ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

CONTRIBUTIONS TO THE SDGS USING THE QFD METHOD IN ICT COMPANIES'

M.Sc. THESIS

Enes Çalışkan

Department of Management

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Thesis Advisor: Prof. Dr. Hatice Camgöz AKDAĞ

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

QFD METHODU İLE BİLGİ VE İLETİŞİM TEKNOLOJİSİ FİRMALARININ SÜRDÜRÜLEBİLİR KALKINMA HEDEFLERİNE KATKILARININ İNCELENMESİ

YüKSEK LİSANS TEZİ

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HAZİRAN 2024

Enes Çalışkan, a M.Sc. student of ITU Graduate School student ID 403211016, successfully defended the thesis entitled "CONTRIBUTIONS TO THE SDGS USING THE QFD METHOD IN ICT COMPANIES'", which he/she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 24 May 2024
Date of Defense : 07 June 2024

To my spouse and family,

FOREWORD

In today's rapidly evolving global landscape, the pursuit of sustainable development has emerged as a paramount goal for societies, governments, and businesses alike. At the heart of this endeavor lies the United Nations' Sustainable Development Goals (SDGs), a comprehensive framework designed to address the world's most pressing social, economic, and environmental challenges. Within this framework, Information and Communication Technology (ICT) companies play a pivotal role, leveraging their innovative capabilities to drive positive change and contribute to the advancement of the SDGs.

This thesis delves into the intersection of ICT companies and the SDGs, exploring how the Quality Function Deployment (QFD) method can be utilized as a strategic tool for enhancing their contributions towards sustainable development. By systematically translating customer requirements into actionable design specifications, QFD offers a structured approach to aligning business objectives with societal needs, thereby fostering the creation of products, services, and solutions that drive meaningful impact.

Through rigorous research and analysis, this thesis seeks to shed light on the potential of QFD in empowering ICT companies to address a diverse array of SDGs, ranging from affordable and clean energy (SDG 7) to quality education (SDG 4) and sustainable cities and communities (SDG 11).

As the global community continues to grapple with complex challenges such as climate change, inequality, and digital divide, the role of ICT companies in driving sustainable development has never been more critical. By embracing innovative approaches like QFD and integrating sustainability into their core business practices, these companies have the potential to not only mitigate risks and unlock new opportunities but also to catalyze positive social and environmental change on a global scale.

This thesis represents a culmination of extensive research, collaboration, and dedication towards advancing our understanding of how ICT companies can harness the power of QFD to contribute meaningfully to the SDGs. It is my sincere hope that the insights and findings presented herein will inspire further inquiry, dialogue, and action within the academic community and beyond, as we collectively strive towards a more sustainable and inclusive future for all.

June 2024

Enes Çalışkan
(Network Engineer)

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ABBREVIATIONS

AI : Artificial Intelligence
AIDS : Acquired Immune Deficiency Syndrome
DVD : Digital Video Disc
ESG : Environmental, Social, Governance
GDP : Gross Domestic Product
GDPR : General Data Protection Regulation
GHG : Greenhouse Gas
GRI : Global Reporting Initiative
GWP : Global Warming Potential
HBCUs : Historically Black Colleges & Universities
HEMS : Home Energy Management Systems
HVAC : Heating, Ventilation, Air Conditioning
HoQ : House of Quality
ICT : Information and Communication Technology
IIoT : Industrial Internet of Things
ITU : International Telecommunication Union
IVR : Interactive Voice Response
IoT : Internet of Things
M2M : Machine to Machine
NGO : Non-governmental Organization
PF : Precision Farming
QFD : Quality Function Deployment
R&D : Research & Development
RAN : Radio Access Network
SD : Sustainable Development
SDGs : Sustaniable Development Goals
STEM : Science, Technology, Engineering, Mathematics
TB : Tuberculosis
UN : United Nations
UNW : United Nations Women
Vi CSR : Vodafone Idea Corporate Social Responsibility
WASH : Water, Sanitation, Hygiene
WEF : World Economic Forum
WING : Worldwide IoT Network Grid
Wi-Fi : Wireless Fidelity

SYMBOLS

CO_2	**:** Carbon Dioxide
CO_{2e}	**:** Carbon Dioxide Equivalent
$^{\circ}C$	**:** Celsius

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SUMMARY

There is no doubt that humanity needs to realize the sustainability problems in the world and take serious actions regarding that. All members of the United Nations adopted The 2030 Agenda for Sustainable Development, the most comprehensive study on sustainability internationally, in 2015. The summary of the study is 17 sustainable development goals. It covers everything about sustainability such as environment, social and governance. The use of Information and Communication Technology (ICT), such as internet, mobile phones, and satellites, is essential for tackling the main issues facing sustainable development. Hence, contributions of 3 major ICT companies to the sustainable development goals are assessed in this study.

Quality Function Deployment (QFD) is utilized as a methodology for this study. Since QFD is an excellent instrument for comparing businesses on relevant subjects. House of Quality must be established to complete the QFD application. In order to develop a House of Quality, the demanded qualities (voice of the customer) and quality characteristics (technical requirements) must first be determined. UN SDGs are used as demanded qualities. Quality characteristics are derived from annual sustainability and corporate social responsibility reports of ICT companies. The companies' efforts, as indicated by the QFD results, are concentrated on the use of recycled raw materials and recycling, reducing GHG emissions through energy saving and improved connectivity, decarbonizing the value chain, protecting the environment and water resources by collaborating with businesses that have completed CDP water assessments and paying attention to reducing water consumption, ethical business practices, and reducing inequality. The evaluations of the three businesses are found to be very similar when they are compared. The small differences between the companies are usually about the region they serve. Efforts that made from the companies are mostly concentrate on the responsible consumption and production, life below water, climate action, sustainable cities and communities goals. These efforts are included improving connectivity in needed areas for providing access to information, education and healthcare.

QFD METHODU İLE BİLGİ VE İLETİŞİM TEKNOLOJİSİ FİRMALARININ SÜRDÜRÜLEBİLİR KALKINMA HEDEFLERİNE KATKILARININ İNCELENMESİ

ÖZET

Şüphesiz ki insanlık, dünya üzerindeki sürdürülebilirlik sorunlarını fark etmeli ve bunlarla ilgili ciddi önlemler almalıdır. Birleşmiş Milletler üyelerinin 2015 yılında kabul ettiği 2030 Sürdürülebilir Kalkınma Gündemi, uluslararası alanda sürdürülebilirlik üzerine en kapsamlı çalışmadır. Çalışmanın özeti, 17 sürdürülebilir kalkınma hedefini kapsar. Bu, çevre, sosyal ve yönetişim gibi sürdürülebilirlikle ilgili her şeyi içerir. Bilgi ve İletişim Teknolojisi (Information and Communication Technology, ICT) kullanımı, internet, mobil telefonlar ve uydu gibi, sürdürülebilir kalkınma hedefleri ile ilgili başlıca sorunların üstesinden gelmek için kritik bir öneme sahiptir. Bu nedenle, bu çalışmada sektörün en büyüklerinden 3 Bilgi ve İletişim Teknolojisi şirketinin sürdürülebilir kalkınma hedeflerine katkıları değerlendirilmektedir.

Literatürde Birleşmiş Milletler sürdürülebilir kalkınma hedeflerine Bilgi ve İletişim Teknolojisi şirketlerinin katkılarını inceleyen çok az çalışma vardır ve bunların hiçbiri Kalite Fonksiyon Dağılımı (Quality Function Deployment, QFD) yöntemini kullanmamıştır. Bu boşluğu doldurmak için, bu çalışmada Bilgi ve İletişim Teknolojisi şirketlerinin Birleşmiş Milletler sürdürülebilir kalkınma hedeflerine katkıları ile ilgili literatür ve projeler incelenmiş ve üç önemli Bilgi ve İletişim Teknolojisi şirketinin katkıları karşılaştırılmıştır. Bu çalışmanın metodolojisi olarak Kalite Fonksiyon Dağılımı kullanılmaya uygun görülmüştür. Bir başka neden olarak, Kalite Fonksiyon Dağılımı, işletmeleri ilgili konularda karşılaştırmak için mükemmel bir yöntem olduğundan, bu çalışmada kullanılmıştır. Kalite Fonksiyon Dağılımı uygulamasının tamamlanması için Kalite Evi kurulmalıdır. Kalite Evi kurulması için öncelikle talep edilen nitelikler (voice of the customer) ve kalite özellikleri (teknik özellikler) belirlenmelidir. Birleşmiş Milletler sürdürülebilir kalkınma hedefleri, talep edilen nitelikler olarak kullanılmıştır. Kalite özellikleri, Bilgi ve İletişim Teknolojisi şirketlerinin yıllık sürdürülebilirlik ve kurumsal sosyal sorumluluk raporlarından türetilmiştir. Kalite Fonksiyon Dağılımı sonuçlarına göre şirketlerin çabaları, geri dönüştürülmüş hammadde kullanımı ve geri dönüşüm, enerji tasarrufu ve geliştirilmiş bağlantı yoluyla sera gazı emisyonlarının azaltılması, değer zincirinin karbon emisyonlarının azaltılması, CDP su değerlendirmelerini tamamlamış işletmelerle iş birliği yaparak çevre ve su kaynaklarının korunması, su tüketiminin azaltılmasına dikkat edilmesi, etik iş uygulamaları ve eşitsizliğin azaltılmasına odaklanmıştır.

Bilgi ve İletişim Teknolojisi şirketlerinin diğer bir incelenme nedeni, sektörün Birleşmiş Milletler sürdürülebilir kalkınma hedeflerine ulaşmada yüksek oranda

faydalı etkisinin olmasıdır. Akıllı şehirler, akıllı su yönetimi, akıllı ev uygulamaları ve sektörler arası entegrasyon aracılığıyla enerji tasarrufu, bu önemli etkiyi gösteren katkıların birkaç örneğidir. Bilgi ve İletişim Teknolojisi şirketleri, iklim değişikliğini izlemek, sonuçlarını azaltmak, uyum sağlamak ve daha sürdürülebilir bir gelecek oluşturmaya yardımcı olmak için kritiktir. Ortalama bir evin genel enerji tüketimi, akıllı ev ekipmanının benimsenmesiyle potansiyel olarak %33 azalma ile ortalama %61 azaltılabilir [6]. Ayrıca, Bilgi ve İletişim Teknolojsi çözümlerinin 2015 seviyelerini korurken küresel CO2e emisyonlarını 2030'da %20 daha düşürme potansiyeli vardır.

Bilgi ve İletişim Teknolojisi firmaları, internet ve şebeke bağlantı kalitesini arttırarak şehirlerde güvenliği ve yaşam kalitesini artırmak için Nesnelerin İnterneti (Internet of Things, IoT) teknolojisini desteklerler. Ayrıca, döngüsel iş modeli, daha etkili ve atıksız üretim ve tüketim alışkanlıklarını teşvik ederek doğal kaynaklara olan ihtiyacı azaltır. Üstelik işletmelerin sensör ve bağlantı teknolojisini ilerletme kapasitesi, su altı yaşamı, karada yaşam ve iklim eylemi hedeflerine ulaşmak için hayati öneme sahiptir. Bilgi ve Haberleşme Teknolojisi çözümlerinin çevre üzerindeki etkisi çeşitli şekillerde incelenmektedir. Bilgi ve Haberleşme Teknolojisi ürünlerinin üretilmesi gerekliliği açık bir gerçektir. Bu ürünlerin imalatı ve kullanımı değişen çevresel etkilere sahiptir [8]. Bu ürünlerin üretilirken ve kullanılırken oluşturdukları çevresel etki genellikle enerji tüketimi ve küresel ısınma potansiyeli (Global Warming Potential, GWP) gibi iyi bilinen ölçütler kullanılarak analiz edilmektedir. İklim değişikliğinin yanı sıra, bu ürünlerin dikkate alınması gereken doğrudan çevresel etkileri de vardır. Kaynak tüketimi, su tüketimi, arazi kullanımı ve biyoçeşitlilik sonuçları en önemli hususlardır. Öte yandan, birçok faydalı etkileri de bulunmaktadır. Dematerializasyon bunlardan biridir. Dematerializasyon ve ikame, fiziksel nesnelerin dijital ürünlere dönüştürülmesini ifade eder. Dematerializasyon veya fiziksel nesnelerin sanal ürünlerle değiştirilmesi, Bilgi ve Haberleşme Teknolojisi uygulamaları aracılığıyla çevresel olumsuz sonuçları azaltmanın bir yolu olarak görülmektedir. DVD izlemenin yerini internet üzerinden video izlemeye ve kağıt kitapların yerini e-kitaplara bırakması dematerilazsyona örnek verilebilir [9]. Dematerializasyon tam olarak doğru terim değildir, çünkü dijital ürünler veya hizmetlere geçiş hala e-kitaplar gibi materyaller gerektirir. Bu dijital ürünler ve hizmetler herhangi bir türde materyalsiz sunulmaz. Fakat sonuca bakıldığında dijital ürünlerin çevresel açıdan daha az zararlı ve daha sürdürülebilir bir çözüm olduğu görülmektedir. Akıllı tarım uygulamaları, Bilgi ve İletişim Teknolojisi çözümlerinin başka bir çevresel faydalı yönüdür. Hassas tarım (Precision Farming, PF), çiftçilerin doğru miktarda girdiyi doğru zamanda ve doğru yerde uygulamalarını sağlayan bir yöntemdir ve bu da mahsulleri, bitkileri, toprakları ve yeraltı suyunun kullanımını iyileştirmektedir [10]. Gübreler ve pestisitlerin uygun yönetimi, doğrudan tarlalardan N_2O (Azot Protoksit) emisyonlarını azaltmanın yanı sıra, bu tür girdileri koruyarak üretim aşamasındaki dolaylı emisyonları da azaltır.

Üç şirket karşılaştırıldıktan sonra, Şirket B toplamda 85 üzerinden 75 puan alarak en iyisi olmuştur. On iki talep edilen nitelik için en yüksek puanı Şirket B almıştır. Şirket A, 72 puanla ikinci sırayı almaktadır. On talep edilen nitelikler açısından, Şirket A en yüksek puanı almıştır. 70 puanla Şirket C, sekiz talep edilen niteliklerin tamamında en yüksek puanı almıştır. Üç işletmenin değerlendirmeleri, karşılaştırıldığında oldukça benzer bulunmuştur. Şirketler arasındaki küçük farklar genellikle hizmet verdikleri bölgeyle ilgilidir. Şirketlerin harcadığı çabaların çoğu, sorumlu tüketim ve üretim, su altı yaşamı, iklim eylemi, sürdürülebilir şehirler ve

topluluklar hedeflerine odaklanmıştır. Bu çabalar, bilgi, eğitim ve sağlık hizmetlerine erişim sağlamak için gereken alanlarda bağlantıyı geliştirmeyi içerir.

Bilgi ve İletişim Teknolojisi çözümlerinin sürdürülebilirlik üzerindeki etkisi, sadece doğrudan çevresel faktörlerle sınırlı değildir. Bu çözümler aynı zamanda toplumların ve ekonomilerin daha sürdürülebilir bir şekilde yönetilmesine olanak tanır. Örneğin, akıllı şehir teknolojileri, şehirlerin enerji verimliliğini artırarak kaynakları daha etkin bir şekilde kullanmalarına yardımcı olabilir ve bu da sürdürülebilirlik hedeflerine katkıda bulunabilir.

Ayrıca, sürdürülebilirlik çabalarının küresel boyutta koordinasyonu ve işbirliği de kritik öneme sahiptir. Tek bir şirket veya sektörün çabaları tek başına yeterli olmayabilir. Bu nedenle, sürdürülebilirlik alanında çok taraflı işbirliklerinin teşvik edilmesi ve desteklenmesi önemlidir. Örneğin, Birleşmiş Milletler'in sürdürülebilir kalkınma hedeflerine ulaşmak için şirketler, hükümetler, sivil toplum kuruluşları ve diğer paydaşlar arasında güçlü bir işbirliği gerekmektedir.

Son olarak, sürdürülebilirlik çabalarının değerlendirilmesi ve raporlanması önemlidir. Şeffaflık ve hesap verebilirlik, sürdürülebilirlik performansının iyileştirilmesine ve toplumun güveninin artırılmasına yardımcı olabilir. Bu nedenle, şirketlerin sürdürülebilirlikle ilgili faaliyetlerini düzenli olarak raporlaması ve paylaşması önemlidir.

Bu noktaların göz önünde bulundurulması, Bilgi ve İletişim Teknolojisi sektörünün sürdürülebilirlik alanında daha etkili bir şekilde hareket etmesine ve daha büyük bir toplumsal fayda sağlamasına yardımcı olabilir. Gelecekteki araştırmaların ve uygulamaların bu yönde ilerlemesi, küresel sürdürülebilirlik hedeflerine ulaşmada önemli bir adım olabilir.

1. INTRODUCTION

In today's rapidly evolving world, sustainability is more crucial than ever for the earth to remain a livable environment. The alignment between sustainability and governmentsorganizations concluded in the adoption by all United Nations Member States of 17 sustainable development goals at the UN Sustainable Development Summit in September 2015. They acknowledge that eradicating inequality and other forms of deprivation must be combined with initiatives to enhance environmental and governance circumstances. Connectivity is one of the most dynamically emerging technologies of the twenty-first century, and accelerating the development of many other technologies. Thus, the Information and Communications Technology (ICT) sector, which includes numerous examples such as sensors, supply chain tracking systems, smart cities, and irrigation systems, makes a significant contribution to sustainable development goals. Therefore, this study examined at how ICT enterprises contribute to sustainable development goals.

Sustainable development goals are highly related. Since Quality Function Deployment (QFD) is an excellent tool for comparing many businesses on similar subjects, it is selected as the methodology of the study. Aim of the study is comparing 3 major ICT companies' contributions to SDGs using the QFD method. A review of the literature was done for the study's second chapter, which is divided into five chapters. The sustainable development goals are outlined at the beginning of this review. Afterwards, ESG, a topic that intersects with sustainability, is investigated. Common headings for ESG, SDGs, and ICT are added to the ESG section for the purpose of detail. Under these headings, the interrelationships, integration and common outcomes of the subjects are examined. The study's methodology, QFD, is addressed in the third chapter. Details of why QFD is selected and the implementation of QFD are explained. The fourth chapter includes a case study application. The thesis subject is applied to QFD. House of Quality is prepared step by step, and the outcomes are shared. Sustainable development goals that stand out as a result of the contributions made

by the companies and the factors that limit the work are discussed in Conclusion and Limitations as last chapter.

2. LITERATURE REVIEW

2.1 Sustainable Development Goals (SDGs)

Sustainable Development Goals (SDGs) have gained significant prominence, originating from the UN Sustainable Development Summit in 2015, which marked the adoption of the 2030 Agenda. The SDGs have been described as the most comprehensive framework ever developed to address global societal grand challenges such as environmental (e.g., natural resource depletion, biodiversity loss, and climate change), social (e.g., world hunger, growing inequalities, systemic racism, human-health deficiencies, and education deficits), and governance (e.g., gender gaps, corruption, and war) [11].This agenda goes beyond its predecessor, the Millennium Development Goals (MDGs), by introducing more ambitious objectives, including the eradication of poverty, hunger, and the promotion of good health and well-being, universal education, sustainable energy, and climate action [12].

Before dive into sustainable development, we need to identify sustainability. Sustainability was defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their needs [13].

> As a follow-through of sustainability, the concept of sustainable development (SD) has historical roots, emerging in the context of environmental concerns and finding expression in documents such as the World Charter for Nature, Our Common Future, and Agenda 21 of the Earth Summit in 1992 [14].

The importance of quantitative indicators for measuring sustainable development has been recognized since the early stages of the SD concept, with Agenda 21 of the Earth Summit in 1992 calling for indicators to assess progress towards a more sustainable world [15]. Despite efforts by international organizations and governments, theoretical consensus on measuring well-being and sustainability has not been achieved, leading to the ongoing exploration of appropriate indicators [16, 17].

The proposal to develop SDGs with concrete indicators was officially introduced at the Rio, aiming to create a universal set of goals, targets, and indicators to guide UN member states in framing their agendas and policies over the next 15 years [18].

Figure 2.1 displays the 17 sustainable development goals.

Figure 2.1 : 17 UN Sustainable development goals [1].

The adoption of the 2030 Agenda and the Paris Agreement has provided a framework for national and global efforts on sustainable development, focusing on the five Ps: Prosperity, People, Planet, Peace, and Partnership [19]. The SDGs, with their time-bound targets, are recognized as interdependent, requiring deep, structural changes across all sectors of society [20]. To address the critical question of how to organize strategies for achieving the 17 SDGs, a systemic policy approach is proposed, outlining six transformations as a semi-modular action agenda involving government, business, and civil society. Each transformation represents a major change in societal structure to achieve long-term sustainable development, contributing to multiple SDGs and working at global, regional, and national scales [21].

2.1.1 Overview of the sustainable development goals and targets

Goal 1 - No Poverty

By 2030, the goal is to eradicate extreme poverty, measured as individuals living on less than .25 a day. This involves reducing the proportion of people in poverty by at least half across all dimensions. National appropriate social protection systems should be implemented to achieve substantial coverage for the poor and vulnerable. In

addition, there is a need to guarantee equal rights for economic resources, fundamental services and ownership of land in particular for the poor. Increasing the resilience of the poorest populations and reducing their vulnerability to climate change events and impacts is the most important part. To eliminate poverty as comprehensively as possible, it is essential that resources are mobilised, in particular for emerging countries, and proper policy frameworks have been established at all levels of government [22].

Goal 2 - Zero Hunger

Ending hunger by 2023 focuses on ensuring universal and equitable access to safe and nutritious food, especially for the poor and vulnerable All forms of malnutrition, such as stunting in all children and the eradication of preventable deaths of children under five years old, should be eliminated by 2025. It is especially important to increase the income of women and indigenous small-scale food producers and communities by doubling their productivity. Sustainable food production systems and resilient agricultural practices considering climate change, extreme weather events, and disasters should be established by 2030. Emphasis is placed on preserving genetic diversity and promoting equal access to resources. Measures such as increased investment, correcting trade restrictions, and ensuring the regular functioning of food commodity markets are necessary to limit excessive food price volatility [22].

Goal 3 - Good Health and Well-being

Reducing maternal mortality, eliminating avoidable deaths of infants and children under five, and fighting several diseases, such as AIDS, TB, and malaria, are the goals by 2030. Premature death from non-communicable illnesses should be cut by one third, with an emphasis on mental health promotion. Importance should be given to global access to prevention and treatment of drug abuse, sexual and general health treatments. Targeted outcomes include a decrease in pollution-related diseases and fatalities as well as assistance for vaccine and medication development and research. Additionally, there is a focus expand the health sector, the focus is on improving the number of health workers and health systems [22].

Goal 4 - Quality Education

The objective by 2030 is to ensure inclusive, equitable, and quality education, with a focus on completing primary and secondary education for all girls and boys. Access to quality early childhood development and pre-primary education is essential. Equal access to affordable technical, vocational, and tertiary education, including university, should be ensured. Increasing the number of individuals with relevant skills for employment, eliminating gender disparities in education, and promoting literacy and numeracy are key targets. Knowledge and skills acquisition should encompass sustainable development, human rights, gender equality, and cultural diversity. Building and upgrading education facilities and expanding scholarships for developing countries are essential, along with increasing the supply of qualified teachers through international cooperation [22].

Goal 5: Gender Equality

Goal 5 focuses on achieving gender equality and empowering women. Key targets include ending discrimination, eliminating violence, harmful practices, and ensuring universal access to sexual and reproductive health. Reforms in economic rights, technology access, and policy enforcement are emphasized [22].

Goal 6: Clean Water and Sanitation

Goal 6 aims for universal and equitable access to safe drinking water and sanitation by 2030. Targets include improving water quality, increasing water-use efficiency, implementing integrated water resources management, and protecting water-related ecosystems. International cooperation and community participation are highlighted [22].

Goal 7: Affordable and Clean Energy

Goal 7 focuses on ensuring universal access to affordable and modern energy services. Targets include increasing the share of renewable energy, improving energy efficiency, and expanding infrastructure for sustainable energy services globally, with a focus on developing countries [22].

Goal 8: Decent Work and Economic Growth

Goal 8 aims for sustained economic growth and full employment. Targets include diversifying economic productivity, promoting development-oriented policies, improving resource efficiency, achieving full and productive employment, and eradicating forced labor and child labor [22].

Goal 9: Industry, Innovation and Infrastructure

Goal 9 focuses on developing resilient infrastructure, sustainable industrialization, and innovation. Targets include promoting inclusive industrialization, upgrading infrastructure for sustainability, enhancing scientific research, and providing support for technology development in developing countries [22].

Goal 10: Reduced Inequalities

Goal 10 focuses on reducing inequality within and among countries. Targets include achieving sustained income growth for the bottom 40%, promoting social inclusion, ensuring equal opportunities, adopting policies for greater equality, and enhancing representation for developing countries in global decision-making [22].

Goal 11: Sustainable Cities and Communities

Goal 11 aims to make cities and human settlements inclusive, safe, resilient, and sustainable. Targets include ensuring access to housing and basic services, safe and sustainable transport, inclusive urbanization, protection of cultural and natural heritage, disaster risk reduction, and universal access to green and public spaces [22].

Goal 12: Responsible Consumption and Production

Goal 12 addresses sustainable consumption and production patterns. Targets include implementing programs on sustainable consumption, efficient use of natural resources, reducing food waste, managing chemicals and waste, promoting sustainable business practices, and increasing awareness for sustainable development [22].

Goal 13: Climate Action

Goal 13 calls for urgent action to combat climate change and its impacts. Targets

include strengthening resilience to climate-related hazards, integrating climate measures into policies, enhancing education and awareness, and mobilizing financial resources for climate-related planning and management [22].

Goal 14: Life Below Water

Goal 14 focuses on conserving and sustainably using oceans, seas, and marine resources. Targets include preventing marine pollution, managing and protecting marine ecosystems, addressing ocean acidification, regulating fishing practices, conserving coastal areas, and providing access for small-scale fishers [22].

Goal 15: Life on Land

Goal 15 aims to protect, restore, and promote sustainable use of terrestrial ecosystems. Targets include conservation of ecosystems, sustainable management of forests, combating desertification, reducing natural habitat degradation, promoting fair sharing of biodiversity benefits, and mobilizing financial resources for biodiversity conservation [22].

Goal 16: Peace, Justice and Strong Institutions

Goal 16 promotes peaceful and inclusive societies, access to justice for all, and effective, accountable, and inclusive institutions. Targets include reducing violence, ending abuse and exploitation, promoting the rule of law, reducing corruption, ensuring legal identity for all, and fostering inclusive decision-making [22].

Goal 17: Partnerships for the Goals

Goal 17 focuses on strengthening means of implementation and revitalizing the global partnership for sustainable development. Targets include mobilizing financial resources, enhancing international cooperation on science and technology, promoting sustainable trade, enhancing policy coherence, and encouraging multi-stakeholder partnerships for sustainable development. Additionally, it addresses issues related to data, monitoring, and accountability, including enhancing capacity-building support for data availability and promoting measurements of progress beyond GDP [22].

2.2 ESG

ESG (Environmental, Social, Governance) is not a new concept. It has previously been called by different names: Socially Responsible Investment [23], Ethical Investment [24] and Social Investment [25]. ESG is a framework used to evaluate the environmental, social and governance performance of companies and institutions. Hence, those ESG evaulations have been used by investors who cares about responsible investing. According to CFA Institute [26], indicators to measure and evaluate the sustainability and social responsibility performance of companies are listed in the following section. Here are the key elements of ESG:

Environmental: Conservation of the natural world

Climate change and carbon emissions: Addressing climate change involves reducing the emission of greenhouse gases such as carbon dioxide. Sustainable practices like using renewable energy sources, promoting energy-efficient technologies, and offsetting carbon emissions through reforestation projects can be implemented by companies.

Air and water pollution: Companies can contribute to environmental conservation by adopting cleaner production methods, minimizing pollutants in their operations, and investing in advanced waste treatment technologies. Continuous monitoring and documentation of air and water quality is critical to verifying compliance with environmental regulations.

Biodiversity: Businesses should seek to protect and promote biodiversity by sourcing raw materials responsibly, avoiding practices that harm ecosystems, and supporting conservation projects. For instance, a company may choose suppliers who adhere to sustainable harvesting practices to prevent the depletion of endangered species.

Deforestation: To combat deforestation, companies can commit to sustainable sourcing of wood and paper products, and invest in initiatives that contribute to reforestation efforts. Implementing a paperless office policy and supporting certification programs for responsibly sourced wood are examples of such initiatives.

Energy efficiency: Focusing on energy efficiency helps reduce the environmental footprint of a company. In order to reduce dependence on fossil fuels measures can be taken by using energy-saving technologies, simplifying production methods and allocating resources to renewable energy sources.

Waste management: Proper waste management includes recycling, reducing waste generation, and adopting circular economy practices. Companies can implement waste reduction programs, encourage recycling among employees, and collaborate with suppliers who prioritize eco-friendly packaging.

Water scarcity: Businesses operating in water-scarce regions should implement water conservation measures, such as optimizing water use in production processes, investing in water-efficient technologies, and supporting community initiatives for responsible water management.

Social: Consideration of people relationships

Customer satisfaction: Prioritizing customer satisfaction involves delivering quality products or services, addressing customer concerns promptly, and seeking feedback for continuous improvement. Engaging with customers through surveys, social media, and customer service channels demonstrates commitment to their needs.

Data protection and privacy: Companies must safeguard customer and employee data through robust cybersecurity measures and compliance with data protection regulations. Transparency about data handling practices, secure data storage, and obtaining informed consent are crucial aspects of maintaining privacy.

Gender and diversity: Fostering gender and diversity inclusivity involves creating a workplace culture that values and respects differences. Diversity training, set inclusive hiring practices, and establish employee resource groups can be implemented by companies to support underrepresented groups.

Employee engagement: Promoting employee engagement includes providing opportunities for skill development, recognizing achievements, and fostering a positive work environment. Regular communication, employee feedback mechanisms, and wellness programs contribute to increased job satisfaction and productivity.

Community relations: Supporting community initiatives, participating in philanthropic activities, and transparency in the company's social responsibility projects make a difference in establishing positive relationships with local communities. Collaboration with local organizations and participation in community events strengthen ties.

Human rights: Upholding human rights in business operations entails ensuring fair labor practices, avoiding discrimination, and preventing any form of exploitation. The

company exhibits its dedication to upholding human rights through periodic audits, compliance with global human rights norms, and transparent reporting.

Labor standards: Adhering to labor standards involves providing fair wages, safe working conditions, and respecting workers' rights. In order to contribute to maintaining labor standards, companies should implement occupational health and safety measures, compliance with labor laws and engaging in social responsibility initiatives.

Governance: Standards for running a company

Board composition: Ensuring a diverse and independent board composition enhances corporate governance. Companies should have a balanced mix of skills and experiences among board members to promote effective decision-making and strategic oversight.

Audit committee structure: Ensuring a diverse and independent board composition enhances corporate governance. Aiming to encourage effective decision making and strategy oversight, companies should have a balance of skills and experience among their board members.

Bribery and corruption: Companies should have robust anti-bribery and anti-corruption policies in place. Training of employees on ethical behaviour, due diligence on business partners and the establishment of mechanisms for reporting and combating corruption will be part of this.

Executive compensation: Transparent and fair executive compensation practices align with good governance. It is advisable for companies to connect executive compensation with performance, reveal the structures of compensation, and maintain equilibrium between rewarding leaders and enhancing shareholder value.

Lobbying: Seeking to impact or influence legislative action or inaction through verbal or written communication, or trying to gain the favor of a member or employee of the legislature [27]. Transparent and ethical lobbying practices contribute to good governance.

Political contributions: Transparent reporting of political contributions is essential for good governance. Companies consider making public their political contributions, comply with relevant legislation and ensure that activities in the field of politics correspond to company values and ethical standards.

Whistleblower schemes: Implementing effective whistleblower schemes allows employees to report unethical behavior without fear of retaliation. ensure transparency and accountability, companies should set up transparent reporting channels, protect whistleblowers as well as conduct thorough investigations of allegations made. Companies should establish clear reporting channels, protect whistleblowers, and conduct thorough investigations into reported concerns to maintain transparency and accountability.

ESG measures not only a company's financial performance but also its environmental and social impacts, becoming part of a company's sustainability strategy. A more detailed view of the company's long term value and risk profile can be provided by this framework. Assessment of a company's sustainability efforts is guided by the ESG criteria, guiding investors and stakeholders.

2.2.1 Relationship between ESG and SDG

The ESG and SDG frameworks share the objective of fostering sustainability and ethical corporate practices. While ESG criteria can coincide with some SDGs (for example, environmental goals), they are not specifically intended to encompass all parts of the SDGs. The SDGs comprise a larger set of goals that extend beyond the specific emphasis areas of ESG. Businesses may match their ESG practices with specific SDGs, so contributing to global sustainability objectives. When discussing firms' contributions to the SDGs, it is critical to ensure that ESG performance metrics advance UN sustainability goals. Figure 2.2 shows which ESG pillars covers the SDGs [2].

Figure 2.2 : Sustainable development goals through the lens of ESG [2].

According to a text mining analysis of Japanese listed firms' annual reports revealed a strong correlation between SDGs and ESG practices in business. 131 businesses used the term "SDGs" in their reports, 218 firms used "ESG", and 114 firms (87% = 114/131) fell between the two [28]. Also, Javier et al. [3] provide a few examples of ESG indicators that may be used to assess a company's sustainability effect and possible contributions to attaining the SDGs. Figure 2.3 lists a variety of ESG metrics and their equivalents to SDG indicators [3]. Distinguishing between ESG elements is not always straightforward, as seen in the instance of "environmental partnerships," where the suggested indicator might be classed as belonging to all three categories of ESG factors.

SDG	SDG target	SDG indicator	ESG variable	
	Target 6.4 Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.	6.4.1 Change in water-use efficiency over time.	Water use to revenues • Total water withdrawal in cubic meters divided by net sales or revenue in millions of USD.	E factors
	Target 7.1 Ensure universal access to affordable, reliable, and modern energy services.	7.1.2 Proportion of population with primary reliance on clean fuels and technology.	Renewable energy use ratio • Total energy purchased from primary renewable energy sources divided by real energy use.	
	Target 13.2 Integrate climate change measures into national policies, strategies, and planning.	13.2.1 Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan, which increases their ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions.	CO_2 equivalent emissions to revenues • Total CO_2 and CO_2 equivalent emissions in tons divided by net sales or revenue.	
	Targets 3.9 Substantially reduce the number of deaths and illnesses from hazardous chemicals, air, water, and soil pollution, and contamination.	3.9.2 Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene. 3.9.3 Mortality rate attributed to unintentional poisoning.	Health-safety policy • Whether the company has a policy to improve employee health and safety within the company and its supply chain.	S factors
	Target 8.8 Protect labor rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment.	8.8.1 Frequency rates of fatal and non-fatal occupational injuries by sex and migrant status.	Total accidents • Number of injuries and fatalities reported by employees and contractors while working for the company.	
	Target 5.5. Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic, and public life.	5.5.2 Proportion of women in managerial positions.	Board gender diversity • Percentage of females on the board.	G factors
			Executive management gender diversity • Percentage of female executives.	
	Target 16a. Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and crime.	16.a.1 Existence of independent national human rights institutions in compliance with the Paris Principles.	Human-rights policy • Whether the company has a policy to ensure the avoidance of child, forced, or compulsory labor, or to guarantee the freedom of association universally applied independent of local laws.	

Figure 2.3 : Sample equivalencies between ESG elements at the company level and SDGs at the society level [3].

2.2.2 ESG and ICT integration

The merging of ESG and ICT symbolizes a potent union that transforms the realm of environmentally mindful business methodologies. The infusion of Information and Communication Technology (ICT) into the frameworks of Environmental, Social, and Governance (ESG) enhances the organizational prowess in gathering, overseeing, and scrutinizing ESG-associated data, ushering in a fresh epoch of knowledgeable decision-making [29].

The World Economic Forum (WEF) convened in Davos the previous year emphasized the various ways in which digital technology is transforming global efforts for environmental conservation. These range from utilizing blockchain technology to

combat illegal fishing and overhaul certification and traceability systems to employing artificial intelligence for the protection of endangered species. The WEF believes that digital technologies have the potential to cut global emissions in the three highest-emitting sectors by 20% by 2050. But digital technology can be equally effective on an organizational level. The utilization of digital technology within corporations, described as employing electronic tools, devices, systems, and resources for data generation, storage, or processing, holds significant potential to drive an organization's ESG strategy and implementation. This is why, from the perspective of businesses, ESG and digital technology can be seen as two sides of the same coin. Digital technology must be absolutely central to an organization's ESG journey, from strategy through to transformation [30].

Information and Communication Technology (ICT) acts as a crucial element for effective ESG data administration, enabling organizations to gather and consolidate data pertaining to essential metrics like energy usage, water consumption, waste handling, and emissions.Cloud-based platforms, exemplified by Schneider Electric's "EcoStruxure™ Resource Advisor," smoothly integrate ICT with ESG data management. EcoStruxure Resource Advisor uses data from sensors and smart meters to offer instant insights, benchmarking capabilities, and reporting tools, empowering entities like Schneider Electric to improve resource efficiency and advocate for environmentally conscious approaches [31].

Furthermore, through the collaboration between sustainable supply chain management ESG and ICT, technology plays an important role in improving transparency and responsible methodologies. ICT aids in supervising the tracking and tracing of raw materials, ensuring supplier adherence to ESG standards, and utilizing digital platforms in tandem with blockchain technology to authenticate and ethically obtain products. The partnership between IBM and MineHub Technologies stands as a paradigm, showcasing a blockchain-centric resolution that enhances openness and traceability in mineral supply chains, thereby championing ethical management of the supply chain [31].

Stakeholder engagement and communication are further enriched by ICT platforms, providing companies with effective tools to communicate ESG performance data, initiatives, and progress reports. Unilever's "Sustainable Living" website stands as

an example, leveraging dedicated ICT platforms to communicate its ESG goals and progress transparently. Through websites, social media, and portals, companies can engage with investors, customers, employees, and communities, fostering real-time information exchange, feedback mechanisms, and accountability [31].

ICT's impact extends to energy efficiency and carbon footprint reduction, where the deployment of smart grids, energy management systems, and Internet of Things (IoT) devices optimizes energy usage. Cisco Systems exemplifies this with its "Smart+Connected Real Estate" solution, integrating ICT infrastructure to monitor and control lighting, HVAC systems, and other energy-consuming assets, resulting in significant energy savings and reduced environmental impact [29].

Lastly, the integration of ICT into ESG practices contributes to digital inclusion and social impact by bridging the digital divide. Google's "Google Station" initiative, utilizing ICT infrastructure to provide free Wi-Fi access in public spaces in developing countries, stands as an exemplary case. By enhancing connectivity and access to online resources, ICT initiatives like this promote social impact, skill development, and economic opportunities in marginalized communities [31].

2.2.3 Data-driven decision making

In the age of information abundance, the prowess of data-driven decision-making stands out as a game-changer in organizational strategie. Companies today prioritize issues such as sustainability and social responsibility, focusing on environmental, social, and governance (ESG) problems in addition to financial success. In this section, why ESG data collection and analysis, as well as data-driven decision-making, are crucial, and what aspects should be considered throughout this process will be discussed.

> ESG data collection involves integrating information from a variety of sources and measuring a company's environmental, social and governance performance. Data from sources such as financial reports, environmental impact reports, employee satisfaction surveys, and stakeholder interviews help objectively evaluate a company's sustainability efforts [32].

Furthermore, ICT leverages an extensive number of metrics and sensors in order to gather data such as energy and water consumption, carbon emissions, and waste creation.

> For example, The Port of Los Angeles, with its application called "Port Optimizer", is a cloud-based ICT solution that allows ports and supply chains to operate more efficiently and helps cargo owners bring their goods to market in a more predictable and timely manner [33].

The obtained ESG data is thoroughly evaluated utilizing analytical techniques and procedures. In order to assess the company's progress toward its sustainability objectives, environmental implications, social obligations, and governance practices ESG data needs to be analyzed. ESG data analysis helps businesses recognize their strengths and weaknesses, discover opportunities for change, and communicate more transparently with stakeholders. For instance, a company called Salesforce supports employee well-being and social impact with its platform called "Work.com". With this platform, they aim to protect employees and approach them with a special behavior like a customer [34].

ESG data collection and analysis strengthens companies' data-driven decision-making processes that includes not only financial performance but also factors such as sustainability, ethics and social responsibility. Companies' capabilities in ESG data collection and analysis by using Machine Learning, AI algorithms and data modeling in data-driven decision-making will help them gain competitive advantage and gain the trust of investors and consumers by recognizing and completing deficiencies.

2.2.4 Improved reporting and transparency for stakeholder engagement

Transparent reporting on Environmental, Social and Governance (ESG) metrics has emerged as a cornerstone for organizations looking to engage effectively with their stakeholders. This chapter addresses the importance of improved reporting and transparency and highlights ways organizations can improve their ESG profiles through comprehensive disclosure mechanisms. The analysis in this section examines reporting methodologies and their impact on stakeholder engagement, aiming to uncover strategies that increase trust, contribute to sustainable business practices, and align organizations with the expectations of an increasingly conscious global audience.

The majority of corporate companies share sustainability reports at the end of the year. These reports include the standardized The Global Reporting Initiative's (GRI) sustainability reporting guideline [35]. GRI is an independent organization that

provides a global framework for measuring and reporting sustainability performance. The initative was established to enable companies, governments and non-governmental organizations to convey sustainability-related information to their stakeholders in a more transparent and standardized manner. It contains economic, environmental and social performance data within sustainability. By standardizing this data, it makes it easier for companies to follow their scores and development over the years and to compare themselves with organizations in the same sector and take action [36].

2.2.5 Innovative ict solutions for sustainable practices

Information and communication technology (ICT) stands out as a strong ally in the pursuit of developments in ecological sustainability. This section attempts to highlight a variety of technical advances by examining recently developed sustainable ICT solutions that may be used by governments or corporations. Highlighting innovations that steer companies toward ecologically and socially responsible behaviors is the goal. These innovations range from energy-efficient technology to data-driven insights allowing resource efficiency. The aim is to fully utilize ICT as a catalyst for promoting positive social and environmental change, by exploring new frontiers in technical inventiveness.

Innovative ICT solutions encompass various initiatives utilizing smart technologies in critical economic sectors, including smart grids, buildings, and intelligent transport systems. These technologies have the capacity to significantly decrease global energy consumption and lower greenhouse gas (GHG) emissions. Projections suggest that by 2020, the implementation of these ICT-enabled applications could lead to a reduction of 9.1 gigatons of GHG emissions, translating to substantial gross energy and fuel savings amounting to $1.9 trillion. This reduction represents approximately 16.5% of global emissions, as indicated in GesI's SMARTer2020 report [37].

A further example, IBM's "Smarter Planet" initiative investigates the role of ICT and advanced data analysis in addressing sustainability issues such as energy, food security, traffic congestion, national security, urban growth, and water shortages [38]. Another IBM's initiative served as the systems integrator for American Electric Power's "gridSmart" initiative, which aims to improve the distribution grid's ability to manage distributed power generation, storage, and efficiency programs.

The ECOtronics initiative intends to employ materials that can be safely recycled, composted, or even allowed to decay naturally [39]. Biodegradable materials will be required in devices used to measure soil or other environmental conditions. The project's materials R&D will focus on substrate materials used as a basis for electrical and optical components, rather than typical circuit board materials. In terms of manufacturing processes, the project focuses heavily on printing technologies that allow electronics and optics to be printed directly on thin, roll-to-roll base materials. As an additive manufacturing approach, printing completely fills in the component materials, resulting in no waste throughout the production process. Antti Backman, Chief Design Officer at New Cable Corporation Oy., said "We are already producing cables using roll-to-roll techniques, but we want to develop the materials further to make them even more environmentally friendly. I believe that the ECOtronics project will support our goal in many different ways." to convey his support for this initiative.

In 2022, Fortum, Finland's top energy company, and Microsoft announced a revolutionary alliance [4]. Fortum will use the excess heat generated by a planned Microsoft data center in the Helsinki metropolitan region. These data centers will use 100% emission-free power. Fortum will then transfer the clean heat collected during the server cooling process to households and businesses connected to its district heating network. This waste heat recycling idea will be the largest of its type worldwide. "If we are to limit global climate warming to 1.5°C as required by the Paris agreement, we need innovative thinking to drive change at higher pace and bigger scale. This investment in the data centre region is a flagship example of climate action and circularity.

> The project is the first of its kind of this size, but we hope to inspire further development in the use of waste heat to deliver clean energy," says Nebahat Albayrak, SVP Corporate Affairs, Safety and Sustainability at Fortum [4].

This was considered while deciding where Microsoft's data centers will be. Microsoft intends to establish a data center region between the cities of Espoo and Kirkkonummi, where it will ultimately provide 40% of the district heat required in the area. Recycling surplus heat from emissions-free power used by data centers would drastically reduce the region's total emissions while also keeping district heating prices competitive. Furthermore, the data center heat can reduce 400,000 tons of CO_2 emissions annually,

as well as cover 2-3% of Findland's new emission reduction goal. The following diagram in Figure 2.4 illustrates the recycling of waste heat [4].

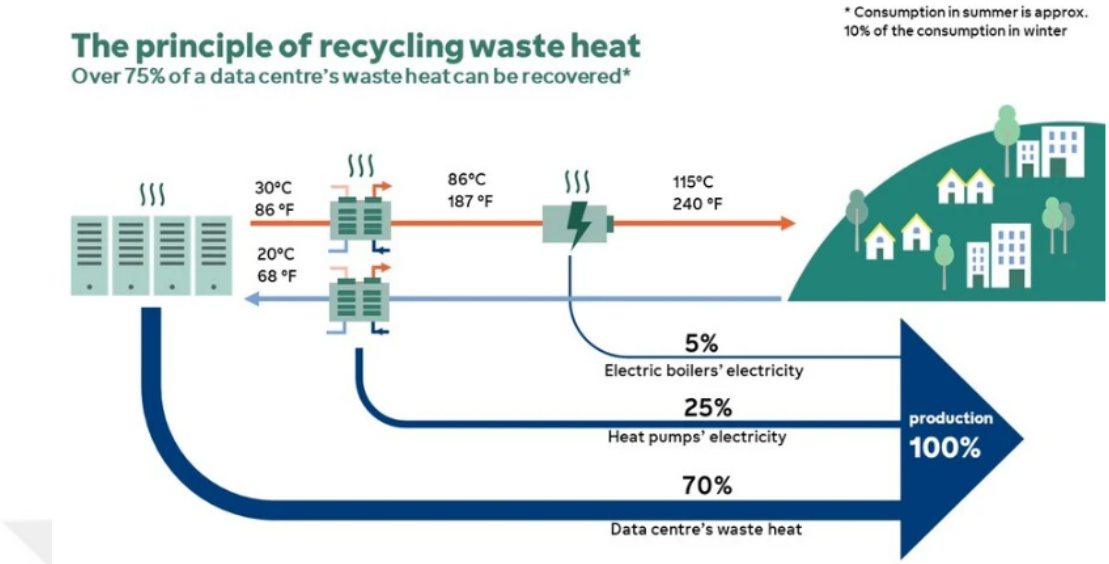

Figure 2.4 : Diagram of the principle of recycling waste heat [4].

2.2.6 ESG and ICT supply chain

The global supply chain of Information and Communication Technology (ICT) products carries profound implications for the environmental and social footprint of organizations. This section scrutinizes the integration of Environmental, Social, and Governance (ESG) principles into the ICT supply chain, exploring how responsible sourcing, ethical labor practices, and environmental considerations can be seamlessly incorporated. Through a detailed examination of the ESG dimensions within the ICT supply chain, the thesis aims to unravel strategies that create a more sustainable and ethically sound foundation for the production and distribution of ICT products, aligning supply chain practices with ESG objectives.

For example, Nokia is working with the goal of reducing any impact that may occur due to its supply chain to zero. By the end of 2022, 98% 3TG traceability and conflict-free status were achieved [40]. Many industries, including electronics, technology, medical services, jewelry, and automotive, must carefully monitor the purchase of Tin, Tantalum, Tungsten, and Gold (3TG), often known as "conflict minerals." The exploitation of these minerals raises serious human rights concerns, highlighting the importance of supply chain transparency [5]. Additionally, Nokia aims for its final assembly suppliers to reach zero emissions and for its suppliers'

GHG emissions to decrease by 50% by 2030. Typical supply chain participants in the 3TG supply chain are demonstrated in Figure 2.5 [5].

Figure 2.5 : Diagram of typical supply chain participants in the 3tg supply chain [5].

Supply chain emissions totaled 9% of Ericsson's overall value chain carbon footprint [41]. As part of its Net Zero goal, Ericsson is trying to decrease these through design improvements, transportation efficiency, and supplier involvement. Efforts to minimize product weight and size continued throughout the year, as did activities aimed at carbon-intensive materials and processes, such as aluminum. The company has also looked into ways to collect supply chain emissions data more effectively and correctly. Ericsson hopes that by 2025, 350 high-emitting and strategic direct suppliers will have established their own emission reduction objectives in line with the 1.5 °C goal. The Paris Agreement's 1.5 °C goal is to keep global temperature rise to "well below 2 degrees °C above preindustrial levels" while "pursuing efforts to limit the temperature increase to 1.5 degrees C." [42]. These suppliers, and their supply chains, account for the vast bulk of Ericsson's supply chain-related carbon footprint. To be accepted, a supplier's aim must contain a halving of emissions in relevant scopes by 2030 relative to the target baseline, be made public, and be supported by public progress reporting. By the end of 2022, 225 suppliers had established objectives that met these criteria, putting the company on track to accomplish its engagement goal within the timeframe specified. Ericsson continues to work with suppliers that have not yet set coordinated objectives. Ericsson and the Exponential Roadmap Initiative collaborated to host an online webinar and co-create the 1.5 C Business Playbook

and Supplier Engagement Guide, with the goal of assisting companies in setting 1.5 C-ambition aligned targets and engaging with their own supply chains.

As an another ICT firm, Cisco ranked first in The Gartner Supply Chain Top 25 Companies for 2022 [43]. One of the key attributes was ESG scores for ranking.

> One of the reasons is that Cisco reduce absolute GHG emissions from purchased goods and services, upstream transportation and distribution, and use of sold products by 33% by the end of 2022, even the goal was 30% reduction by 2030 [44].

Also, they declare that their second-largest source of emissions is their supply chain. Cisco has set a goal for 80% of their main component, manufacturing, and logistics suppliers to publish public GHG emissions reduction objectives by 2025, and they periodically share their insights with them.

2.2.7 Digital transformation and social impact

Digital transformation is an interdisciplinary subject of study, and the definition of digital transformation varies across the literature. One of the definitions refers to the changes that digital technology may bring about in a company's business model and organizational structure [45]. These changes can be detected in both individual and corporate environments. Digital transformation is now commonly considered as such employment of information and communication technology, where not simple automation is conducted, but fundamentally new capabilities are produced in company, public government, and people's and society life. The ongoing digital transformation has transcended mere technological advancement to become a potent force shaping societal dynamics. As a result, it creates social impact on various issues [46].

Singapore's Ministry of Education collaborated together with other government organizations and commercial firms to prepare the workforce for the digital [47]. The SkillsFuture program provides for Singaporeans aged 25 years and above for courses in engineering, blockchain system planning, even drone maintenance. It was created in 2015 and offers three different credit types. Different varieties are specified for various age groups. This initiative is an important example of educational access, which represents an example of the social impacts of digital transformation.

The influence of digital revolution on healthcare is various. It ranges from electronic recording and accessibility of medical information and prescriptions to smart watches

that allow users to monitor their own health (e.g. real-time heart rate tracking). Therapy can also be delivered via virtual channels (e.g. smartphones, computers), saving crucial time, or a patient can attend an appointment by phone or video conference via telehealth services [48]. There are also several illness detection applications that use personal health data from wearable devices, as well as automation solutions for tracking systems. However, it appears that they are unable to meet their user count objective.

The impact of digital transformation on the environment can be examined in various ways. The need for the production of ICT products for digital transformation is an undeniable fact. The manufacturing and usage of ICT goods have varying environmental impacts [8]. ICTs' environmental effect is often analyzed using well-known measures, such as energy usage and GWP (global warming potential). In addition to climate change, ICT also has direct environmental implications that must be considered. Resource consumption , water consumption, land usage, and biodiversity consequences are all important considerations. On the other hand, there are plenty of beneficial impacts. Dematerialisation is one of them. Dematerialisation and substitution refer to the conversion of physical things into digital commodities. Dematerialization, or the replacement of physical things with virtual commodities, is viewed as one of the ways to reduce environmental negative consequences through ICT applications, such as videostreaming vs. DVD viewing and e-books vs. paperbooks [9]. Dematerialisation is not the absolute correct term, because transitioning to digital goods or services still requires materials, such as e-reader to read a digital book rather than paper books. These digital products and services are not offered without any kind of material. Smart agricultural applications are another environmentally beneficial aspect of digital transformation. Precision farming (PF), a method that allows farmers to apply the proper quantity of inputs at the right time and in the right location, can improve crops, plants, soils, and groundwater [49]. The proper management of fertilizers and pesticides reduces direct N_2O emissions from fields as well as indirect emissions from the production phase by conserving such inputs.

2.3 Contribution to SDG Using the QFD Method in ICT Companies'

In the literature review research, no study was found on the contribution to the SDGs using the QFD method in ICT companies', but there are plenty of study about ICT companies' contribution to SDGs. It can be seen that in those studies, the greatest value in today's world is knowledge and ongoing improvement. As a result, both developed and developing countries place a high priority on the advancement of information and communication technology. After the expansion of knowledge and research in numerous disciplines, interest in economic, social, and environmental development has grown significantly, generating knowledge and information a critical method of reaching society while minimizing environmental impact [50].

For example, Global e-Sustainability Initiative (GeSI) is an initiative led by Fujitsu and other global ICT companies such as Accenture Strategy, Ericsson, Microsoft, and Samsung Electronics, as well as international organizations such as the International Telecommunication Union (ITU), the United Nations Environment Programme (UNEP), and WBCSD. GeSI produces reports on how numerous ICT services might significantly contribute to the accomplishment of the SDGs [51]. As a consequence of this report, it is clear that digital solutions will have a significant and measurable beneficial influence on each of the three interconnected pillars of development addressed by the SDGs: improving people's quality of life, supporting fair growth, and environmental protection.

Zero hunger (SDG 2), good health and well-being (SDG 3), quality education (SDG 4), peace, justice and strong institutions (SDG 16) are included in the first part, which is the improving people's quality of life. Smart agriculture, for example, boosts agricultural output while lowering the demand for precious resources like water (SDG 2). Precision agriculture may be achieved through optimized farm management and automated irrigation systems. M2M/IoT, soil sensors and satellites, as well as integrated real-time weather information, traceability, and tracking systems, would all help to boost production. According to GeSI's 2015 research (GeSI Accenture Strategy, "SMARTer2030: ICT Solutions for 21st Century Challenges", 2015), these technologies are expected to enhance agricultural yields by more than 900 kg/ha by 2030. Another project, Nokia and Vi CSR (Vodafone Idea Corporate Social

Responsibility) use the SmartAgri technology to improve farming operations [52]. The pilot initiative is being conducted in 100 areas throughout Madhya Pradesh and Maharashtra, benefiting over 50,000 farmers by increasing production and revenue. Over 400 sensors have been put over 100,000 hectares of farmland to capture various data points, which are then analyzed by a cloud-based and locally tailored Smart Agriculture software. The app supports local languages and includes weather forecasts and irrigation management information. The sensors provide information that helps to boost soy and cotton crop yields. Crop management using Nokia's Worldwide IoT Network Grid (WING) may include smart irrigation, smart pesticide control, and proactive crop and weather information exchange frameworks. Healthcare's digitization and networking are already yielding benefits (SDG 3). ICT companies such as Cisco, Nokia, and Ericsson etc. assist healthcare businesses in using intelligent infrastructure and digital technology to cut costs and provide better, more focused patient care [41].Their technologies streamline laborious operations, make it easier to communicate medical information, and give connection to assist health monitoring, automated workflows, and revolutionary new therapies. High-resolution video consultations, support robots, and 5G-enabled smart wearables all contribute to increased treatment efficiency and efficacy. Education plays an unquestionable role in allowing individual and national economic growth (SDG 4). Nokia's corporate community investment initiatives also stress the value of education. In 2020, Nokia continues to collaborate with UNICEF to provide internet connection and high-quality digital education resources to Kenyan children [52]. Since 2018, the campaign has impacted over 90,000 youngsters in Kenya. The program has four main objectives: accessible, high-quality digital education content, meaningful teacher training, internet connectivity options for schools, joint communication and advocacy.

The second part of the three interconnected pillars of development addressed by the SDGs is fostering equitable growth. This part covers no poverty (SDG 1), gender equality (SDG 5), decent work and economic growth (SDG 8), industry, innovation and infrastructure (SDG 9), and reduced inequalities (SDG 10). ICT has a crucial role in combating poverty by enhancing productivity and empowering individuals to better support themselves and their families. This may be achieved through several means, including quick and reliable information services, allowing services like

mobile banking and micro-credit, and assisting small manufacturers in finding suitable markets [53]. Cisco contributes to international poverty reduction initiatives through its social investment approach, which supports early-stage, technology-enabled solutions that assist underprivileged populations. By increasing access to inclusive digital financial services, they also generate chances for education and employment, therefore breaking the cycle of poverty [54]. Opportunity International enables people living in poverty to support their families while also establishing new employment in their communities, which contribute to economic progress. More than 1.7 billion people throughout the world do not have access to financial services such as loans, insurance, or savings accounts, making it impossible for them to start their own enterprises, secure their crops, save for their children's education, or invest in their families' health. Cisco's collaboration with Opportunity International has increased service reach and impact by concentrating on equitable, technologically driven, and efficiently scaled solutions [54]. During the worst of the COVID-19 epidemic, Opportunity promoted the use of digital media to maintain services despite travel restrictions. During the pandemic, clients benefited from an integrated system of digital services and notifications that included SMS, Interactive Voice Response (IVR), and increased call centers. While 5.5 million employment were provided, 36 million lives were positively impacted between 2017 and 2020, with 92% of those reached being women. Cisco also launched the Women Rock-IT campaign to challenge IT stereotypes and promote gender equality. This initiative provides women with free IT training and opportunities [55]. Regarding to SDG 89, ICT plays a crucial role in building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation in emerging information and knowledge societies [56]. These societies rely on open access to academic research, transparency to make informed decisions, and online collaboration for cross-sector and in-house co-creation, learning, and work. Studies have observed that a 10% increase in broadband penetration leads to a GDP growth of up to 1.38% [57]. In another study, it is expected that 70% cut in oil consumption in 2030 compared to 2016 from all digital solutions examined [58]. In order to reduce inequalities (SDG 10), Punto Mexico Connectado Project gives opportunities to underpriviliged people of Mexico [57]. An interactive robotics class designed to provide youngsters insight and help them build their ICT abilities at a

young age. The Puntos Mexico Conectado Program aims to bridge the digital gap in order to promote access to ICT and leverage on the limitless potential it has to offer. The PMC initiative achieves this goal by establishing one center in each state of Mexico, typically in particularly disadvantaged communities with high poverty rates. In this approach, the initiative helps individuals who are less likely to have access to connection or computers in their daily lives.

The last seven SDGs mainly concentrated on conserving ecology, ensuring that the other objectives are met without compromising the planet's ability to regenerate for future generations (SDG 6, SDG 7, SDG 11, SDG 12, SDG 13, SDG 14, SDG 15).

> According to Mouhamed's study which meets SDG 6(clean water and sanitation) and SDG 14(life below water), ICT may be a critical enabler of institutional reform to meet the demand for improved water and sanitation services, particularly among hard-to-reach impoverished people in rural and urban regions [59].

In order to maximize its transformative function in the sector, ICT should be viewed as a conduit or instrument that must be effectively handled on a constant basis in order to contribute to a solution. Impact and success should be assessed not just in terms of new technology adoption or acceptance, but also in terms of meeting the goals and priorities of the Water, Sanitation, and Hygiene (WASH) sector. ICT solutions attempt to increase water usage efficiency while also improving access to water. Smart water meters in California are predicted to cut water use by 5-15% [60]. Furthermore, water authorities must assess current water supply and characteristics to meet future demands for sustainable economic growth, taking into account increased stress from climate change. Mapping water resources is becoming more vital for water utility businesses.

> For example, in Liberia, the adoption of FLOW, an open source mapping program, enabled the mapping of over 10,000 sources of water in less than six months in 2011 and allowed the development of a national WASH sector investment plan from 2012 to 2017 [59].

In Liberia, a typical paper-based survey would take at least a year to complete, with no assurance of data quality. Moreover, ICT provides smart appliances, sensors, connected infrastructure/IoT, big data analytics and cloud computing, smart buildings, and other services to assure sustainable and energy-efficient communities (SDG 7, SDG 11, SDG 12, SDG 13).

According to studies conducted by the European Commission, buildings consumed 40% of total energy in Europe in 2018. Approximately 75% of the building stock was energy inefficient [61].

The most significant reductions in energy usage in buildings can be obtained by utilizing ICT in heating, ventilation, air conditioning (HVAC) and lighting systems [62]. ICT technologies with regulated thermal performance could automate and optimize space and water heating, which are key drivers of energy efficiency improvements. Additionally, LED lights and daylight sensors improve the energy efficiency of lighting systems via ICT. An average of 61% reduction in total energy consumption is possible, and of that 33% might be enabled by the application of ICT/HEMS(Home Energy Management Systems) [63]. Last but not the least, by 2030, ICT could allow a 20% reduction in worldwide CO2e emissions, maintaining emissions at 2015 levels (SDG 13) [6]. Figure 2.6 is drawn from the GeSI study and illustrates the Gt $CO2_e$ abatement potential by ICT industry for 2030.

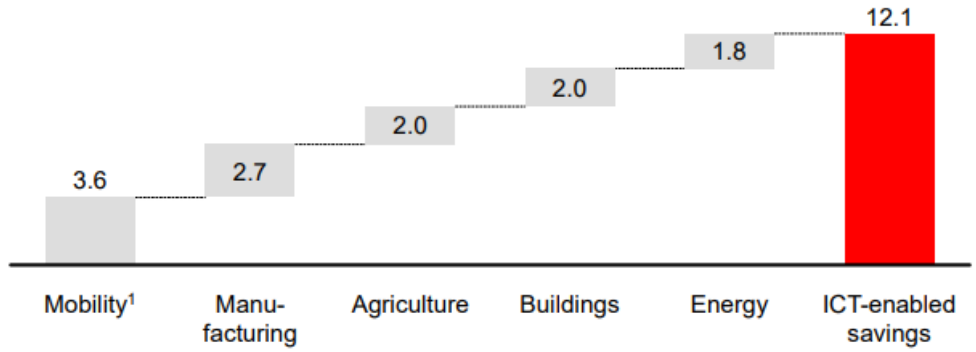

Figure 2.6 : Gt Co2e abatement potential by sector (2030) [6].

Also, ICT not only lowers carbon emissions but also has substantial positive effects on the environment. GeSI's study found that the biggest advantages were a 30% increase in agricultural crop yields, an annual savings of over 300 trillion liters of water, and a savings of 25 billion barrels of oil (SDG 12, SDG 15).

With smart banking, energy and traffic systems in cities, smart agriculture, and health applications, ICT businesses have contributed the most to the SDGs. In addition, initiatives like women-only courses, IT programs, and conventional education schools have been started in the name of community investments. Consequently, it is obvious that ICT enterprises contribute significantly and in a quantifiable way to the SDGs. This is the primary motivation for choosing the contribution of ICT industry as a thesis topic.

3. METHODOLOGY

3.1 Quality Function Deployment (QFD)

Every firm has customers, some have just internal customers, some only external clients, and a few both. When it comes to determining what you need to do to satisfy or even excite your clients, quality function deployment is an invaluable tool. QFD is a focused process for carefully listening to the customer's voice and then effectively meeting their requirements and expectations. Most customers make their purchasing decisions based on a broad opinion of quality or value [64]. To remain competitive, firms must understand what influences consumers' perceptions of value or quality of a product or service. They must determine which product attributes, such as reliability, appearance, or performance, influence the customer's opinion of quality and value.

QFD was initially created in Japan by Yoji Akao in the late 1960s as a result of Total Quality Control technique applications while working at Mitsubishi's shipyard. It was then adopted by other businesses, especially Toyota and its supply chain.

> [65] defined QFD as a strategy for generating design quality with the goal of satisfying the consumer and then transferring the consumer's desire into design objectives and significant quality assurance points to be utilized throughout the manufacturing phase.

Mazur also defines QFD as a system and methods for assisting in the planning and development of products and services, as well as ensuring that they meet or exceed customer expectations [66].

One of the finest aspects is its ease of implementation, analysis, and documentation while prioritizing the customer's demands. As a result, it is willing to continuously improve product quality [67]. Because it is quality-oriented, it explicitly converts client needs into a study topic and provides knowhow for the business. Through constant touch with consumers, the organization can identify its strengths and limitations in customer communication.

3.1.1 Implementing quality function deployment

The Quality Function Deployment approach is a four-phase procedure that includes actions across the product development lifecycle. At each step, a number of matrices are used to transform the Voice of the Customer into system, subsystem, and component design requirements. The first phase entails gathering demanded qualities for the product (Voice of Customer), which are then transformed into quality characteristics (functional requirements), known as HOWs. This phase is so critical in product development that the related QFD matrix is dubbed the HoQ. The HoQ, also known as Product Planning [68] or Customer Requirement Planning [69], connects customer demands to the technical replies developed by the development team to address those needs. The second step, known as Parts Deployment, converts the previous phase's prioritized technical measures into part characteristics. The third step, Process Planning, converts key component qualities into process parameters or operations, which are then translated into production needs or operations in the fourth phase, Production Planning [7].

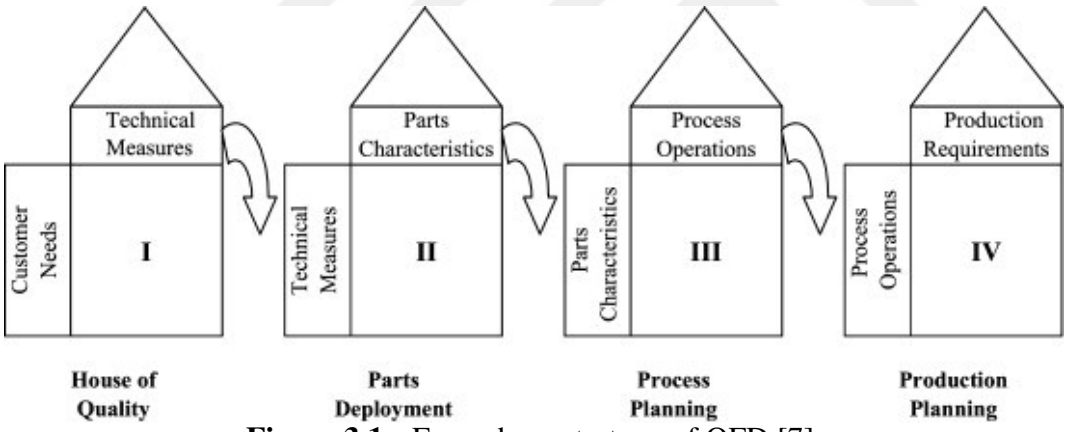

Figure 3.1 : Four-phase strategy of QFD [7].

A four-phase strategy that represented above Figure 3.1 involves employing a set of matrixes to coordinate product team operations and provide standard documentation during product and process development [7]. Each phase contains a matrix made up of a vertical column of "Whats" and a horizontal row of "Hows". "Whats" are CR, and "Hows" are methods of accomplishing them. At each level, the "Hows" are transferred to the following phase as "Whats" [70]. The House of Quality as a whole shared the below Figure 3.2.

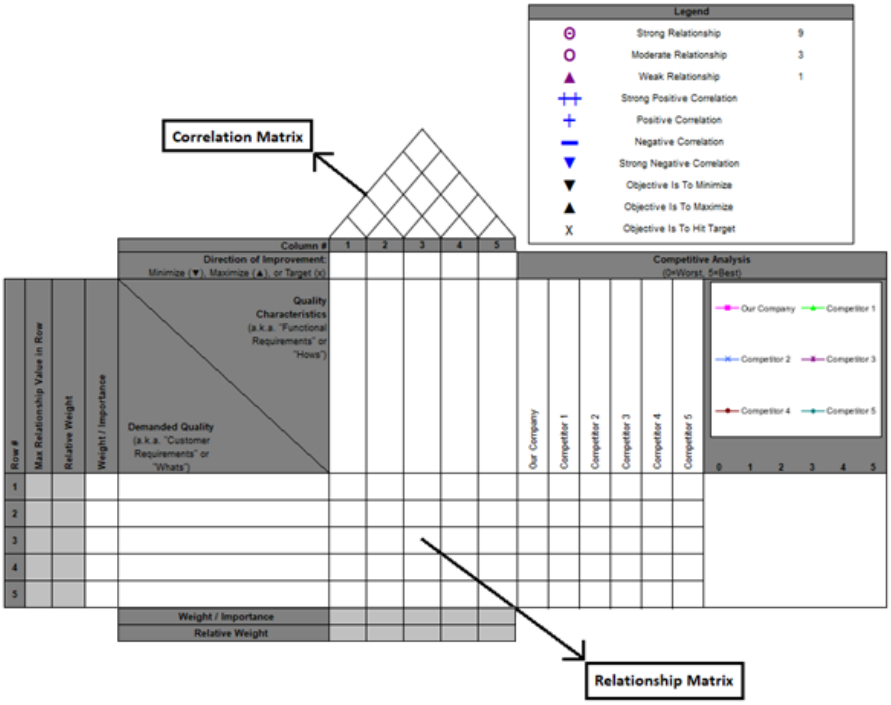

Figure 3.2 : House of Quality

Competitive Analysis block compares a company's product/service to similar rival products/services on the market. The comparative data will assist the developer place the product on the market and determine how pleased the consumer is now. The consumer rates each product on a scale of 1 to 5, with 5 being the highest level of satisfaction and 1 representing the lowest. For comparison, three of the best companies in the ICT industry were chosen.

Demanded qualities are acquired from client feedback. The group gathers client needs and assigns a number on a 1-3-9 scale, where 1 is the least significant and 9 is the most. In this case, desired qualities are defined as UN SDGs. Moreover, quality characteristics are technical parameters that should be put into a product in order to meet the demanded qualities. They are also known as "hows" since they are the responses to whats: how can the requirements be handled or accomplished. They represent the engineers' technical grasp of what customers actually desire. In order to be employed in design, technical specifications must be quantifiable or measurable. The quality characteristic features are taken from the yearly sustainability reports and social responsibility initiatives of ICT corporations.

The relationship matrix is used to maintain the link between demanded qualities and quality characteristics. In other words, the matrix represents the "whats" vs "hows".

It is the core component of the HoQ and must be completed by the technical team. A weight of 1-3-9 or 1-3-5 is commonly used for internal representation of relationships, with 1 representing the weakest relationship and the highest number representing the strongest relationship.

The correlation matrix is the triangular component on top of the HoQ. This matrix shows how the quality characteristics interact with each other. Interrelationships are rated from strongly positive to strongly negative, with a blank field indicating no connection.

Weight of the quality characteristic is calculated as the sum of, each of the initial weights multiplied by the relationship coefficients. Relative weights are expressed as percentages of the total. The result is important for rating each of the "Hows" and selecting where to focus the most resources. The weight of a quality characteristic divided by the total weight is known as relative weight. Equations may be found at the below Equation 3.1 and Equation 3.2 (P is the initial weight of the demanded quality, R is the relationship coefficient between the demanded quality and quality characteristic).

$$\text{Weight} = \sum_{i=1}^{n} P_i \cdot R_i \tag{3.1}$$

$$\text{Relative Weight} = \frac{\text{Weight}}{\text{Total Weight}} \tag{3.2}$$

Despite the fact that GDPR makes it impossible to write the names of the three firms that were chosen explicitly, they were picked because they are the leading ICT corporations. This thesis examined of their sustainability contributions since they are pioneers in the ICT industry as well as in terms of their contributions to sustainability goals. When analyzing features that interact with one another, QFD is a valuable technique. The UN SDGs have a strong association with one another. As a consequence, it was determined to deploy QFD in this thesis.

4. APPLICATION AND RESULTS

4.1 Contributions to the SDGs Using the QFD Method in Ict Companies': A Case Study

In 1966, Yoji Akao created Quality Function Deployment for the first time in Japan. It serves as a planning tool to identify the most important areas, given our technical skills, where the effort should be concentrated.

> The QFD method is typically used to develop new goods and services or to alter already-existing ones so that they (as much as feasible) meet the needs of the [71].

Translating customer needs into suitable actions for the organization to take at each stage of the product's development is known as quality function deployment. Because of this, it's also occasionally referred to as customer driven engineering (Design-controlled by the Customer) or an array of product planning (Matrix Product Planning).

A House of Quality (HoQ) is the central component of the Quality Functional Deployment methodology that entails gathering and evaluating the "voice of the customer." It serves to clarify how a customer's needs and a product or company's capabilities relate to one another.

4.2 Demanded Qualities (Voice of the Customer)

The first step in creating a House of Quality is gathering demanded qualities or "Whats". After collecting client needs, the team assigns a weight value to each one: 1, 3, or 9, with 9 being the most significance and 1 the lowest. The relative weight is next determined. In our case, UN SDGs are used for demanded qualities and showed the below Figure 4.1. The importance of the requirements is assessed based on anonymous survey submitted to the sustainability team of Company A. Due to GDPR, name of the compaines cannot be revealed.

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats")
1	3	2,6	3,0	No poverty
2	3	2,6	3,0	Zero hunger
3	3	7,7	9,0	Good health and well-being
4	9	7,7	9,0	Quality education
5	9	2,6	3,0	Gender equality
6	9	7,7	9,0	Clean water and sanitation
7	3	7,7	9,0	Affordable and clean energy
8	9	7,7	9,0	Decent work and economic growth
9	9	7,7	9,0	Industry, innovation and infrastructure
10	9	2,6	3,0	Reduced inequalities
11	9	7,7	9,0	Sustainable cities and communities
12	9	7,7	9,0	Responsible consumption and production
13	9	7,7	9,0	Climate action
14	9	2,6	3,0	Life below water
15	9	2,6	3,0	Life on land
16	9	7,7	9,0	Peace, justice and strong institutions
17	9	7,7	9,0	Partnerships for the goals

Figure 4.1 : Demanded Qualities of the Case Study

4.3 Quality Characteristics

Quality characteristics or “Hows” are in line with client feedback. This stage might be challenging since it requires to identify the variables that could have the biggest impact on the customer need elements. Also, variables needs to be global, quantifiable, and relevant. Then, direction of improvement should be selected for those characteristics. In our case, the quality characteristics are extracted from the annual sustainability reports and social responsibility projects of ICT companies and can be seen the below Figure 4.2.

Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▲	▼	▲	▲	▲	▲	▲	▲	x	▼	▲
Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Circularity	Machine learning	GHG emissions	Connectivity	Community investment programs	Working with providers who completed the CDP water assessment	Decarbonizing the value chain	Protecting biodiversity	Empowerment of women	Ethical business practices	Water usage through all processes	Energy efficiency

Figure 4.2 : Quality Characteristics of the Case Study

Circularity: The creation of materials accounts for about 50% of worldwide CO_2 emissions, while fewer than 10% of materials are handled in a circular manner [40]. Therefore, decreasing waste and promoting circular activities are essential to slowing climate change. Firstly, ICT companies design their goods with sustainability in mind to increase circularity. In addition, they make an effort to utilize recyclable materials. They usually provide a service after the sale to retrieve the customer's disassembled excess inventory. Additionally, they offer refurbishing services that not only prolong the life of hardware but also test and validate customer-owned, disassembled product equipment before it is put back to use. Also, in order to reduce e-waste, products can be recycled when the product comes to end-of-life.

Machine learning: Utilizing machine learning, artificial intelligence, and other technologies to cut down on energy consumption when network traffic is light [41]. Nokia launched Intelligent Radio Access Network (RAN) operations, which can save up to 15% of the power consumed by 4G and 5G base stations through the application of machine learning [40].

GHG emissions: One of the main threats to climate change and sustainability is greenhouse gas emissions. It can be avoided by the ICT solutions. Video call may have the biggest efect on GHG emissions as an ICT solution. It eliminated the need to travel for face to face meeting. Another example is that the GHG emissions can be reduced from saving energy through live monitoring by automation tools. Also, ICT firms can reduce their GHG emissions with using renewable energy. In this characteristic, the company's contribution to decreasing GHG emissions and GHG emissions they caused examined combined.

Connectivity: Many processes in the modern world are automated. These automations make use of the information obtained from different kinds of sensors using a variety of

wired and wireless connectivity options. ICT companies' involvement in this scenario is superior for practically all industries. Additionally, connectivity can help to reduce inequalities. For instance, four organizations that assist the homeless in the United States—LifeMoves, Destination: Home, Covenant House Alaska, and Westhab—are receiving technical assistance from Cisco engineers [44]. Their contributions are expanding these NGOs' access to connectivity for the homeless and formerly homeless persons, which is a crucial first step for those looking for housing and employment.

Community investment programs: ICT companies should share their profits with underprivileged communities. Typically, they create educational initiatives. Cisco supports Historically Black Colleges Universities (HBCUs [72]. With a $50 million pledge, Cisco became the first corporate supporter of Student Freedom Initiative's "Access to Education" fund. By May 2022, over $1.6 million has been distributed to 119 students at seven HBCUs, thanks to the endowment that has been presented to over 20 HBCUs. Nokia promises to construct an ecosystem and provide STEM education for females and families in schools and at home. They cooperate with UNW and the Kenyan Ministry of Education for this program.

Working with providers who completed the CDP water assessment: In order to accomplish the Sustainable Development Goals, CDP uses accountability and transparency to pressure governments, businesses, and financial institutions to separate growth from the degradation of freshwater resources and direct investment toward a water-secure economy [73]. They accomplish this by gathering data on a company's management, governance, use and stewardship of water resources for the benefit of investors, clients, and policy makers. The CDP water security questionnaire offers information on present and future water-related hazards and possibilities to both data users and the companies themselves. The water security questionnaire, in conjunction with CDP's water scoring methodology, facilitates benchmarking against industry best practices and assists businesses to make improvements in water management.

Decarbonizing the value chain: ICT companies need to continuously control their footprint as data grows at a rapid rate. It is essential for them to guarantee optimal energy and material efficiency in the network infrastructure they develop and provide to their clients. According to Nokia's evaluation in 2022, 95% of their total emissions occured from the use phase. Therefore, their ability to continuously reduce the power

consumption of their products has the most influence on decarbonizing the value chain and improves the products' energy efficiency when used by their customers. Using sustainable energy sources is another way that ICT firms decarbonizing their value chain. Also, enhancing the silicon, hardware, software, and services could lead to solutions.

Protecting biodiversity: The UN Biodiversity Conference (COP 15) demonstrates that two of the greatest challenges to our world remain: biodiversity loss and climate change [74]. Governments from all across the world gathered in Montreal, Canada, from December 7–19, 2022, to decide on a new set of objectives that will direct global action through 2030 to stop and reverse the loss of nature. ICT companies have an impact on the depletion of the environment since the manufacturing of ICT hardware involves a multi-tier supply chain that uses different metals, minerals, plastics, chemicals, energy, and water.

Empowerment of women: In recent years, efforts have been made to achieve balance in the ICT sector, which has a high male density. They strive to create a workplace where gender balance reflects the world around them, and where men and women have equal opportunities to achieve in all roles and at all levels. One example of a training and certification program designed especially for women by ICT businesses to raise the number of women in the sector is Women Rock-IT, which was introduced by Cisco.

Ethical business practices: As with any industry, the ICT sector values ethical working conditions. Under this heading, important issues such as responsible supply chain, a structure that respects human and employee rights, freedom of speech, health, security and labor conditions are evaluated.

Water usage through all processes: Due to the difficulties the water sector is facing as a result of urbanization, climate change, and deteriorating infrastructure, public policy started to prioritize issues related to water usage and sustainability. According to life cycle assessments of ICT products, the production of electricity required to power ICT devices in their customers' networks is the primary cause of the predominant water withdrawal. Their primary impact on water withdrawal is to minimize power use during the items' lifetime, as they require electricity. Apart from water usage

by ICT companies, the introduction and uptake of low-power Industrial IoT (IIoT) sensors, along with the availability of more information and operational data, hold great potential to completely transform the management of water systems as an ICT solutions.

Energy efficiency: Improving energy efficiency is the largest action ICT organizations can take to lower GHG emissions and energy consumption. This is the reason that ongoing research is done on the chips in the hardware, and attempts are made to build automation systems in order to maximize energy savings. Automation systems can be used to program devices to automatically switch energy-saving mode during off-peak hours and maintain optimal fan settings based on the device's temperature.

4.4 Correlation Matrix

The relationship between the quality characteristics is depicted in the matrix below Figure 4.3. Strong positive correlations (++) to strong negative correlations (▼) are the evaluations for the interrelationships; a blank box indicates no interrelationship.

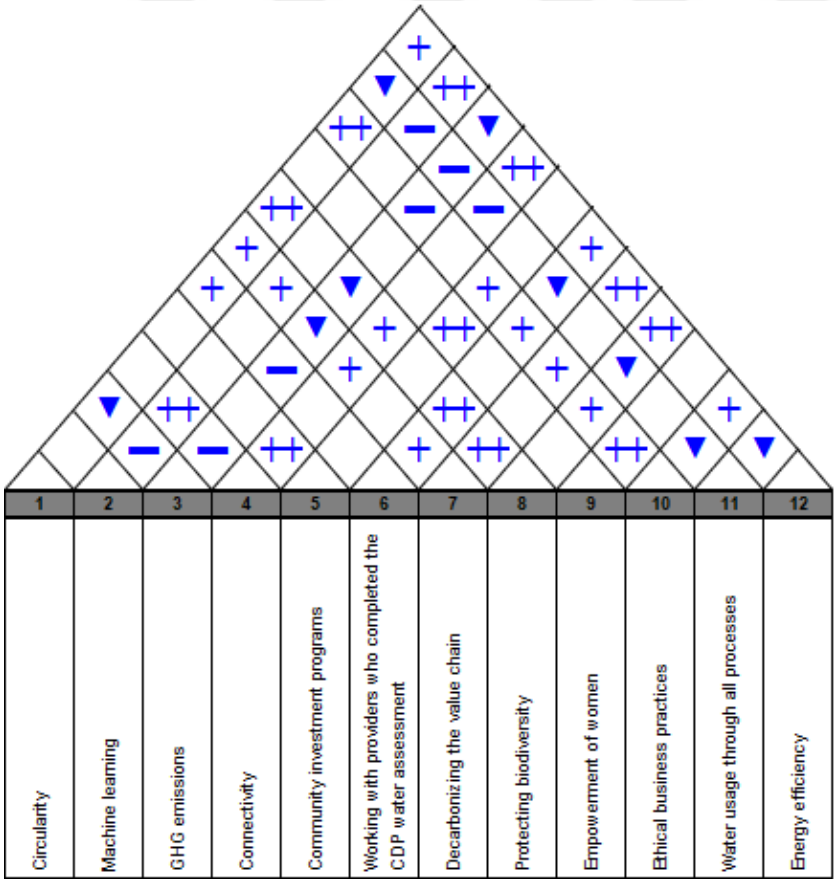

Figure 4.3 : Correlation Matrix of the Case Study

4.5 Relationship Matrix

There is a developed association between the demanded qualities and the quality characteristics which shown in the below matrix Figure 4.4. Strong relationship (Θ), moderate relationship (O) and weak relationship (▲) are the evaluations for the interrelationships and related with 9, 3, 1 number ratings; a blank box indicates no interrelationship.

Demanded Quality (a.k.a. "Customer Requirements" or "Whats") \ Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Circularity	Machine learning	GHG emissions	Connectivity	Community investment programs	Working with providers who completed the CDP water assessment	Decarbonizing the value chain	Protecting biodiversity	Empowerment of women	Ethical business practices	Water usage through all processes	Energy efficiency
No poverty	O			O	O			O			O	O
Zero hunger	O	O		O	O			O			O	O
Good health and well-being	O		O	O			O	O				O
Quality education		▲			Θ				O			
Gender equality					O				Θ	Θ		
Clean water and sanitation	Θ							Θ			Θ	
Affordable and clean energy				O								
Decent work and economic growth	O		O	Θ		Θ	O		O	Θ		O
Industry, innovation and infrastructure		Θ		Θ								
Reduced inequalities				▲	Θ				Θ	Θ		
Sustainable cities and communities	Θ	O	Θ	O		O	Θ	Θ				Θ
Responsible consumption and production	Θ		Θ			Θ	Θ	Θ		O	Θ	Θ
Climate action	Θ		Θ			Θ	Θ	O			Θ	Θ
Life below water	Θ		Θ			Θ	Θ	Θ			Θ	Θ
Life on land	Θ		Θ				Θ	Θ			O	Θ
Peace, justice and strong institutions					Θ				O	Θ		
Partnerships for the goals				O	O	O	O		Θ			

Figure 4.4 : Relationship Matrix of the Case Study

4.6 Competitive Evaluation

Competitive evaluation aids in understanding competitor items that meet client criteria. In our case, competitive analysis shown below Figure 4.5 was determined

by examining companies' year-end sustainability reports and corporate social responsibility projects. 1 to 5 scale is used, with 1 being the worst and 5 being the best.

Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Company A	Company B	Company C
No poverty	3	5	5
Zero hunger	5	4	3
Good health and well-being	3	5	4
Quality education	5	4	3
Gender equality	5	5	5
Clean water and sanitation	4	4	4
Affordable and clean energy	3	3	3
Decent work and economic growth	5	5	4
Industry, innovation and infrastructure	5	5	5
Reduced inequalities	4	5	4
Sustainable cities and communities	5	4	4
Responsible consumption and production	3	5	4
Climate action	4	5	5
Life below water	5	3	4
Life on land	5	3	3
Peace, justice and strong institutions	4	5	5
Partnerships for the goals	4	5	5

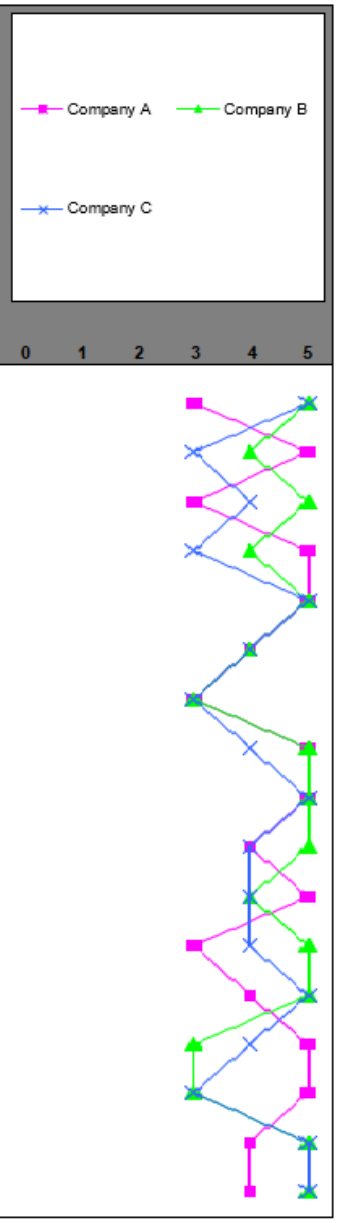

Figure 4.5 : Competitive Evaluation of the Case Study

4.7 Importance Rating

After multiplying the entire sum of each column by the weight/important component, the result is the importance rating which shown below Figure 4.6. It's vital to know where to put the most resources and this importance rating is advantageous. The relative weight, or important percentage, is then determined.

	Circularity	Machine learning	GHG emissions	Connectivity	Community investment programs	Working with providers who completed the CDP water assessment	Decarbonizing the value chain	Protecting biodiversity	Empowerment of women	Ethical business practices	Water usage through all processes	Energy efficiency
Weight / Importance	384,6	107,7	300,0	248,7	207,7	276,9	323,1	315,4	184,6	207,7	253,8	315,4
Relative Weight	12,3	3,4	9,6	8,0	6,6	8,9	10,3	10,1	5,9	6,6	8,1	10,1

Figure 4.6 : Importance Rating of the Case Study

4.8 House of Quality Relative Weight Results

As a result of QFD, relative weights are determined for each functional criterion individually. The contribution of each technical requirement to customer requirements is expressed as a percentage. In our case, the quality characteristics that ICT firms use to contribute to the United Nations Sustainable Development Goals are given in the Table 4.1 below, along with their relative weight. While the quality characteristic with the highest percentage is the most significant, it becomes less relevant as the percentage declines.

Table 4.1 : Ranking of the Relative Weights

Ranking	Quality Characteristic	Relative Weight
1	Circularity	12,3%
2	Decarbonizing the value chain	10,3%
3	Energy efficiency	10,1%
4	Protecting biodiversity	10,1%
5	GHG emissions	9,6%
6	Working with providers who completed the CDP water	8,9%
7	Water usage through all processes	8,1%
8	Connectivity	8,0%
9	Ethical business practices	6,6%
10	Community investment programs	6,6%
11	Empowerment of women	5,9%
12	Machine learning	3,4%

4.9 Summary of Results

Circularity has a relative weight of 12.3%, making it the ICT sector's largest contribution to the UN SDGs, according to the QFD data. It promotes responsible

consumption and production, which is the most significant contribution of ICT companies to sustainable development goals. This outcome is further corroborated by the annual sustainability reports from the corporations, since most ICT equipment have been made from recycled materials for a while. In addition to this, it's crucial that companies usually take back and recycle their products when their life cycle ends. Following that, the weights of GHG emissions, protecting biodiversity, energy efficiency, and decarbonizing the value chain as ICT companies' contribution are nearly identical around 10%. Lowering CO_2 and GHG emissions is their shared objective. For this reason, ICT businesses develop their devices with energy efficient design language. They also take care to ensure that the production or utilization of their devices does not contaminate the environment or need excessive amounts of power or water. The following two functional are related to water consumption. Throughout the whole process, from the procurement of the product's raw materials to the end of its life cycle, water usage is crucial. As a result of the anaylzes conducted by ICT companies taking this into consideration, the importance of these requirements is high. All of them are drive to preserve life below water and life on land. The largest technology that ICT businesses have created is connectivity, which came in eighth place when contributions were weighted. Connectivity has made it possible for various technologies that benefit both nature and humans to advance daily. The next three are about ethical corporate practices, supporting underprivileged society and gender equality. These are crucial components for preserving sustainability and global equality. ICT firms are aware of this and provide excellent instructional and supportive initiatives related to these concerns. These quality characteristics are motivated to improve decent work and economic growth, reduce inequalities and bring quality education for everyone. And lastly, machine learning. One of the popular subjects in technology these days is machine learning, which aims to increase device energy efficiency in order to determine the best possible method for gadgets to operate and so on. As a result, it is among the crucial functional needs for ICT businesses.

When the firms are compared, Company B came out on top with a total score of 75 out of 85. It received the greatest score out of all 12 demanded qualities. With 72 points, Company A concludes in second. Out of 10 demanded qualities, Company A has the highest score. At last, Company C shared the highest score of 8 demanded qualities

with a total score of 70. It is obvious that all three firms' ratings are quite similar. The minor variations among the businesses, their countries of origin, the regions they serve, and national administrative matters have been effective.

5. CONCLUSION AND LIMITATIONS

Sustainability gained much more attention with the acceleration of environmental degradation. Therefore, 17 SDGs were endorsed with The 2030 Agenda for Sustainable Development by all United Nations Member States in 2015. It has been observed that the literature has very few studies that look at how the ICT industry contributes to sustainable development goals. In this study, the contributions of three major ICT companies to the UN SDGs are compared using the QFD method. Every one of the UN's goals is essential, due to the strong relationships between each objective. This is the main justification for this study's use of the QFD approach. Full of House of Quality is shared in the Appendix A. The reason for examining ICT companies is that the ICT sector has a huge beneficial impact on achieving the UN SDGs. Smart cities, smart water management, smart home appliances, and energy savings through cross-sectoral integration are a few examples of contributions that demonstrate this important influence. Also, each of these three companies are among the top in the ICT sector. They are also making significant, tangible progress toward the UN SDGs. As a result, these three businesses are examined. ICT companies are essential for monitoring the climate change, reducing its consequences, adjusting to them, and helping to create a more sustainable future. An average house's overall energy usage may be reduced by an average of 61%, with the adoption of smart home equipment potentially enabling a 33% decrease in that amount. Additionally, ICT has the potential to keep global CO2e emissions 20% lower by 2030 while maintaining 2015 levels.

Based on the analysis of the QFD data, the sustainable development goals that ICT companies have contributed most to responsible consumption and production, life below water, climate action, and sustainable cities and communities. The most contributed goals resulting from QFD are the ones in which ICT companies produce their technologies and take care to minimize the damage to the environment while producing. These goals are supported by quality characteristics provided from ICT

companies, such as circularity, decarbonizing the value chain, energy efficiency, lowering the GHG emissions. ICT firms use IoT technology to improve safety and quality of life in cities by expanding connection. Moreover, their circular business model reduces the need for natural resources by promoting more effective and waste-free consumption behaviors. Furthermore, the capacity of businesses to advance sensor and connection technology is crucial for achieving the goals of life below water, life on land, and climate action.

There are very few studies in the literature that examine ICT companies' contributions to the UN SDGs, and none of them use the QFD method. In this study to fill the gap, the literature on ICT companies contributions to the UN SDGs, as well as their projects, are examined, and the contributions of three significant ICT companies are compared using the QFD method. After comparing the three companies, Company B received a total score of 75 out of 85, making it the best. Company B obtained the highest rating for the twelve demanded qualities. Company A comes in second place with 72 points. Regarding to the ten demanded qualities, Company A has the highest score. With a final score of 70, Company C acquired the highest score across the eight demanded qualities. The evaluations of the three organizations are very close. The small differences between the companies, their home nations, the areas they service, and national administrative issues have been influential.

The biggest limitation faced throughout the study is that the names of the three firms cannot be disclosed due to GDPR. In addition, progressing with the internal information of companies can take this study to the next level. The study is limited to publicly available data.

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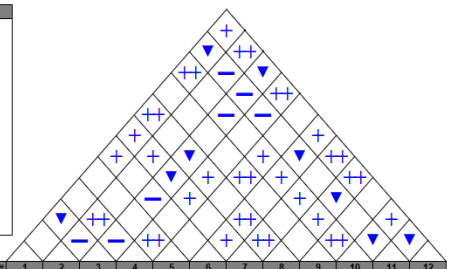
APPENDICES

APPENDIX A : Full of House of Quality

APPENDIX A: Full of House of Quality

Legend		
⊙	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
−−	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	



Column #				1	2	3	4	5	6	7	8	9	10	11	12	Competitive Analysis (0=Worst, 5=Best)			
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▲	▼	▲	▲	▲	▲	▲	▲	x	▼	▲			
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Circularity	Machine learning	GHG emissions	Connectivity	Community investment programs	Working with providers who completed the CDP water assessment	Decarbonizing the value chain	Protecting biodiversity	Empowerment of women	Ethical business practices	Water usage through all processes	Energy efficiency	Company A	Company B	Company C
1	3	2,6	3,0	No poverty	O			O	O			O			O	O	3	5	5
2	3	2,6	3,0	Zero hunger	O	O		O	O			O			O	O	5	4	3
3	3	7,7	9,0	Good health and well-being	O		O	O			O	O				O	3	5	4
4	9	7,7	9,0	Quality education		▲			⊙				O				5	4	3
5	9	2,6	3,0	Gender equality					O				⊙	⊙			5	5	5
6	9	7,7	9,0	Clean water and sanitation	⊙							⊙			⊙		4	4	4
7	3	7,7	9,0	Affordable and clean energy				O									3	3	3
8	9	7,7	9,0	Decent work and economic growth	O		O	⊙		⊙	O		O	⊙		O	5	5	4
9	9	7,7	9,0	Industry, innovation and infrastructure		⊙		⊙									5	5	5
10	9	2,6	3,0	Reduced inequalities				▲	⊙				⊙	⊙			4	5	4
11	9	7,7	9,0	Sustainable cities and communities	⊙	O	⊙	O		O	⊙	⊙				⊙	5	4	4
12	9	7,7	9,0	Responsible consumption and production	⊙		⊙			⊙	⊙	⊙		O	⊙	⊙	3	5	4
13	9	7,7	9,0	Climate action	⊙		⊙			⊙	⊙	O			⊙	⊙	4	5	5
14	9	2,6	3,0	Life below water	⊙		⊙			⊙	⊙	⊙			⊙	⊙	5	3	4
15	9	2,6	3,0	Life on land	⊙		⊙				⊙	⊙			O	⊙	5	3	3
16	9	7,7	9,0	Peace, justice and strong institutions					⊙				O	⊙			4	5	5
17	9	7,7	9,0	Partnerships for the goals				O	O	O	O		⊙				4	5	5
				Weight / Importance	384,6	107,7	300,0	248,7	207,7	276,9	323,1	315,4	184,6	207,7	253,8	315,4			
				Relative Weight	12,3	3,4	9,6	8,0	6,6	8,9	10,3	10,1	5,9	6,6	8,1	10,1			

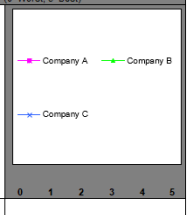


Figure A.1 : House of Quality of the Case Study

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