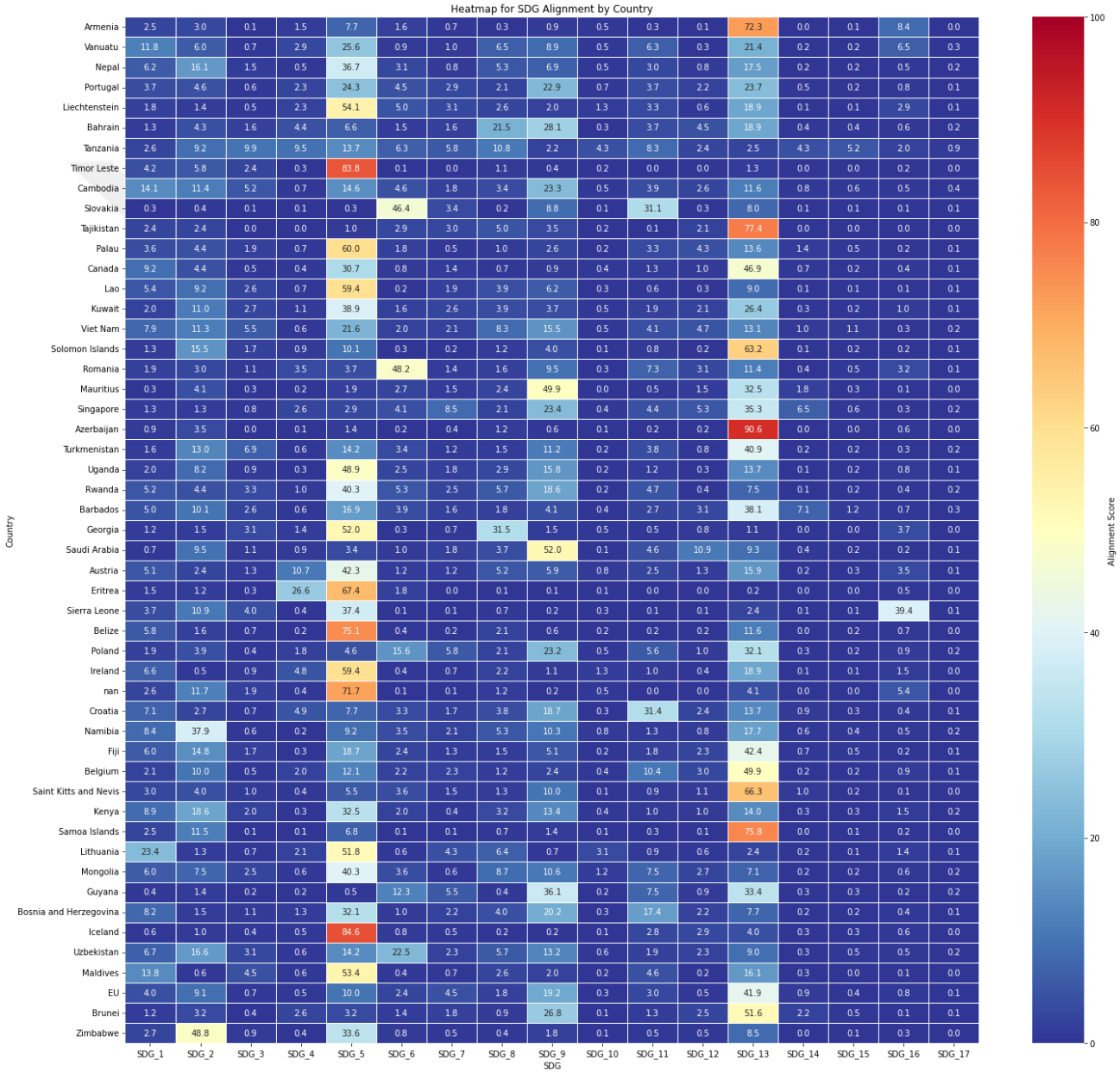
Table below shows the SDG scores of all countries analyzed. These scores demonstrate the level of alignment to SDGs by each country.

Countries	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
Armenia	2,473	3,024	0,102	1,471	7,725	1,619	0,685	0,262	0,874	0,527	0,268	0,084	72,326	0,049	0,051	8,427	0,034
Vanuatu	11,751	5,986	0,737	2,855	25,622	0,913	0,999	6,546	8,906	0,545	6,258	0,253	21,369	0,215	0,249	6,546	0,250
Nepal	6,170	16,118	1,524	0,454	36,723	3,099	0,849	5,299	6,910	0,510	2,955	0,791	17,524	0,183	0,241	0,467	0,184
Portugal	3,687	4,629	0,590	2,344	24,346	4,532	2,938	2,066	22,948	0,740	3,665	2,194	23,691	0,548	0,225	0,750	0,107
Liechtenstein	1,798	1,402	0,468	2,300	54,091	5,007	3,120	2,554	2,024	1,330	3,301	0,596	18,903	0,072	0,091	2,878	0,066
Bahrain	1,318	4,274	1,574	4,444	6,602	1,501	1,584	21,458	28,102	0,339	3,736	4,513	18,881	0,444	0,422	0,623	0,186
Tanzania	2,553	9,224	9,901	9,520	13,723	6,329	5,774	10,786	2,209	4,293	8,322	2,448	2,547	4,262	5,215	1,980	0,914
Timor	4,211	5,755	2,376	0,339	83,783	0,070	0,031	1,128	0,442	0,222	0,047	0,020	1,299	0,015	0,014	0,232	0,015
Cambodia	14,057	11,378	5,207	0,662	14,560	4,647	1,847	3,357	23,281	0,512	3,903	2,626	11,631	0,769	0,646	0,548	0,368
Slovakia	0,264	0,415	0,144	0,137	0,340	46,376	3,431	0,235	8,840	0,096	31,060	0,264	8,016	0,104	0,096	0,117	0,066
Tajikistan	2,382	2,405	0,045	0,035	0,956	2,867	3,043	5,010	3,486	0,162	0,061	2,062	77,382	0,024	0,026	0,032	0,021
Palau	3,593	4,360	1,883	0,712	60,003	1,803	0,478	0,959	2,571	0,209	3,307	4,278	13,596	1,405	0,528	0,216	0,099
Canada	9,209	4,445	0,473	0,418	30,734	0,824	1,362	0,718	0,923	0,405	1,277	1,007	46,876	0,718	0,156	0,400	0,055
Lao	5,369	9,207	2,555	0,702	59,412	0,239	1,862	3,928	6,227	0,284	0,590	0,333	8,970	0,072	0,084	0,106	0,061
Kuwait	2,017	10,993	2,710	1,150	38,914	1,581	2,596	3,888	3,666	0,526	1,879	2,057	26,356	0,291	0,233	1,006	0,137
Viet	7,938	11,336	5,471	0,640	21,594	1,997	2,129	8,280	15,482	0,480	4,115	4,707	13,091	1,045	1,132	0,313	0,249
Solomon	1,267	15,470	1,712	0,913	10,076	0,317	0,188	1,194	4,002	0,069	0,825	0,161	63,216	0,107	0,213	0,214	0,056
Romania	1,856	2,963	1,057	3,509	3,657	48,204	1,385	1,629	9,517	0,279	7,276	3,072	11,436	0,353	0,488	3,212	0,107
Mauritius	0,347	4,071	0,332	0,201	1,852	2,727	1,496	2,370	49,905	0,048	0,520	1,475	32,470	1,816	0,269	0,066	0,037
Singapore	1,324	1,305	0,769	2,564	2,907	4,141	8,462	2,125	23,374	0,395	4,446	5,292	35,323	6,480	0,558	0,348	0,189
Azerbaijan	0,888	3,461	0,029	0,093	1,365	0,249	0,355	1,193	0,602	0,138	0,175	0,186	90,567	0,009	0,010	0,632	0,049
Turkmenistan	1,551	12,969	6,852	0,612	14,155	3,381	1,167	1,484	11,187	0,238	3,803	0,761	40,947	0,191	0,213	0,296	0,193
Uganda	2,004	8,215	0,885	0,265	48,927	2,530	1,825	2,931	15,773	0,161	1,192	0,323	13,727	0,150	0,222	0,794	0,077
Rwanda	5,221	4,363	3,290	0,986	40,330	5,263	2,465	5,728	18,562	0,222	4,725	0,387	7,545	0,141	0,217	0,362	0,193
Barbados	4,950	10,070	2,588	0,637	16,930	3,853	1,590	1,783	4,063	0,355	2,681	3,060	38,121	7,138	1,217	0,704	0,260
Georgia	1,196	1,536	3,140	1,400	52,039	0,306	0,731	31,462	1,504	0,500	0,520	0,811	1,108	0,028	0,031	3,663	0,025
Saudi	0,713	9,484	1,111	0,912	3,358	0,972	1,838	3,691	52,027	0,108	4,632	10,925	9,317	0,435	0,242	0,150	0,086
Austria	5,099	2,358	1,332	10,675	42,292	1,221	1,235	5,206	5,930	0,791	2,517	1,341	15,861	0,238	0,321	3,452	0,131
Eritrea	1,494	1,202	0,325	26,639	67,378	1,819	0,032	0,140	0,054	0,085	0,048	0,044	0,177	0,034	0,021	0,498	0,009
Sierra	3,693	10,892	3,978	0,374	37,440	0,143	0,091	0,692	0,201	0,283	0,108	0,084	2,419	0,085	0,070	39,368	0,079
Belize	5,767	1,596	0,735	0,186	75,089	0,448	0,216	2,114	0,642	0,192	0,245	0,198	11,592	0,035	0,180	0,746	0,019
Poland	1,934	3,914	0,426	1,778	4,576	15,597	5,771	2,119	23,175	0,470	5,574	0,997	32,090	0,261	0,222	0,933	0,162
Ireland	6,622	0,542	0,885	4,813	59,385	0,409	0,735	2,162	1,132	1,342	1,031	0,360	18,926	0,059	0,067	1,486	0,043
South Sudan	2,644	11,734	1,858	0,411	71,653	0,080	0,057	1,201	0,217	0,532	0,047	0,027	4,059	0,022	0,028	5,399	0,029
Croatia	7,133	2,663	0,718	4,944	7,653	3,287	1,654	3,786	18,728	0,315	31,365	2,367	13,658	0,921	0,268	0,396	0,143
Namibia	8,365	37,941	0,619	0,237	9,190	3,530	2,143	5,312	10,299	0,829	1,265	0,811	17,724	0,613	0,409	0,543	0,170
Fiji	6,047	14,753	1,698	0,257	18,680	2,390	1,275	1,538	5,082	0,174	1,812	2,347	42,413	0,666	0,536	0,248	0,086
Belgium	2,054	10,002	0,459	2,004	12,137	2,206	2,311	1,220	2,417	0,445	10,424	3,008	49,883	0,231	0,159	0,948	0,092
Saint and Nevis	2,997	4,018	1,032	0,393	5,497	3,558	1,474	1,316	9,995	0,061	0,880	1,077	66,347	1,017	0,214	0,080	0,045
Kenya	8,940	18,596	1,968	0,256	32,527	1,963	0,444	3,166	13,377	0,411	1,047	0,966	14,042	0,294	0,276	1,514	0,212
Samoa	2,507	11,527	0,082	0,065	6,818	0,105	0,096	0,693	1,366	0,134	0,332	0,108	75,807	0,045	0,074	0,230	0,010
Lithuania	23,351	1,266	0,672	2,094	51,780	0,616	4,267	6,368	0,705	3,143	0,929	0,640	2,439	0,187	0,097	1,364	0,081
Mongolia	5,964	7,541	2,483	0,557	40,251	3,583	0,567	8,687	10,574	1,212	7,501	2,708	7,140	0,188	0,218	0,647	0,178
Guyana	0,404	1,412	0,224	0,228	0,497	12,344	5,486	0,394	36,056	0,174	7,486	0,925	33,407	0,276	0,348	0,167	0,171
Bosnia and Herzegovina	8,185	1,463	1,076	1,309	32,116	1,045	2,179	3,989	20,199	0,269	17,386	2,185	7,698	0,153	0,173	0,435	0,139
Iceland	0,646	0,992	0,439	0,473	84,623	0,811	0,493	0,247	0,242	0,140	2,762	2,929	4,005	0,308	0,279	0,600	0,011
Uzbekistan	6,679	16,558	3,100	0,561	14,246	22,528	2,288	5,661	13,170	0,571	1,883	2,282	8,995	0,264	0,456	0,522	0,236
Maldives	13,806	0,596	4,454	0,584	53,385	0,407	0,661	2,553	2,006	0,238	4,647	0,162	16,071	0,279	0,050	0,070	0,031
EU	4,005	9,052	0,669	0,464	10,048	2,353	4,525	1,759	19,194	0,325	2,979	0,518	41,907	0,934	0,384	0,758	0,126
Brunei	1,200	3,226	0,385	2,606	3,234	1,383	1,840	0,867	26,764	0,107	1,334	2,502	51,647	2,215	0,494	0,129	0,066
Zimbabwe	2,684	48,799	0,916	0,385	33,579	0,840	0,521	0,441	1,807	0,091	0,457	0,469	8,458	0,039	0,145	0,337	0,032

Notes: *1) All numbers are rounded up to three decimals.*

7.2 Appendix 2: Heatmap for SDG Alignment by Country

This heatmap indicates how SDGs are aligned by the countries. This visualization shows the level of alignment with different colors.



7.3 Appendix 3: SDG Alignment Score by Economic Category from 2023 and 2024 VNR Reports

The table below indicates the average SDG alignment scores for developed, developing and underdeveloped countries.

Economic Category	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
Developed	2,743	3,015	0,529	2,322	39,219	4,769	3,029	2,310	12,486	1,035	3,483	1,395	21,297	0,310	0,158	1,814	0,086
Developing	7,112	4,505	0,419	2,163	16,674	1,266	0,842	3,404	4,890	0,536	3,263	0,168	46,848	0,132	0,150	7,487	0,142
Underdeveloped	4,524	8,223	1,833	1,991	28,447	4,807	1,848	3,878	10,978	0,487	4,173	1,715	24,185	0,756	0,382	1,646	0,126

Notes: *1) All numbers are rounded up to three decimals.*

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ENDNOTES

The dataset used in this thesis can be found through the links below.

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