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TECHNOLOGY AND INNOVATION MANAGEMENT FOR SUSTAINABILITY

MASUDEM

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MASTER STUDIES IN SUSTAINABLE DEVELOPMENT AND MANAGEMENT

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INTRODUCTION

In today's world, technology, innovation, and sustainability are interconnected more than ever before. The ability to manage these domains effectively is crucial for driving sustainable development. Against the backdrop of increasing threats posed by the climate crisis, this module offers a comprehensive exploration of how these domains intersect and contribute to sustainable practices. The module is aimed at master's degree students and it delves into the fundamentals of technology and innovation management, their role in driving sustainability, and the emergence of new technologies that are shaping the future of sustainable practices. The module covers a range of topics, including the principles of sustainable development, the challenges and opportunities of technology and innovation management, and the latest trends and innovations in sustainable practices. By the end of the module, students will have a thorough understanding of how technology, innovation, and sustainability are interconnected and will be better equipped to drive sustainable development in their future careers.

Part 1 of the module, 'Technology and Innovation Management,' lays the groundwork by examining the circular economy as a transformative approach to sustainability. It underscores the importance of integrating sustainable practices within business operations and value chains, highlighting the role of digital technologies in this transition. This section also reflects on the dynamic relationship between human factors and technology, emphasizing the need for balance and ethical consideration.

In Part 2, 'Technology and Sustainability Performances,' we shift our focus to the tangible impacts of technology on sustainability. This includes an in-depth look at sustainability performance metrics and how technological advancements can both positively and negatively impact sustainability efforts. The section further explores sustainable technology innovation, including the assessment of technology needs and the design and development of sustainable products and services.

Finally, in Part 3, 'Emerging Technologies for Improving Sustainability Performances,' introduces cutting-edge technologies such as Big Data analytics, Artificial Intelligence, Robotics, the Internet of Things (IoT), Blockchain Technology, and Agent-Based Simulation and Digital Twins. This section examines how these technologies can be leveraged to enhance sustainability performances, offering a glimpse into the future of sustainable technology and innovation management.

Throughout this module, students will delve deep into the multifaceted realm of technology and innovation in the context of sustainability. Engaging with critical reflections, case studies, and real-world examples, students will develop a profound understanding of how technology and innovation can be harnessed to drive sustainable practices and protect our planet. The module will not only equip students with a wealth of knowledge but also inspire them to think critically about the role of technology in promoting sustainability and to commit to responsible and ethical technology management.

The integration of advanced technology and innovative solutions with environmental conservation and sustainability has emerged as a crucial and highly impactful approach to tackle some of the most pressing issues of our time. By synergizing cutting-edge advancements with environmental stewardship, we can unlock new opportunities to create a greener, cleaner, and more sustainable world. The convergence of these two domains holds immense potential to drive transformative change and accelerate progress toward a healthier, thriving, and regenerative planet for all.

Sustainable development has become a major concern for governments, businesses, and individuals alike. With the increasing awareness of the impact of human activities on the environment, there is a growing need for innovative solutions that can help reduce carbon emissions and improve resource efficiency. Fortunately, technology and innovation have emerged as key drivers of sustainable development, offering a wide range of solutions to environmental issues. From renewable energy technologies that can help reduce our reliance on fossil fuels to smart manufacturing processes that can improve resource efficiency, technology has the potential to revolutionize industries and make them more sustainable, efficient, and environmentally friendly.

The shift from a linear to a circular economy is an important move towards sustainable development. This shift involves rethinking our approach to resource management, moving away from the traditional 'take-make-dispose' model and towards one that is regenerative and restorative. Technological innovations such as near-infrared (NIR) spectroscopy and chemical recycling are helping to enhance the precision and efficiency of material recovery. Product Lifecycle Management (PLM) software is transforming product design by encouraging manufacturers to consider the entire lifecycle of a product, from creation to disposal. This approach is particularly evident in the electronics industry, where modular designs facilitated by PLM are extending product lifespans and reducing electronic waste. The integration of 3D printing and additive manufacturing in production processes is also helping to create a more circular economy. These technologies allow for precise, on-demand production while significantly cutting down on material waste. Additionally, the Internet of Things (IoT) is playing a pivotal role in supply chain management by tracking products through their lifecycle, providing invaluable data on product use, maintenance, and end-of-life management. This data enables companies to make more sustainable decisions in product design and recycling.

Advanced technologies like Big Data analytics and Artificial Intelligence (AI) have emerged as empowering tools for decision-making, offering a glimpse into a future where efficiency and environmental stewardship go hand in hand. These technologies, by harnessing the power of vast data, enable organizations to make informed decisions that significantly enhance sustainability. Consider the realm of energy management. AI's role in optimizing energy use has been groundbreaking. A compelling example is Google's deployment of DeepMind AI to control the cooling systems in its data centers. This AI-driven approach led to a 40% reduction in cooling energy usage, showcasing how AI can turn complex, data-rich environments into models of energy efficiency (Evans and Gao, 2016)[1]. In the agricultural sector, the impact of AI and Big Data is equally transformative. Precision farming, powered by these technologies, allows for a meticulous approach to agriculture. By analyzing data on soil conditions, weather, and crop health, AI equips farmers with insights to optimize resource use and maximize yield. Companies like John Deere are at the forefront, integrating AI into their machinery, thus enabling farmers to make decisions that balance productivity with sustainability (Marr, 2019)[2].

The far-reaching effects of AI are evident in the intricate networks of supply chains. With the help of AI and Big Data, companies are transforming the way they predict demand and allocate resources. For instance, IBM has developed Watson Supply Chain Insights, an AI-based solution that significantly enhances the decision-making process in supply chain management. This technology offers advanced AI capabilities to provide greater visibility and insights throughout the entire supply chain. By utilizing IBM Watson, supply chain professionals can efficiently manage data overload, predict and mitigate disruptions and risks, and make more informed decisions. This AI-driven approach improves not only the visibility of data across the supply chain but also enhances decision-making and efficiency at every level, making it a valuable tool for businesses seeking to create a more agile, intelligent, and customer-centric supply chain (Galea-Pace, 2020)[3].

As we embrace the fusion of technology and innovation with sustainability, we must also confront its ethical challenges. For instance, AI-driven supply chain decisions might reflect underlying biases in their programming, leading to unequal impacts on suppliers and customers. Similarly, advancements in manufacturing technologies, while improving operational efficiency, often grapple with significant environmental consequences. The deployment of Big Data in operations management raises intricate data privacy issues, necessitating a delicate balance between data utilization and individual privacy rights. Furthermore, the increasing automation in operations, though beneficial for efficiency, poses ethical concerns regarding workforce displacement. These challenges highlight the

[1] https://deepmind.google/discover/blog/deepmind-ai-reduces-google-data-centre-cooling-bill-by-40/
[2] https://www.forbes.com/sites/bernardmarr/2019/03/15/the-amazing-ways-john-deere-uses-ai-and-machine-vision-to-help-feed-10-billion-people/?sh=532f5b002ae9
[3] https://supplychaindigital.com/technology/ibm-watson-how-ai-transforming-supply-chain

need for a nuanced approach that ensures technological advancements are in harmony with ethical considerations and environmental responsibility.

By the end of this introduction, we urge you to take the plunge to the Technology and Innovation Management for Sustainability module. This module intertwines the crucial aspects of technology, innovation, and sustainability, offering a multifaceted perspective on how these elements can collectively forge a path towards a more sustainable future. Each segment of the module, enriched with real-world scenarios and emerging technological trends, aims to ignite your curiosity. It invites you to explore the complex yet fascinating interplay between technological advancements and sustainable practices. Finally, learning is not just about acquiring knowledge but about engaging with the nuances and challenges that define the current landscape of sustainable technology and innovation management. From exploring the ethical considerations in AI and the digital divide to examining the environmental impact of tech manufacturing, the module challenges you to think critically and reflectively. It encourages you to question, explore, and envision the role you can play in shaping a sustainable technological future.

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PART I
TECHNOLOGY AND INNOVATION MANAGEMENT

CHAPTER 1: CIRCULAR ECONOMY AND FUNDAMENTALS OF TECHNOLOGY AND INNOVATION MANAGEMENT

Circular economy (CE) can be defined as an economic system that emphasizes the importance of managing limited or scarce resources wisely and responsibly with regeneration rather than consumption principles to reduce or even eliminate wastes to achieve a sustainable life cycle.

1.1 Circular Economy

Some important features of this new paradigm are as follows:

1. Shift from a linear to a circular model of an industrial economy. The linear approach simply follows a source-make-consume-wastes processes. In this approach, companies only care about their business and how they can sell as many products as they can without thinking about the wastes generated from their products. As a consequence, wastes pile up in landfills, and many of them are not biodegradable, causing land, water, and air pollution, and contributing to global warming and climate change. On the other hand, the circular approach attempts to use a closed-loop system to minimize or even eliminate any leakages of resources along the processes and recirculate the wastes as input for continuous sourcing and production.
2. Shift from consumption to regeneration. While consumption is required for our current economic system to function, CE suggests that overconsumption can lead to depleted resources, especially if the resources are scarce. As such, CE proposes the concept of regeneration rather than consumption, in that the whole society only enjoys the values of the products they produce or buy but contributes to regenerating resources used to create and deliver the values. Some examples of regeneration are planting trees, reusing and recycling materials, using biological wastes as fertilizers and foods for livestock, etc.
3. Distinction between consumable and durable products management. CE separates consumables from durable products. Consumables can result in biological wastes that need to be managed so that they are not harmful to the environment. Durable products, on the other hand, can be maintained as long as possible, shared, reused, redistributed, refurbished, remanufactured, and recycled.
4. The use of renewable energy. CE also emphasized the critical role of renewable energy in replacing fossil fuel, which has been proven to have negative effects on our planet due to carbon emissions and overuse of scarce earth resources. Examples of renewable energy include wind, solar, biogas, hydrogen, etc.
5. Applied in life cycle stages, including design, production, distribution, and consumption. CE paradigm can be applied in many stages of business processes. Using CE, products need to be designed to increase durability and, therefore, lifecycle. The products also need to be practically designed to minimize or generate no wastes. When wastes are generated from the products, they should be easily managed. The production process can be powered by renewable energy such as solar panels or wind energy. Products can be distributed using electric trucks or other vehicles. Consumers also need to be aware of environmentally friendly products and be responsible for what they consume. In other words, CE requires both producer and consumer extended responsibilities to manage their business processes and wastes resulting from the processes.
6. Changes in business model. For CE to be effective, some businesses might need to change their business model because the current business model might not guarantee the sustainability of their financial performance. As an illustration, a company might produce and sell

durable products, such as batteries. According to the CE recommendation, the company needs to make the battery more and more durable, prolonging its lifecycle, and therefore reducing resources needed to make the battery and wastes generated from the non-functional battery. From the company's financial point of view, the more durable is the product, the longer is the lifecycle, and therefore the longer is their cash-to-cash cycle. In other words, the more durable the products, the longer it takes for the company to generate other sales after the initial sale of the products. The company needs to either have strong working capital or change their business model to address this issue. One way the company can do this is, for example, turning their business into solution provider. This way, the company sells service solutions rather than the products themselves. The company can rent or lease the battery to customers, while ensuring that any damages or problems with the battery will be handled by the company given service fees paid by the customers. This new business model could potentially maintain the company's financial sustainability while applying CE practices to help environmental sustainability in the future.

Given the above definition and practical features of CE, the implementation of this new paradigm requires a system thinking. From a system perspective, CE can be defined as "a regenerative production-consumption system that aims to maintain extraction rates of resources and generation rates of wastes and emissions under suitable values for planetary boundaries, through closing the system, reducing its size and maintaining the resource's value as long as possible within the system, mainly leaning on design and education, and with capacity to be implemented at any scale" (Suárez-Eiroa et al., 2019:958). The following seven principles of CE can be used as a general guideline to transition towards CE practices:

1. Adjusting inputs to the system to regeneration rates. This principle emphasises on the use of environmentally friendly materials and other factors of production. Using renewable energies, biodegradable materials, saving the use of current energies and materials by mean of increasing operational efficiency and productivity, as well as driving policies to prioritise walking, cycling, using EVs, and biofuels are amongst important strategies to adjust inputs so that resources can be regenerated.

2. Adjusting outputs from the system to absorption rates. The outputs of any business processes including manufacturing also needs to be controlled so that businesses do not produce wastes or if it is inevitable to produce wastes, they are environmentally friendly wastes. The production processes also need to be modified to achieve that aim.

3. Closing the system. This principle focusses on getting the materials back to the production system if they are wastesd. Companies need to be able to separate organic and non-organic wastes, remanufacture products which have become wastes, convert wastes to energy such as electricity, heat, or biofuels, and be responsible for wastes generated from their businesses. To close the system, companies can also do down cycling (reproduce wastes with a lower value than the original product), recycling (reproduce wastes with the same value as the original product), and upcycling (reproduce wastes with higher value than the original product).

4. Maintaining resource value within the system. This principle means that companies need to strive to make their products useful within an extended period of time. For example, companies can sell and distribute second-hand products, produce wastes that can be used by other companies or industries, increase durability of products so that they can be used longer and easier to be maintained or repaired, and reduce the number of obsolete products.

5. Reducing the system's size. This principle suggests that the way we do business and consume things needs to be controlled. Companies need to encourage consumers to consume more environmentally friendly products, provide proper information on product labelling, and encourage them to be responsible for wastes from their consumption. Companies can also promote and apply a sharing economy, such as renting products, changing products into services, and sharing the use of vehicles, using local products and suppliers, as well as adjusting sales according to the ideal needs of consumers.

6. Designing for the circular economy. This principle emphasises the importance of product and business model design as one of the first steps for transitioning to CE practices. Companies can use durable and environmentally friendly product designs that can be replicated in other locations using local resources, design products based on their functionality and buyers' needs, design new business models and strategies to sell environmentally friendly products or services, design new methods for continuous improvement to provide environmentally friendly products, and design projects to encourage environmentally friendly business practices.

7. Educating for circular economy. Finally, this principle is crucial because awareness of CE practices needs to be promoted within and beyond the companies. With this principle, companies need to participate in updated trainings to face the future business challenges including the challenge to be environmentally friendly, promote knowledge, skills, capabilities, and values required to transform the company to be more sustainable, and promote habits and individual actions to support environmentally friendly practices.

Whilst CE is part of efforts towards sustainable development, the concept of CE is different from sustainability in general. Geissdoerfer et al. (2017) suggest that sustainability originates from environmental movement, whereas CE is based on school of thoughts such as cradle-to-cradle. Sustainability is more open-ended system with multiple goals depending on stakeholders' interests, while CE emphasises on closed-loop system by reducing or even eliminating wastes from the system. Responsibilities for sustainability is shared between stakeholders, while private sectors and regulators are mainly responsible for CE implementation. Table 1 present the summary of differences in more detail.

Table 1.1 Differences Between Sustainability and CE

Aspects	Sustainability	Circular economy
Origin of the term	Environmental movement	Cradle-to-cradle
Goals	Open-ended system with multiple goals based on stakeholders' interests	Close-loop, eliminating wastes from the system
Main motivation	Reflection on the past environmental events	Better use of resources, wastes, leakages
System priority	Triple bottom line	The economic system
Beneficiaries	Environment, economy, society	Mainly economic actors, which could have impacts on environment and society
Institutionalisation	Frameworks that can be adapted to different contexts and aspirations	Emphasising on economic and environmental advantages
Agent	Stakeholders set their own priorities	Companies, governments, NGOs
Timeframe	Open-ended (indefinitely)	When input and leakage thresholds have been met
Responsibilities	Shared between stakeholders, not clearly defined	Private sectors and regulators

Source: Geissdoerfer et al. (2017)

CE can also be understood using a 9R framework (Kirchherr et al., 2017). Table 2.2 present this framework in more detail.

Table 2.1 9R Framework of CE

Shift of paradigm	Principles	Strategies	Description
Circular economy	Smarter approach to product use and manufacturing	R0 Refuse	It practically means that we should buy products that we really need and refuse products that cannot be reused or recycled.
		R1 Rethink	Use products more intensively. Sharing the product use can also be applicable.
		R2 Reduce	Use less natural resources or materials and increase efficiency in the production process.
	Extending product lifespan	R3 Reuse	Discarded but functional products can be reused by other consumers
		R4 Repair	Defective products can be repaired to maintain its function
		R5 Refurbish	Restore and update old products
		R6 Remanufacture	Discarded products can be used as parts of new products with the same function
		R7 Repurpose	Discarded products can be used as parts of new products with different function
	Useful application of materials	R8 Recycle	Processing materials to obtain the same, higher, or lower grade of quality
Linear economy		R9 Recover	Wastes to energy conversion

Source: Kirchherr et al. (2017)

In practice, CE implementation requires changes in companies' supply chain operations. Close-loop systems require designing the business process to accommodate reverse logistics, bringing the defective, unwanted, discarded, or wastesd products back to the business operations. Companies for example need to invest in wastes collection facilities or collaborate with other companies or society to ensure that necessary wastes for CE can be collected in time. The wastes then need to be separated, transported back to the companies' facilites, and reprocessed for new products. In big scale companies, significant investment and commitment are also required to provide designated facilities for reverse logistics, for example by dedicating specific areas in a warehouse for returned products and establish specific processes with skilled workers to managed returned products until they are ready for redistribution.

Most importantly, CE transition requires external forces to work. Customer behaviour needs to change towards consuming more environmentally friendly products. Consumers also need to take part and be responsible for their own wastes. As such, both companies and consumers need to extend their responsibility beyond their usual scope or function, refering to the concepts of extended producer responsibility (EPR) and consumer extended responsibility (CER). Without this necessary change, companies might lack motivation to adopt CE as they do not see any market potential that drives changes in their operations. In addition, governments need to impose regulations to support the transition to CE practices. However, they also need to be wise in doing so as many companies particularly SMEs might not be ready to implement such transition due to their limited financial and non-financial resources. SMEs might want to instead focus on their business survival and increase their performance before confidently adopting CE practices. In summary, despite the great potential of CE to support sustainable development in the future, its application requires system thinking due to complex operations and costly execution incurred in the transition process.

1.2 Fundamentals of Technology and Innovation Management

Technology originates from the word "techne" which means create (using skill and art) and "logos", meaning logic or oder. Volti (2009:6) as cited in Carroll (2017) defines technology as "a system created by humans that uses knowledge and organization to produce objects and techniques for the attainment of specific goals". In other words, technology is something that helps humans do their jobs and meet their need easily, effectively, and efficiently. By this definition, management is also a subject of technology applications as it covers activities including planning, organising, leading, and controlling to get things done with other people within an organisation. To manage these activities, technologies from familiar softwares such as Microsoft Excel to artificial intelligence (AI) can now be utilized.

Technologies can be related to the concept of innovation. The UK Department of Trade and Industry (DTI, 1998) as cited in Adams et al. (2006) defines innovation broadly as the successful exploitation of new ideas. Innovation can manifest in products, services, process, and technology. Technologies can be considered innovations as they can bring something new to help improve business operations and meet customers' demand. There are four types of innovations that have impacts on companies' competitive advantage (i.e. what differentiates the companies with others and makes them win the market) (Tidd, 2001):

1. Disruptive innovation. This type of innovation completely changes the competitive game by offering a new value proposition to the market. The rise of digital ride hailing applications in developing countries can be an example of a disruptive innovation as it changes how consumers use transportation services with more convenient and relatively fairer rate compared to traditional approaches.
2. Radical innovation. Companies with this innovation offer novel products or services with relatively premium prices. Apple could be an example of a company which radically innovates by changing our way to see computers not only as a tool to work on complex jobs, but as an identity with elegant designs and premium prices, while maintaining the computing performance.
3. Complex innovation. To achieve a competitive advantage using this type of innovation, companies need to have certain technologies which are not easy to be replicated, preventing other companies within the industry to enter the market. ASML could be an example of a company fit with the description of this innovation. Whilst it produces semiconductors which could disrupt the market due to their extremely small sizes and powerful application, the technology behind the production is extremely complex and difficult to be replicated by other companies.
4. Continuous incremental innovation. This type of innovation might often be found in many companies aspired to improve and develop their businesses. Novelty in products or services is created along the way and by increasing efficiency or improving performance of the companies' business processes. Resource constraints could also be the reason for companies adopting this type of innovation.

Companies can further choose to adopt closed and/or open innovation. In the closed innovation paradigm, innovation can be the source of competitive advantage while keeping the knowledge and innovation processes internally. Sharing the innovation might be a concern for the companies as their ideas could be misused by external parties to weaken their competitive advantage.

Some companies however embrace the notion of open innovation as they value collaboration as a way to enhance their competitive advantage and broaden their market potential. There are two types of open innovation:

1. Outside-in. This type of open innovation suggests that innovation can be driven by external parties including customers, other companies, and the wider society. Companies could for example create a competition, inviting external parties to participate in proposing new product designs or ideas to be executed. Companies can state that, whilst the selected ideas will be executed, the copy right is kept for the companies. This type of innovation is useful because companies could also ensure that customers and other external stakeholders are involved in the product or service development, which could also be used as a way to validate their proposition to meet the customers' expectations.
2. Inside-out. In this case, companies could offer their unused or idle facilities to support innovation from external parties. Companies might for example have laboratories, machines, or expertise which are not currently in use so they offer them to external parties including other companies to use the facilities. In return, external parties could pay discounted prices, involve the companies in their business, or any other arrangement that should benefit both sides. Companies can also make the facilities free to use for a corporate social responsibility (CSR) purposes. For example, big companies might want to help SMEs develop their products by offering advices on product design or laboratories to test the durability of the SMEs' products.

Innovation can change over time. Similarly, technologies change over time and they change quicker than ever as human knowledge accumulates and technology companies keep innovating to bring new products to the market. On the other hand, whilst businesses innovate by changing their processes and models, their changes might not be as agile as that of technologies. In addition, many companies might not have enough financial and non-financial resources to keep up with technology development, so that priorities need to be set up. For them, technologies might not be their core competencies and are rather seen as enablers of the business operations. As such, technologies need to be managed to fit with the companies' needs.

Technology management can be driven by two different but related perspectives – technological and commercial perspectives (Phaal et al., 2004). Cetindamar et al. (2009) suggest that within the technology management framework, the use and development of technologies can be driven by internal capabilities of companies (technological perspective). In this case, technologies can be used and developed as it is part of the companies' strategies. For some companies, technologies can be used to obtain competitive advantages. For example, companies might use robotic process automation and AI to forecast sales as part of their strategies to better understand customers' needs, provide reliable services, and therefore increase their market share. Techologies can also be part of the companies' innovations, such as the use of web-based application, chat bot, and metaverse to give unique experiences for customers buying the companies' products. Finally, technologies can help increase efficiencies in the companies' operations. The use of conveyor belts, robots, and digital kanban systems to replace manual signal of production can reduce production time, increase productivity, and thus minimise production costs within the companies. These internal drivers to technological applications are also called push mechanisms.

From a commercial perspective or pull mechanism, companies need to invest in technologies to fulfill the market requirements. For example, companies might need to invest in electric vehicles and upgrade their production machines to use biofuel as there are pressures from the market that needs more environmentally friendly products and processes. As the market changes so that consumers are more conveniently shopping online, companies also need to adapt by joining large online shopping platforms, developing their own platforms, or exploiting the use of social media to market and sell their products. Without this adaptation, companies might not be able to catch up with the current market trend and not be able to survive. All in all, to effectively and efficiently manage technologies, companies need to pay attention to the interaction between organisation and environment as it is key in the technology management framework (Phaal et al., 2004; Cetindamar et al., 2009).

Technology management can go through the following cycle of processes (Cetindamar et al., 2009):

1. Identification. In this step, companies search for and build awareness of technologies available in the market that might be of interest. They can also involve an evaluation and recognition of opportunities from using certain technologies. These days, the internet has enabled companies to look for many types of technologies as there are many reviews available to help companies make informed decisions.
2. Selection. Companies can select the most appropriate technologies for their business. Companies' strategies, priorities, and access to technologies including financial and non-financial resources could be used as evaluation criteria to select the best one.
3. Acquisition. Companies need to decide how to bring the technologies to the business. They are faced with alternatives, such as make the technologies internally, buy ready to use technologies from the market, employing external parties to make and install customised technologies, or collaborate with other companies to use the technologies.
4. Assimilation. In this step, companies need to ensure that people within the organisation are aware of the technologies and are capable of using them. Some issues such as familiarity, reluctance to change, and generation gaps need to be resolved to support a smooth transfer and application of the technologies.
5. Exploitation. Companies need to ensure that the applied technologies are effective and beneficial, i.e. achieving the predefined goals of using them and contributing to measured outputs and outcomes such as increased productivity, efficiency, and profit.
6. Protection. This step is critical as it prevents other companies or competitors from irresponsibly making use of the companies' credentials and competitive advantages driven by technologies. When technologies are developed internally, patents should be registered. On the other hand, when they are produced by external parties, non-disclosure agreements might be required. Staff working on the technologies also need to be retained and given contracts to protect the ideas and technologies at work.
7. Learning. Finally, companies need to have a knowledge management system documenting decisions to adopt technologies and lessons learnt from applying them, so that they can make improvement in their technology management processes.

Nowadays, many technologies have evolved into digitalisation. With easier access to computers, smartphones, and internet, there is a growing numbers of digital technologies users around the world. Big data, cloud computing, social media, business analytics, internet of things, robotics, 3D printing, 5G network, blockchain, AI, digital twin, robotic process automation, next generation control tower, and many more are now getting more attention in business organisations. However, one should note that these technologies might not all be relevant for all business organisations, so that comprehensive mapping is needed to understand the maturity of technologies and whether adopting the technologies could result in valuable return on investment (ROI).

According to Banker (2020), technology maturity can be classified into five categories as the following:

1. Hype. In this category, technologies are widely exposed but the performance and values for companies are not yet proven. In 2021, for example, technologies such as 5G and blockchain were still in the hype stage.
2. Promising. Technologies might offer high performance and ROI, but the application of the technologies need to be verified. Examples of technologies in this category include AI, machine learning, autonomous trucking, and digital twin.
3. High ROI, not widely adopted. Technologies offer high ROI, but they might be too expensive for companies to adopt. Technologies such as supply chain control towers, robotic automated storage and retrieval, and robotic process automation are among those belong to this category.

4. Proven and widely adopted. Technologies in this category have been used in many companies as they are proven to be useful. Enterprise Resource Planning (ERP) software is one of the examples of technologies in this category.

5. Aging. Some technologies age over time and the values from using the technologies are diminishing. Technologies such as Material Resource/Requirement Planning (MRP) dan Computer Aided Design (CAD) could increasingly lose their values in the future as new technologies such as ERP and Model Based Enterprise (MBE) transform the business process within companies.

Whilst companies could choose to adopt technologies in any of the above categories, they need to understand the consequences of adopting certain technologies for their business. For example, companies which are not too dependent upon technologies for their operations might choose proven and widely adopted ones to avoid unnecessary investment which could be irrelevant and risky for the future of their business. Small companies which have just started to develop but are not too dependent upon technologies and do not have enough capital to invest in technologies might want to adopt technologies in the aging category. On the other hand, companies with no constraints on capitals and consider technologies as part of their core operations might want to monitor technology development in the market and invest in high ROI, promising, or even hype technologies due to the exploratory nature of their business.

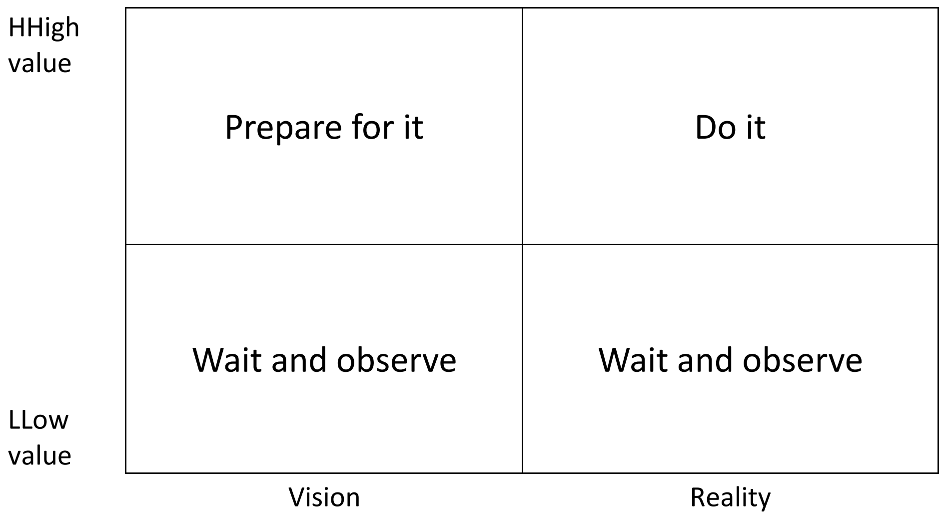

Figure 2.1 Technology adoption matrix.
Source: adapted from Farahani et al. (2015)

Companies can further map out their technological needs based on values expected from the technologies (low vs. high value) and availability of the technological products in the market (vision vs. reality) (Figure 2.1). Ideally, companies need to adopt technologies that bring high values for companies, such as increasing the efficiency of the companies' operations. Techologies including supply chain control tower and predictive analytics are currently available in the market and could increase efficiency in the companies' supply chain operations. As such, companies need to "do it".

Other types of technologies might not be widely available in the market but potentially offers high values for companies so that they need to "prepare for it". Technologies such as digital twin, additive manufacturing, and augmented reality for some companies might be classified in this area. Finally, some technologies might or might not be widely available in the market but they currently offer low values for companies, so that they need to "wait and observe" until they see clear values in its application. Companies could further add timeline to their technology adoption map so that they could monitor their targets of technology adoption and development.

Technologies can be treated as assets that need to be maintained to ensure their reliability. Companies also need to consider important aspects such as safety and security when adopting certain technologies. In the era of digital economy, data, information, and knowledge are key. However, the 90/90 data rule suggests that 90% of data gathered by organisations are not used within 90 days. It means that there are big data out there that are not optimally used to create insight for better business or organisational decision making. Many organisations are also reluctant to share data, information, and/or knowledge to their business partners due to fear of misuse. This could hinder transparency and therefore efforts to achieve efficiency in the business operations.

Summary

In summary, businesses can contribute to sustainable development by transforming their linear operations into a circular system. The transformation requires involvement from multiple stakeholders, including customers and the government. In addition, technology and innovation play a pivotal role to help organisations keep up with the current development and maintain their competitive advantage. The application of technology and innovation, however, needs to be managed so that organisations can optimally allocate resources to acquire necessary technologies and to innovate their businesses towards sustainable development.

Discussion questions

1. What are the challenges of implementing circular economy practices in business organisations?
2. Do you think the size of the organisations affects the implementation of circular economy practices?
3. How often should organisations update their technologies and innovate their business?
4. What sociocultural aspects need to be considered when implementing technologies and innovation for sustainable development?

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CHAPTER 2: BUSINESS OPERATIONS AND THE VALUE CHAIN

2.1 Business Operations

Operations can be defined as a process of transforming inputs into outputs to meet customers' needs. Operations management, therefore, means that the transformation process needs to be planned, organised, led, and controlled effectively and efficiently to achieve business goals. For business organizations, the ultimate goal should be to make and optimize profit. Inputs can be in the forms of raw materials, equipment, human resources, money, information, and any other aspects required for the transformation process to make outputs in the forms of products or services. To illustrate, to make a cheese product you find in a supermarket, a cheese manufacturer needs a number of inputs. It needs milk as the raw material from the farmer, it needs a machine to process the milk, and people to store the processed milk until it is ready to be packed and sent to the supermarket. The transformation process happens when the milk arrives at the factory and is processed by humans and machines to make ready-to-store cheese.

Slack and Brandon-Jones (2019) suggest that operations management can comprise three levels or perspectives. These levels represent a holistic view and scope of work of the operations management. The first level is called "process," explaining how a job is executed. For example, factory staff working on the packaging of products can be considered a process. The second level is called "operations," in which interactions between processes happen. For example, the packaging process within the factory is likely to interact with the production and finance processes, forming complete manufacturing operations. Finally, a "supply chain" perspective sees operations management as a collaborative value delivery process from suppliers to customers involving multiple organizations. Using our previous example, the manufacturing company might interact with different suppliers that provide raw materials. They might also deliver their products to distribution centers and retailers, each with its own processes and operations.

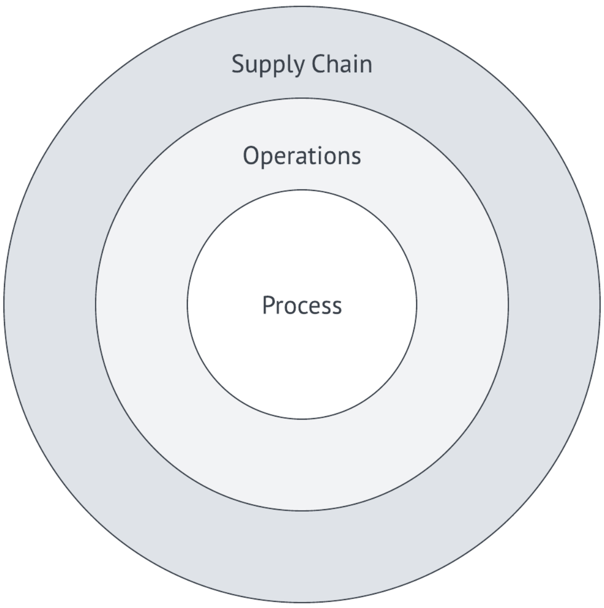

Figure 2.1 Three Levels (Perspectives) of Operations Management
Source: Slack and Brandon-Jones (2019)

There are some important decisions to make in operations management so that the business process is effective and efficient:

1. **Products.** Businesses need to decide what products to produce or sell. This decision also includes the design of products and managing the required inputs to make the products. Products can be further classified into different classes based on their sales volume, values, or other classes to ensure that companies can optimize their profit. To produce products or services for high-scale production, companies need to prepare material requirement planning, material resource planning, or more advanced enterprise resource planning where all requirements, not only production but also finance across their supply chain, can be aligned. Companies also need to consider whether to make their own products or buy them from other parties. Making own products can be expensive as it can be a capital-intensive activity, but it can provide strong control of the products. On the other hand, outsourcing the products to other parties can be cheaper, but the control over the products can be weaker. Companies can then decide on which product strategy is the best to compete in their market. They can either focus on differentiating their products from other competitors, offering low-cost products, or responsive products to achieve competitive advantage.
2. **Services.** It should be noted that services are different from products. Services are usually intangible, even though their delivery could require certain tangible products. For example, to deliver services in barbershops, restaurants, or hotels, companies still need tangible products such as equipment, kitchen appliances, and food. Services cannot be stored as an inventory as the production and consumption of services happen at the same time.
3. **Quality management.** Quality can be seen from different perspectives. From a product perspective, quality means meeting the customer's expectations. On the other hand, from a manufacturing or production perspective, quality means meeting certain standards or specifications within the industry. Total quality management is a wider and more systematic approach to quality management in which leadership and a culture of quality are required to ensure excellent delivery of products or services.
4. **Process design.** The production process needs to be designed to transform inputs into outputs. Depending on the characteristics of products, companies can choose different types of process design. Job shops, for example, are usually used to produce products with a high variety and low volume. It is also appropriate for products that fall under a project management paradigm. On the other hand, mass production can be chosen when companies produce low variety but high volume products. When both product variety and volume are high, mass customization process design can be applied. The process design is important as it can help companies decide the level of investments in inputs of production and help them achieve effectiveness and efficiency in their production.
5. **Capacity planning.** Companies need to prepare their production capacity to meet their demand. Level capacity can be applied when companies decide to make the same level of production in all periods. While this strategy can be cost-effective as capacity can be optimized with the same rate of production, companies face risks of losing customers when the demand exceeds the capacity or overstock when the demand is lower than the set capacity. On the other hand, a chase capacity strategy can be chosen when companies aim to flexibly follow the demand. However, this approach incurs costs to ensure flexibility to increase or decrease production capacity according to demand fluctuations.
6. **Location.** This element is important as it affects the effectiveness and efficiency of business operations. Retailers, for example, need to find strategic locations that are visible and easily accessed with different modes of transport to attract end customers. Manufacturers and distribution centers, on the other hand, can decide whether to locate their facilities closer to customers or closer to suppliers. Each of these options has cost consequences. Being closer to suppliers means that raw materials are secured but the transportation costs to deliver products to customers could be high. The opposite condition could happen when companies choose to get closer to customers. Whilst the delivery costs could be low, the trunking costs to bring raw materials to production and warehouse

facilities could be high. Further physical network design is required to find an optimal solution that minimizes operations costs and, therefore, optimizes profit.

7. **Layouting.** Whilst location decision deals with placing the business at the optimal place, layouting decision covers the way business processes and/or workstations are arranged within the company. For example, within a hospital, the operations manager needs to ensure that admission, operations room, and pharmacy are located in a way to make easy access for patients and to move important equipment around, thus minimizing wastes caused by inefficient processes. Certain tools, such as process mapping and service blueprint, can be used to help analyze the flow of activities within the business process and decide the best layout for the operation.

8. **People.** Managing people in operations is also an important aspect that needs decisions, such as work scheduling, continuous improvement training, and human resource allocation. Companies also need to decide whether to put people or replace them with machines or digital technologies. All of these decisions could affect the effectiveness and efficiency of the business operations.

9. **Inventory.** For some companies, inventory is a critical working capital and is used to assess their reliability performance. In other words, inventory represents product availability, which is considered a key performance indicator in some industries, such as retail. However, some other companies might see inventory as a waste that must be minimized or eliminated from the business process. Nevertheless, some decisions in this area need to be taken, such as how much inventory to store, when, and how much to order. Companies also need to consider the nature of the products and understand the lead time to bring the raw materials or products from their suppliers.

10. **Scheduling.** Many aspects of the operations need to be scheduled and there should be an alignment between schedules such as people, machines, equipment, production, and product deliveries. Companies also need to consider scheduling activities within different scenarios, such as normal and during the event of disruptions or emergencies.

11. **Reliability.** Companies need to ensure that their operations are reliable. One of the ways to ensure reliability is by applying redundancy in their business process. It simply means having a backup system just in case the main system fails. For example, companies can prepare a power generator just in case a power cut happens that would affect the production process. Another power generator might be prepared to mitigate the risk of the first power generator breaking down. However, it should be noted that the more robust the system (i.e., more redundancies), the more costly the operation.

12. **Maintenance.** To ensure that facilities, equipment, and/or machines run well in the long term, companies need to make decisions on how to maintain them. Companies can use routine or planned maintenance, in which maintenance work is regularly scheduled. They can also apply reactive maintenance, that is repairing broken things once they have happened, or using a more advanced approach of predictive maintenance in which companies proactively identify signals of failure and address them before worsening. In this case, companies can use digital technologies such as sensors, the Internet of Things, or digital twin to help them make decisions on what, when, and how much to maintain certain aspects of their operations.

13. **Supply chain.** Companies need to understand their supply chain configuration, i.e., their position and power in the whole supply chain process. They then need to decide on the best strategy to manage their supply chain. There are typically two prominent supply chain strategies – lean and agile. Lean strategy focuses on the efficiency of the supply chain operations, so overall cost-effectiveness is a key measure. This strategy is usually applied to manage the supply chain of commodity products with stable and predictable demand. Agile strategy, on the other hand, emphasizes the responsiveness of the supply chain operations to meet the changing customers' demands. As such, reliability and flexibility of the operations are key. This strategy is usually applicable to fashion products with unpredictable demand.

While these decisions involve some degrees of internal-external interactions, they can be further classified into inward and outward decisions (Figure 2.2). Inward decisions take external information into consideration to make internal decisions. Products, services, quality management, process design, capacity planning, location, layouting, people, inventory, scheduling, and reliability can all be classified as inward decisions, as they are driven by external information such as demand profiles and customer requirements. On the other hand, maintenance and supply chain can be classified as outward decisions. Maintenance, for example, relies on internal operations to monitor the existing system, while supply chain management can be started by understanding the companies' position within the existing supply chain network. Any decision within the maintenance and supply chain domains could affect external stakeholders. A decision to adopt reactive maintenance, for example, could imply that companies will react when the system is broken. As such, customers will need to wait for the system to work, triggering unsatisfactory responses from the customers. A company's decision to source from a single supplier could affect the resilience of the whole supply chain as disruptions within the single tie could delay the product and, therefore, value delivery to the end customers. It is, however, important to note that the inward and outward classification can also change depending on the companies' overall strategy for their operations. Companies that are inclined towards an efficiency strategy might have more inward decisions, whereas those that aspire to adopt an agile strategy might apply more outward decisions.

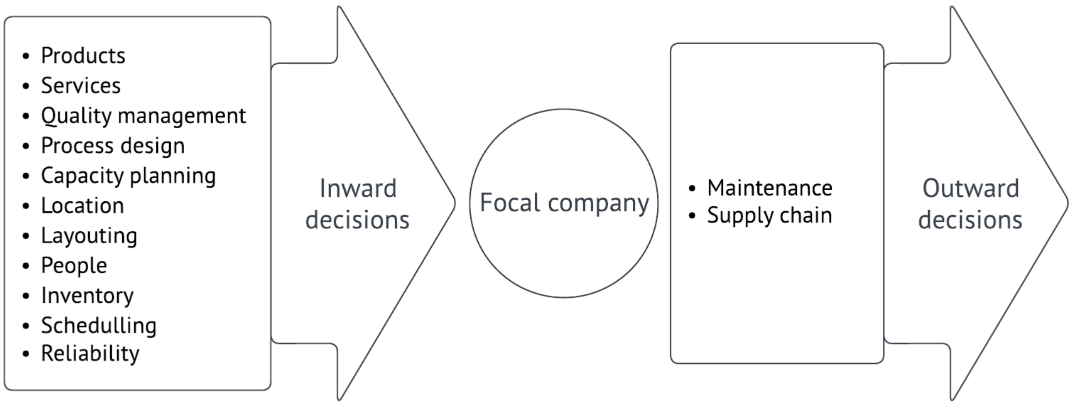

Figure 2.2 Decision-Making Categories in Operations Management

Understanding the product life cycle is also key in operations management. In this case, products can go through several stages from introduction, growth, maturity, and decline. During the introduction stage, typically, companies need to spend money on research and development, new product development, process modification, and ensuring that they have the right suppliers to support the production of new products. In the growth stage, companies typically have more stable product designs so they need to prepare their production capacity to adjust with the demand of the products. The maturity stage is achieved when competitors have become a clear threat to the companies, requiring companies to innovate their products and potentially their business processes and models while making continuous improvements to make their business operations more efficient. If such an effort is not successful in maintaining their business, products can be in a declining stage as they do not make a significant contribution to the business and need to be replaced by new products and offerings. The introduction and the initial part of the growth stages might contribute to high costs and therefore, loss for the companies. In contrast, the end part of growth, maturity, and the beginning of decline stages might bring profitability for companies. Figure 3.3 illustrates the product life cycle.

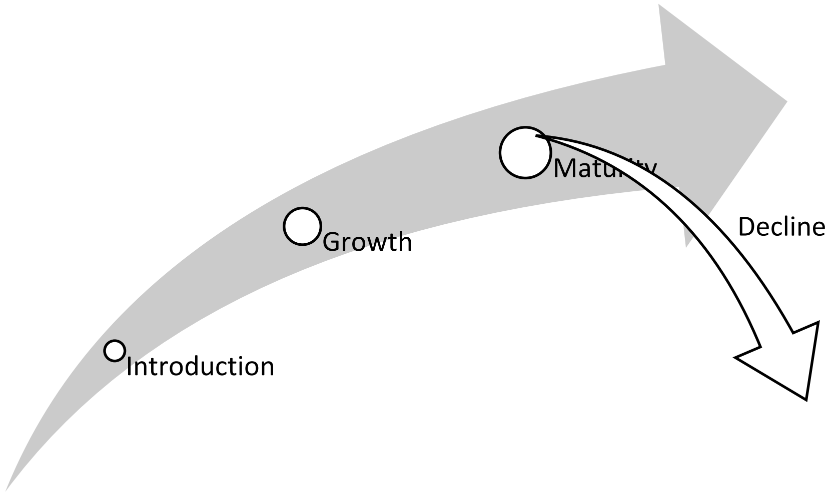

Figure 2.3 Product Life Cycle

2.2 The Value Chain

Business operations management is one of the primary activities within the business value chain (Porter, 2001). In this case, value instead of product is delivered through the value chain process. Product represent tangible or intangible output of business operations which can be used by customers. On the other hand, value represents the benefits the customers gain by buying the products. Put simply, value is benefit over cost. To deliver value, companies need to understand what the customers need or their problems that can be solved by consuming the products. For example, within the ride-hailing industry, companies not only sell applications and get fee-based revenue from customers using the ride-hailing services, but ultimately, they sell value by making the services more cost-effective and convenient for customers. They solve problems where traditionally people had to find cars or motorcycles on the streets or make long calls to get a ride. With the application, customers can conveniently place an order with fairer rates.

Practically, value chain processes represent managerial functions within an organization that work together to deliver value to customers. Porter's value chain management is divided into three parts – primary activities, supporting activities, and margin. Primary activities cover the following aspects:

1. Inbound logistics. This activity deals with the flow of raw materials or products from suppliers to the companies. This may also include the transportation process.
2. Operations. The raw materials or products from the suppliers are then transformed into other products as outputs of operational activity.
3. Outbound logistics. The output products are then transported out to customers.
4. Marketing. The main objective of marketing is to attract customers to buy the products. The 4P (product, price, promotion, place) marketing mix, for example, can be used as a marketing strategy. Companies can highlight the features, packaging, quality, and branding of the products. They can also provide discounts for certain products, promote them using advertisements, and sell the products through different channels, such as online and offline stores.
5. Sales. Whilst marketing attracts customers to buy products, sales ensures that transactions happen and that customers really buy the products.
6. Service. This aspect deals with aftersales service to maintain customer satisfaction and loyalty.

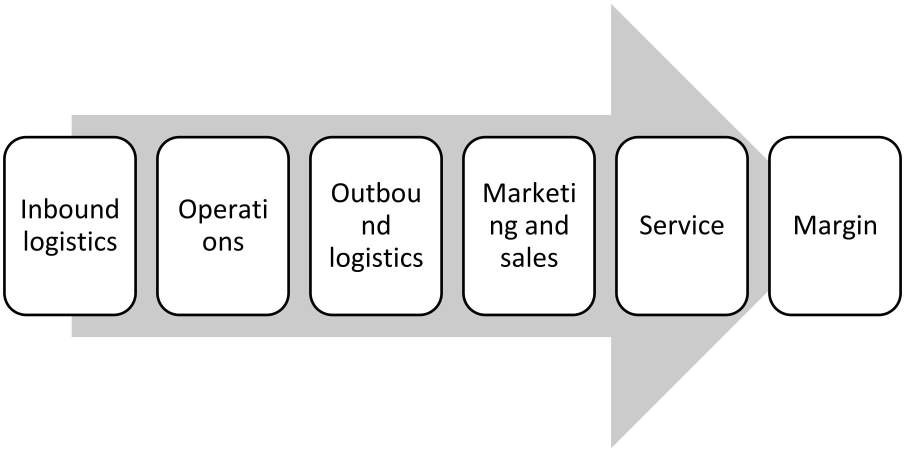

Figure 2.4 Primary Activities of the Business Value Chain
Source: Porter (2001)

These primary activities are key to running the business at any level. When the business develops and gets bigger, activities become more complex, and that supporting activities might be needed. Supporting activities cover but not limited to the following aspects:

1. Firm infrastructure. When companies get bigger, they need to manage and report their business properly. They might also need to manage their finance and investments. Good firm infrastructure including administration and finance management therefore supports the companies to better function their operations.
2. Technology. As discussed in the previous chapter, technologies can help companies run their operations in a more effective and efficient way.
3. Human capital. More developed companies need to manage their talents and deal with recruitment, selection, training, and development to ensure the jobs fit with the people working on them.
4. Procurement. To ensure that inbound logistics run smoothly, companies with more complex operations might have dedicated procurement or purchasing departments to help them secure resources from suppliers.
5. Finally, the last element of the value chain process is margin. At the heart of all business organizations is profit. Businesses run to make a profit, and all primary and supporting activities should be effectively and efficiently orchestrated to optimize companies' profit. While nowadays sustainability should incorporate a triple bottom line approach to also think beyond profit and care more about the planet and people, profit is still key as it potentially maintains business to keep operating.

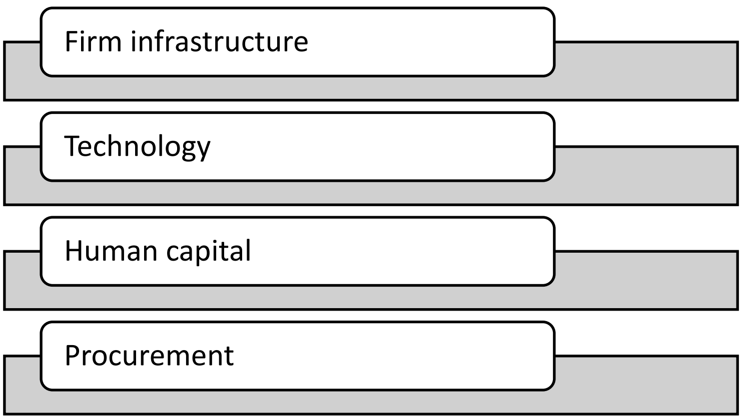

Figure 2.5 Supporting Cctivities of the Business Value Chain Source: Porter (2001)

Operations and business value chain management are important for companies aspiring to achieve sustainable competitive advantage. To win the market, companies need to focus not only on order qualifiers but also on developing capabilities to generate order winners. Order qualifier means that companies need to comply with specific market requirements. For example, to enter and do business in the tourism industry such as running a hotel, a company needs to meet specific requirements to be called a hotel, such as having rooms, cleaning services, receptionists, a booking system, etc. However, more than these facilities might be needed to win the market, so the company needs to have a point of difference so that customers choose the company over others. It is likely that the company positions itself as a sustainable hotel with all elements complying with sustainable standards. This could potentially become the order winner, which helps the company be more competitive in the market.

The resource-based view suggests that sustainable competitive advantage can be achieved when resources within the organization is valuable, rare, inimitable, and organized (VRIO) (Barney, 1995):

1. **Valuable.** Resources need to generate added values that benefit companies internally and customers externally. For example, companies might have access to big data which are useful to make predictions of market demand with high accuracy. As such, they can provide appropriate products to customers while generating profit from selling the needed products.
2. **Rare.** Resources should not be easy to get. For example, big data from customers might not be easily accessible from the internet, and it needs to be processed to generate insights.
3. **Inimitable.** Imitating the resources is virtually impossible. In the case of big data, other companies might need to make significant investments in digital technologies and data analytics, which could be very expensive. Not many companies have the financial capabilities to do so.
4. **Organized.** The resources need to be managed effectively and efficiently to generate the best products and values for customers. For example, companies might have data centers and strong research and development to explore the potential of using big data to support their business operations. They could also have specific decision support systems based on the big data.

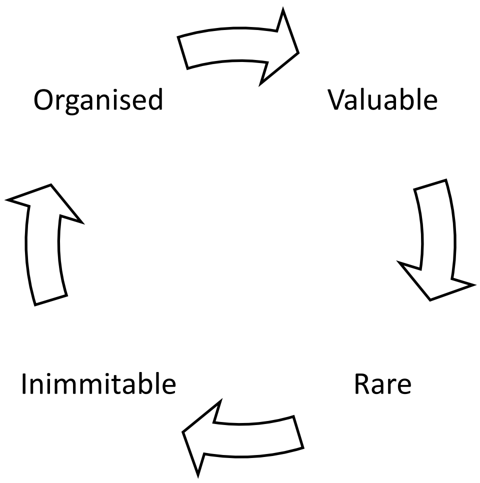

Figure 2.6. VRIO for sustainable competitive advantage
Source: Barney (1995)

Whilst delivering values to customers should become a business priority, efficiency has been at the core of operations management as saving from this function could significantly contribute to increased profit margin. Operational efficiency can be achieved by applying lean principles and eliminating wastes that do not add value to companies and, therefore, customers. There are eight types of wastes that need to be managed (Skhmot, 2017):

1. **Motion.** The first waste is motion, which refers to unnecessary movements of body parts to execute activities within the companies. Motion could lead to inefficiency as it takes more time to complete certain activities. One way to reduce or eliminate motion is to place things needed to perform jobs within arm's length or in places that are easy to access.
2. **Overproduction.** Waste can also come from producing more than needed. As such, it is crucial that companies attempt to forecast their sales and plan their production capacity to avoid unnecessary products being produced with no demand.
3. **Overprocessing.** While operations consist of many processes, some of them might need to be more efficient because they run in complex and complicated steps, resulting in lengthy operations. Such processes can be simplified to avoid time wastes from overprocessing.
4. **Inventory.** From a lean perspective, inventory is considered waste as it occupies spaces and overstocks, which leads to high holding and obsolescence costs. Having ideal inventory levels is, therefore, key to avoiding waste. Some companies even adopt the Just in Time process to ensure zero inventory.
5. **Transportation.** Moving products from one point to another can be considered waste when it is not done in an efficient manner. Optimal physical network design and routing are required to avoid wastes contributed by transportation.
6. **Defect.** Products that do not meet specific quality standards can be considered defects, ending up being wasted or reworked with additional costs.
7. **Waiting.** This waste might be found in many cases and it reduces the productivity of business operations and affects customer satisfaction.
8. **Unused talent**. Not optimizing the potential of talents in contributing to the companies' operations is also considered a waste.

Understanding this waste is important, but in practice, some companies might choose not to follow this waste elimination approach because their focus is not on efficiency but on the agility of their operations.

Summary

In summary, operations management deals with planning, organising, leading, and controlling activities to transform inputs into outputs in the form of products and services. However, it should be noted that products and services need to be valuable, i.e. able to solve customers' problems or fulfil their needs. Resources used in the operations management also need to be valuable, rare, inimitable, and organised, so that organisations can achieve sustainable competitive advantage. Finally, the value chain needs to be managed to ensure collaborations between functions dealing with primary and supporting activities to generate optimal profit for the business organisations.

Discussion Questions

1. How can you apply the value chain framework in service industries?
2. What do you need to do to avoid wasting resources and processes in operations?
3. What strategies can you think about to ensure that the organisation's resources are valuable, rare, inimitable, and organised?
4. What are the consequences of implementing the strategies?

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CHAPTER 3: INTRODUCTIONS TO DIGITAL TECHNOLOGIES

In the analog era, complex systems heavily depended on analog signals, with devices like wired telephones and radio broadcasts serving as primary communication tools. However, analog transmission faced limitations, including signal degradation and interference. Manual manufacturing processes characterized this epoch, marked by labor-intensive efforts, and limited automation, resulting in slower production rates and less precision. The shift from old technologies to digital technologies represents a leap in efficiency, connectivity, and innovation. Digital technologies have not only transformed the way we live and work but have also opened new possibilities that were once unimaginable with traditional methods.

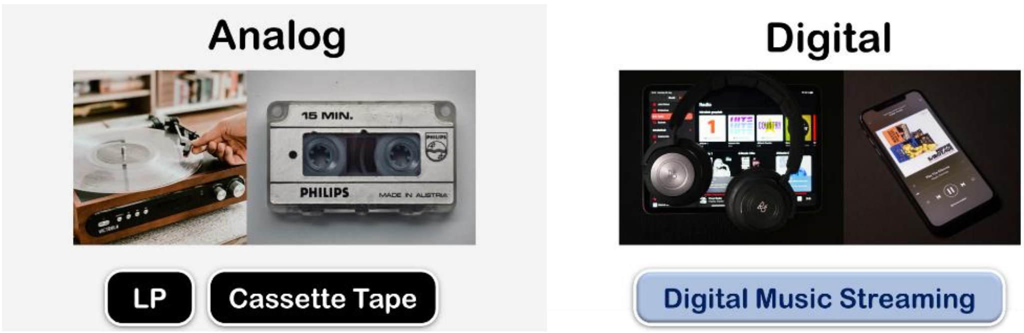

Figure 3.1 Analog Era vs Digital Era

3.1 The Evolution of Industry

The Industrial Revolution was a historical period marked by fundamental changes in the methods of production, economic structures, and societal organization. Industry 1.0, emerging in the 18th century, saw the advent of steam and water plants, revolutionizing sectors such as iron, mining, and agriculture. However, this progress came at the cost of pollution, prolonged working hours, and inadequate working conditions. Industry 2.0, in the 19th century, shifted the focus to iron, steel, railways, and telecommunications, bringing about transformative advancements but also introducing challenges such as increased costs and diminished job opportunities. The 20th-century Industry 3.0 emphasized renewable energy, telecommunications, and integrated circuits, albeit with concerns like e-waste and heightened power consumption. In the 21st century, Industry 4.0 marked a new era with the integration of intelligent systems across all production industries, introducing challenges like cybersecurity risks, extended working hours, and a shortage of skilled labor.

The emergence of Industry 5.0 signifies a shift in focus from technology-centric approaches to emphasizing the crucial interaction between humans and machines. This paradigm change prioritizes the collaboration of high-powered machinery with skilled technicians, promoting efficient, sustainable, and secure production processes. Key pillars of Industry 5.0 include personal focus, resilience, and a human-centered approach, which values employees as an investment rather than a cost. (Aslam et al., 2020; Pyo et al., 2021)

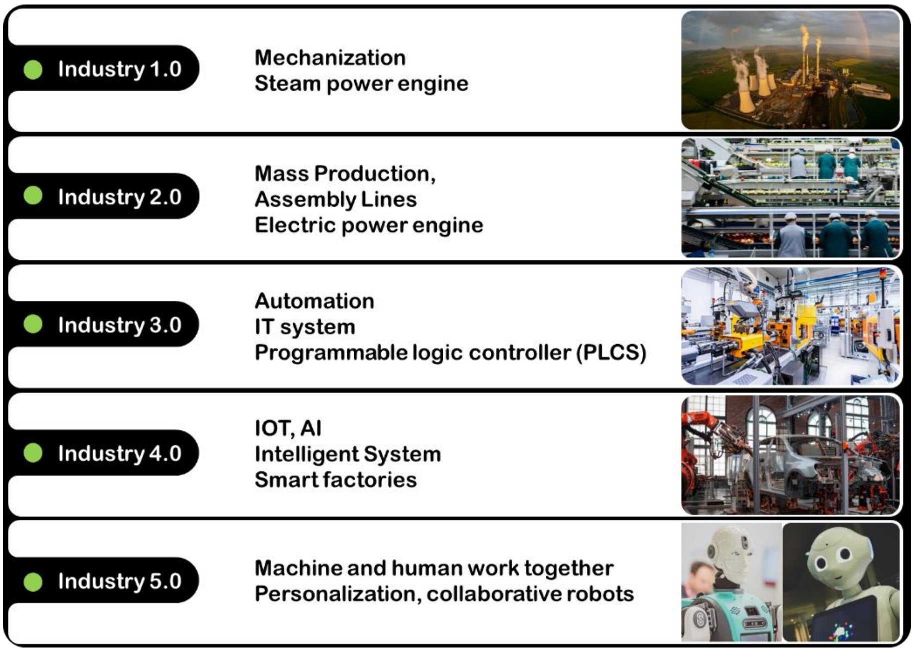

Figure 3.2 The evaluation of Industry 1.0 to 5.0

This human-centric perspective leads to a socially focused and inclusive production process, emphasizing the well-being of workers. The industry is transitioning from viewing employees as a cost to recognizing them as an essential investment. Manufacturing technology is tailored to accommodate the diverse needs of workers, ensuring a supportive environment that upholds basic rights such as independence, human dignity, and privacy. To achieve a healthy and inclusive workplace, continuous skill development and retraining for industrial workers are essential.

3.2 Digital Transformation

The integration of digital technology across all facets of a business is encapsulated in the concept of digital transformation. It surpasses a mere consideration of technology implementation, representing the strategic utilization of digital technologies to enhance customer experiences, optimize operational efficiency, and unlock novel business opportunities. The benefits of digital transformation are manifold. It brings about improved efficiency through streamlined processes and automated workflows, elevates customer experience through personalization and seamless interactions, provides data-driven insights for informed decision-making, facilitates scalability in operations, and furnishes a competitive advantage in the dynamic digital landscape. However, this transformative journey is not devoid of challenges. Resistance to change among employees adapting to new technologies, concerns about data security and privacy in handling sensitive information, the complexity of integrating new systems with existing ones, financial implications and investments associated with transformation, and the imperative cultural shift to align company culture with digital initiatives are hurdles that businesses must navigate. (Tim A. Herberge, 2021)

Rather than viewing technology as a standalone solution, digital transformation involves an integrated and strategic approach, reimagining how businesses operate, interact with customers, and identify innovative pathways for success.

In the dynamic landscape of technology, various fields play crucial roles in shaping our digital future. Data Science, a comprehensive discipline, employs diverse techniques to extract insights from both structured and unstructured data, paving the way for informed decision-making. Its subset, Data Analytics, focuses on analyzing historical data for trend identification, predictions, and decision support. Big Data Analytics specializes in handling and extracting insights from large, complex datasets, contributing to informed decision-making and trend identification in a data-driven era.

3.3 The Data Science Ecosystem

Data Science is a comprehensive field that employs diverse techniques to extract insights from both structured and unstructured data. It spans the entire data processing pipeline, aiming to extract actionable insights and facilitate data-driven decision-making.

Data Analytics, a subset of data science, is more narrowly focused on analyzing and interpreting data to unveil patterns and trends. Its primary concentration lies in examining historical data for trend identification, predictions, and aiding decision-making processes.

Big Data Analytics specifically deals with the processing and analysis of large, complex datasets beyond the capabilities of traditional systems. Its emphasis is on extracting valuable insights from massive volumes of both structured and unstructured data. Big Data Analytics, at its core, involves deciphering immense and diverse datasets to glean actionable insights, guiding businesses in informed decision-making and trend identification.

In summary, data science encompasses a broad array of techniques for insights from various data types, while data analytics, a subset, homes in on analyzing data for patterns. Big data analytics is specialized in handling and extracting insights from large and complex datasets.

Artificial Intelligence (AI) takes center stage, systems with human-like intelligence that leverage machine learning and natural language processing to automate tasks and enhance user experiences. Machine Learning (ML), a key component of AI, autonomously recognizes patterns and makes predictions based on vast datasets. The quality and diversity of the training data shape the effectiveness of ML, highlighting the importance of responsible data selection to avoid biases in predictions. Deep Learning, a subset of ML, further distinguishes itself by autonomously learning high-level features from data and resolving problems in an end-to-end manner.

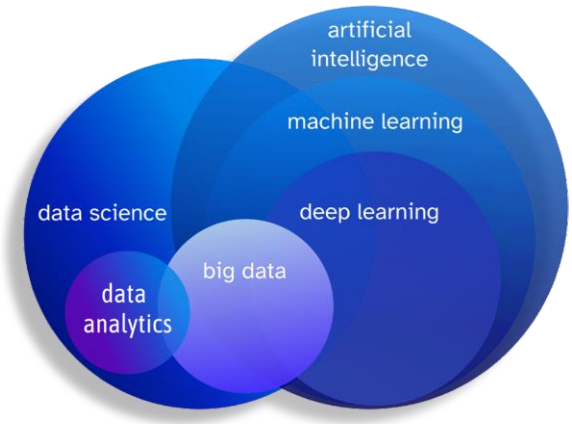

Figure 3.2 Taxonomy of Data Science
Source: The Taxonomy of Artificial Intelligence and Data Science (2020)

3.4 Industry 4.0 and the Internet of Things (IoT)

Industry 4.0 heavily relies on the IoT (Internet of Things) framework, where devices, machines, and systems communicate and share data in real-time. IoT (Internet of Things) is a network of interconnected devices embedded with sensors, software, and connectivity, allowing them to collect and exchange data over the internet. Concurrently, Cloud Computing complements this by providing scalable IT infrastructure, liberating applications from on-premises server constraints.

Indeed, these technologies – Radio-Frequency Identification (RFID), Global Positioning System (GPS), and Near Field Communication (NFC) – epitomize the transformative potential of modern advancements, revolutionizing our daily lives and reshaping various industries.

- Radio-Frequency Identification (RFID) is a technology employing radio waves for object identification. RFID tags store unique data and can be read by RFID readers without physical contact. It is extensively utilized in asset tracking, inventory management, and supply chain management, as well as applications like access control and payment systems.
- The Global Positioning System (GPS) is a satellite-dependent navigation system that furnishes information about location and time. Receivers utilize these signals to determine their position, including latitude, longitude, and altitude. GPS finds extensive applications in navigation, tracking, and mapping.
- NFC, a short-range wireless communication technology, facilitates contactless communication between two devices equipped with NFC capabilities. It is widely utilized for various purposes, including contactless payments, access control, data exchange, and asset tracking.

3.5 Digital Twin Technology: Revolutionizing Industry 5.0

Digital Twin Technology, a cornerstone of Industrial 5.0, involves the creation of digital replicas with applications in predictive maintenance and simulations. It is virtual counterparts of physical entities, processes, or systems, synthesized through the amalgamation of real-time data, sensors, and diverse information sources. To address real-world challenges and enhance operational efficiency through virtual simulations, systematic step-by-step implementation of digital twin technology is imperative. This process should incorporate components such as machine learning algorithms, data analytics, and advanced visualization due to the intricate nature of this technology. (Fuller et al., 2020)

Summary

In the analog era, communication was constrained by analog signals, limiting efficiency. The progression through industrial revolutions from steam and water plants in Industry 1.0 to integrated circuits in Industry 3.0 and intelligent systems in Industry 4.0 culminated in Industry 5.0, emphasizing human-machine collaboration. Digital transformation utilizes digital technologies to enhance efficiency, customer experience, and operations. Data science extracts insights from various data types, while AI automates tasks through machine learning and natural language processing. Industry 4.0 relies on the real-time communication of devices through the Internet of Things, while Industry 5.0 utilizes Digital Twin Technology for predictive maintenance and simulations through machine learning, data analytics, and advanced visualization.

Discussion Questions

1. Compare and contrast the different stages of industrial revolution (Industry 1.0 to Industry 5.0). What are the defining characteristics and challenges of each stage?
2. How does digital transformation contribute to improved efficiency, customer experience, and operational excellence in businesses?
3. What are the potential benefits and risks associated with the adoption of Industry 5.0 and its emphasis on human-machine collaboration?

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CHAPTER 4: HUMAN VS TECHNOLOGY

We cannot imagine our lives today without these technological innovations. Researchers and innovators are working day in and day out to come up with more advanced technologies than ever. An artificially intelligent robot working on deep learning algorithms, capable of sensory functionalities and adaptability is the seeming future. The humans have come a long way from the time of evolution and everything since the start has been a step further towards technology – even the invention of the simple wheel or discovering to light the fire with stones. Slowly and gradually things started evolving and humans worked on more advanced technologies as we moved towards the modern era. Most of the leading nations compete to establish them as the world's biggest superpower and the way goes through technology and automation. The future of technology seems so to be promising and frightening at the same time. Everything has its advantages and disadvantages and so does the evolution of these robots and AI machines. Where automation has potentially reduced human labor and made life much better, providing us with very high standards of living, at the same time it has also led to an exponential fall in the jobs in almost all sectors.

Today, we are not yet faced with humanoid robots that demand our affection or with parallel universes as developed as the Matrix. Yet we're increasingly preoccupied with the virtual realities we now experience. People in chat rooms blur the boundaries between their on-line and off-line lives, and there is every indication that the future will include robots that seem to express feelings and moods. What will it mean to people when their primary daily companion is a robotic dog? Or to a hospital patient when her health care attendant is built in the form of a robot nurse? Both as consumers and as businesspeople, we need to take a closer look at the psychological effects of the technologies we're using today and of the innovations just around the corner.

4.1 Fields Where Technology Is Already Replacing Humans

There are already some industries where humans are being replaced by technology as much as possible. There has been automation in manufacturing industries and small scale factories which has brought down the human intervention as much as possible. Instead of a large number of labor workers carrying out the work, as in earlier days, now there are robots and automated intelligent machines with only a very number of technicians keeping an eye on the proper and smooth working of these machines. It has not only reduced human labor and labor waste but has resulted in precision and accuracy along with higher production in less time as compared to earlier.

Figure 4.1 Industrial Control & Factory Automation Market size 2023
Source: https://www.linkedin.com/pulse/industrial-control-factory-automation-market-size-2023-tiffany-jacoby

As we can see in figure 4.1 we have automation in most of the major industries. We need to draw lines between different kinds of functions, and they won't be straight lines. We need to know what business functions can be better served by a machine. There are aspects of training that machines excel at—for example, providing information—but there are aspects of mentoring that are about encouragement and creating a relationship, so you might want to have another person in that role. Again, we learn about ourselves by thinking about where machines seem to fit and where they don't. Most people would not want a machine to notify them of a death; there is a universal sense that such a moment is a sacred space that needs to be shared with another person who understands its meaning. Similarly, some people would argue that having a machine fire someone would show lack of respect. But others would argue that it might let the worker who is being fired save face.

Although computer programs today are no more able to understand or empathize with human problems than they were 40 years ago, attitudes toward talking things over with a machine have gotten more and more positive. The idea of the nonjudgmental computer, a confidential "ear" and information resource, seems increasingly appealing. Indeed, if people are turning toward robots to take roles that were once the sole domain of people, we think it is fair to read this as a criticism of our society. So when we ask people why they like robot therapists, we find it's because they see human ones as pill pushers or potentially abusive. When we've found sympathy for the idea of computer judges, it is usually because people fear that human judges are biased along lines of gender, race, or class. Clearly, it will be a while before people say they prefer to be given job counseling or to be fired by a robot, but it's not a hard stretch for the imagination.

4.2 Computers Change the Way We Think About Ourselves

As the computers become smarter, the emphasis shifted to the soul and the spirit in the human machine. When Gary Kasparov lost his match against IBM's chess computer, "Deep Blue," he declared that at least he had feelings about losing. In other words, people were declared unique because they were authentically emotional. But when robot cats and dogs present themselves as needing people to take care of them in order to function well and thrive, they present themselves as if they had emotions. We are hearing people begin to describe humans and robots as though they somehow shared emotional lives.

If emotions are not what set us apart from machines, then people search for what does, and they come up with the biological. What makes human beings special in this new environment is the fact that we are biological beings rather than mechanical ones. In the language of children, the robot is smart and can be a friend but doesn't have "a real heart or blood." An adult confronting an "affective" computer program designed to function as a psychotherapist says, "Why would I want to talk about sibling rivalry to something that was never born?" It would be too simple to say that our feelings are devalued; it would be closer to the mark to say that they no longer seem equal to the task of putting enough distance between ourselves and the robots we have created in our image. Our bodies, our sexuality, our sensuality do a better job.

In many intellectual circles, notions of traditional, unitary identity have long been exiled as passé—identity is fluid and multiple. In a way, the experience of the Internet with its multiple windows and multiple identities brings that philosophy down to earth. But human beings are complex, and with fluidity comes a search for what seems solid. Our experiences with today's technologies pose questions about authenticity in new, urgent ways.

4.3 Human Purpose And Technical Design

We need to fully discuss human purposes and our options in technical design before a technology becomes widely available and standardized. Let me give you an example. Many hospitals have robots that help health care workers lift patients. The robots can be used to help turn paralyzed or weak patients over in bed, to clean them, bathe them, or prevent bedsores. Basically, they're like an exoskeleton with hydraulic arms that are directly controlled by the human's lifting movements.

Now, there are two ways of looking at this technology. It can be designed, built, and marketed in ways that emphasize its identity as a mechanical "flipper." With this approach, it will tend to be seen as yet another sterile, dehumanizing machine in an increasingly cold health care environment. Alternatively, we can step back and imagine this machine as a technological extension of the body of one human being trying to care for another. Seen in the first light, one might argue that the robot exoskeleton comes between human beings, that it eliminates human contact. Seen in the second light, this machine can be designed, built, and marketed in ways that emphasize its role as an extension of a person in a loving role.

As machines become more intelligent and human-like, we don't need to fear that this will somehow diminish us as humans. Instead, it will augment us and potentially enable us to become even more human. Kristian Hammond, professor of computer science at Northwestern University, put it eloquently: "As we humanize machines, we stop mechanizing ourselves." In other words, the more effective machines become at doing repetitive tasks for us, the more we are empowered to spend our time and energy on interesting and creative tasks, leading to greater fulfillment and self-actualization. As technology progresses, the relationship between humans and machines becomes interdependent and approaches symbiosis. Our abilities and our machines' abilities complement one another, allowing us to pursue goals that neither we nor they could achieve alone. In many fields, such as transport or telecommunications, humans originally started by building tools: basic technologies to meet a need that we cannot achieve with the human body alone. Examples of these tools include carts for transporting heavy items or microscopes for visualizing fine details.

Next, we turn these tools into machines, from basic technologies to more ergonomic and user-friendly ones that replace some or all human effort, requiring only human control. Examples of this step include moving from horses and carts to cars, from the telegraph to the landline telephone or from computers as a pioneering academic project to ubiquitous home and office PCs with enterprise software. The next step of technological progress is automation, where the element of human control is replaced with an algorithm. Humans make technology smarter and more autonomous, and the technology becomes able to learn from humans and improve itself. Landline telephones become smartphones, with the ability to learn the user's behavior and adapt to it; cars develop features like GPS and cruise control and eventually become fully driverless.

This level of technology includes machine learning, computer vision, natural language processing and self-modifying automation. Commands that trigger automated processes evolve from being manual (such as pressing a button or typing a command) to being event-driven (such as configuring an out-of-office reply to send whenever an email comes in) and eventually to being voice-activated (for example, by asking Alexa to dial a phone number or look up some information). Eventually, the technology becomes able to understand natural language and even anticipate your needs, making its own suggestions about tasks you might like it to do for you. Input and output devices become better integrated with software, streamlining automated processes and removing humans from the loop for routine operation, only requiring human supervision when something unexpected happens. Automation becomes intelligent automation.

Finally, human-machine interaction becomes human-machine symbiosis. The internet of things (IoT) becomes the internet of bodies (IoB), enabling humans to upgrade their link with technology by wearing devices or by embedding sensors or chips in their bodies. Some companies are already using implantable RFID chips as keys or access badges. External brain-computer interfaces can read people's EEG signals, or brain waves, empowering paralyzed people to type or to control their wheelchairs. Similarly, sensors can record the electrical activity in muscles, which, coupled with machine learning to translate this electrical activity into intended movements, can enable amputees to control their prosthetic hands and feet

4.4 Future Developments

No one knows what our future is going to be. But one thing is sure; it would be revolving around artificial intelligence and human-like robots. The leading research and development environments around the world are working on this day in and day out today. We are already using artificial intelligence in many places but what these researchers and innovators wish to develop is a complete human-like robot that can not only work exponentially as compared to a human but is also capable of human emotions using all those machines and deep learning algorithms

In the near future, brain chips, like Elon Musk's Neuralink, may further improve the connection and bandwidth between humans and machines and blur the boundaries between them. We will become bionic, and we'll achieve something like telepathy, as we communicate with others via our brain chips without speaking or writing, or like telekinesis, as we use our brain chips to control objects in the physical world. Some writers have suggested a further step in this process: the transcendence of our individual human bodies and the emergence of a global brain. Humans — by means of their brain chips — and AI systems would all be connected to the global brain, which could enable us to experience full telepathy and even travel using our thoughts alone. Many people may be understandably ambivalent or reluctant to be subsumed into a global brain, but it is worth recognizing it as a possible end state of the increasing symbiosis between human and machine.

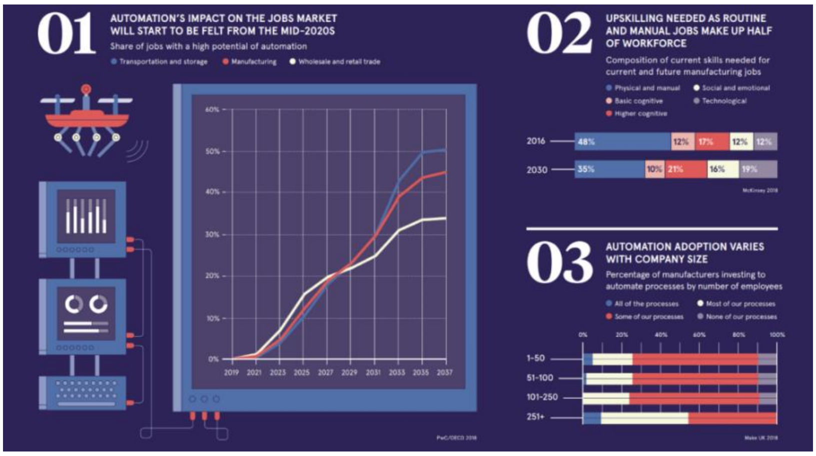

Figure 4.2 The Future of Automation
Source: Visual Capitalist, Age of Automation

Figure 4.2, shows the concerns of the future with all the automation. There would be possibility of more jobs being taken over, more dependency on robots and even some risks and problems that we will only be able to know when this happens. Some of the most ambitious projects going on are:

In the field of medical science.

Even though today the field of medical science is more advanced than ever, scientists are looking forward to introducing more and better technologies. Developing machines that would develop the likelihood of being diagnosed with a disease in the near future by processing our health and activity data is the utmost priority.

Trans-humanism

The scientists want to make our human bodies much smarter, stronger and efficient by introducing things such as exosuits which would make us even stronger, brain and RDIF chips using which we can open locks and doors just by a mere hand motion, biological augmentation which would lead to increased eyesight power, powerful CRISP-R gene-editing technology and things like that to make the embryo intelligent and more capable even before it actually transforms into a small living being! Organizations such as Elon Musk's Neuralink, Facebook and DARPA are working on these wearable augmentations and other brainmachine interfaces (BMIs). These body augmentation technologies would produce humans that are more capable, optimized and much more resilient.

Genetic Engineering.

Humans are trying to read DNA – the code of our biological systems, hack it and then rewrite it the way we want it to be. Gene-editing tools like CRISPR are being studied to transform human DNA and introduce powerful stem cells to fight these cancer cells to execute clinical trials. Just some time back a person was treated with a simple metabolic disorder of hunter's syndrome by the gene-editing of his cells.

General Advancements.

Humans want to develop robots that are capable enough of performing surgical operations all by themselves. Implementation of more accurate ‘polygenic scoring’ is being tried where big data analysis would take over to predict some complex disease risks by analyzing large number 0of sequenced genomes. Recently Arnav Kapur, an MIT media lab researcher developed a device named 'AlterEgo’ which can translate the thoughts into speech. When speaking, the brain sends signals and vibratory cells to the tongue. This device catches these signals and vibrations sent to the tongue or the larynx and translated it into actual speech without explicit speaking. Such devices can prove to be so useful to people suffering from paralysis and other speaking disabilities.

In the field of Nuclear Weapons and Military The whole technological advancements started with the aim of different nations to conquer the world. As we move into the future, the thirst for the same has grown exponentially. All the nations want to exert their supremacy now more than ever. All the leading countries are developing state of the art of nuclear weapons and military equipment. At the moment the US has almost 90-94% of the world's nuclear weapons. The US government predicted that between 2014 and 2023 it will spend around $350 billion on modernizing its nuclear arsenal. Similarly, other nations like China, Russia, India, and North Korea do not want to stay behind and are developing their weapons using the latest technology and most lethal ideas.

Robots vs Humanity Today we have robots and intelligent machines all working around us. But still there exists the difference between these intelligent machines and humans. There are many aspects where robots are exponentially much more efficient as compared to humans and so following there are equally as many aspects where robots do no come even close to performing like living beings. Some of the human limitations where the robots and the most advanced technologies have an upper hand are:

- Using technology we can have exponential efficiency.
- Robots are capable of working much more without getting tired, with greater accuracy and production rate as compared to human beings.
- Robots think more logically than living beings and are almost not persuaded by any emotional scenarios. Robots and intelligent machines are not affected, in any way, by the surrounding and environmental conditions.

The debate does not end here because humans have equally good advantages, maybe not in terms of efficiency but some of them are:

- Humans can adapt to changes and external stimuli. Humans can bend and twist their bodies for any task they want to perform which robots are not capable of. Many trial processes have been there where these robots failed to grab a particular object for long by bending their fingers.
- Robots and technologies are pre-defined and programmed for certain situations only and can work efficiently only under those circumstances.
- The emotional aspect – the machines lack emotions and hence cannot be deployed for delicate tasks such as carrying out surgical operations. Robots cannot do alone in this kind of activities but perhaps only assisting.
- Thinking, planning, and decision making on its own is one forte where robots are much behind humans. Research is being carried out using deep learning algorithms and machine learning to come as close to humans in this aspect still seems to be a concept way ahead in the future.

- The creative thinking, the spontaneity, and the instincts still provide humans the edge over robots and the most advanced technologies.

Applications

When building tech applications, companies need to keep these trends in mind in order to stay relevant and aligned with the likely direction of progress. This means designing technology and interfaces to be people-centric, with the aim of limiting friction between people and technology. In practical terms, this means intuitive and user-friendly interfaces that people don't need to spend cognitive effort thinking about, such as drag-and-drop or visual affordances, or, even better, verbal interfaces.

Design with these three key principles in mind:

- **Accessibility**: Make technology more accessible to non-data scientists and non-programmers, by leveraging intuitive interfaces such as drag-and-drop, friendly screens and no-code functionalities. Provide seamless, frictionless interfaces — particularly using natural language processing to enable verbal interfaces to engage with people.
- **Transparency**: Make technology trustworthy by providing transparency, giving explanations of how machine learning predictions are made or embracing a glass-box culture about how you use people's personal data.
- **Value**: Provide high value-added services, customized to people's needs, by understanding them better — for example, by collecting and analyzing usage data. Other technologies, such as end-to-end data pipelines and machine learning, can help with this step.

4.5 Case Study

Personal Assistant for On-Line Services

The Personal Assistant for the on Line Services PALS project is improving the user experience of mobile internet services [24]. It focused on a generic solution a personal assistant which attunes the interaction to the momentary user needs and use context such as adjusting the information presentation and navigation support to the current context device and interests of the user. The first thing focused on the actual realization of a PALS demonstrator is guided by the cognitive engineering process. In various stages knowledge and/or technology was needed and was developed within the two discipline focused research lines of PALS such as enabling the realization of an effective PALS and extending the HF and AI knowledge base.

Summary

Technology is built by people for people, and it needs to be as close as possible to people in order to better serve them. As technology applications advance, the winning applications will be those that are the closest to their users. This involves cultivating a deep understanding of the users and learning how to collaborate closely with them with a minimum of friction. So, humanity is safe only till the day technology is treated as a add on to human capabilities which reduces human work and makes our life easier and much more comfortable.

Discussion questions

1. What if artificially intelligent robots and technology take over our works completely?Especially in developing country.
2. Discuss the pros and cons regarding the advancement of technology that influence of lives?

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PART II
TECHNOLOGY AND SUSTAINABILITY PERFORMANCES

CHAPTER 5: SUSTAINABILITY PERFORMANCE METRIC

Over the past several years, many organizations have recognized the importance of sustainability and have developed their own sets of metrics, scorecards, ratings, and tools for measuring and tracking it. However, the term "sustainability" means different things depending on who you ask and what you want, and they all seem to have their own set of organization-specific indicators that vary widely in scope and scale. This lack of consistency leaves decision makers, as well as investors, consumers and the public, at a disadvantage. While some people interpret sustainability as environmental inputs and impacts, sustainability as a holistic concept has moved beyond simply an environmental dimension to include various social, governance, and economic factors as well. As one might expect, with multitudes of sustainability definitions comes sustainability indicators that are equally varied and expansive.

A common set of sustainability metrics will better enable organizations to utilize an understanding of sustainability to drive performance and competitiveness, rather than reacting to material environmental risks, stakeholder requests, or regulatory requirements. Deciding what indicators to track and to report is a critical step in engaging organizations, particularly in the private sector, in transitioning to a sustainable economy. Just as we have generally accepted accounting practices and clear definitions of financial indicators, we need to extend that process into physical measures of organizational performance: sustainability metrics. In the absence of a commonly accepted core group of metrics, it is difficult for policymakers to mandate disclosure of an open-ended range of indicators. While this need for universal indicators may be clear, the selection of specific indicators is not. This report represents the first stage in a long-term research project dedicated to developing that set of indicators.

5.1 Key concepts and issues

A. Sustainability Metrics and Indicators

Despite the lack of consensus over the term, over the course of the last few decades, the idea of sustainability evolved from a vague concept to precise definitions that attempt to present sustainability in quantitative terms and indicators (Moldan et. al 2012). However, broad definitions of sustainability lead to sustainability indicators that are equally varied and expansive. Indicators are the variables that are used to describe characteristics or states of a given entity or system. While some interpret sustainability to mean environmental inputs and impacts, sustainability as a concept has moved beyond the environmental dimension and come to include various social, governance, and economic factors as well. This expansion of the definition is demonstrated by the common phrase "environmental, social, and governance" (ESG) metrics, a term often used synonymously with "sustainability indicators," most typically on the corporate side. The term can also be used to describe the "triple bottom line" or sustainability in environmental, social, and economic factors, most typically used to describe governmental sustainability or sustainable development (at the national or city level). Within the broadest definitions of sustainability they include measures of water and energy efficiency but also issues like labor practices and corruption. Our review of sustainability metrics uncovered close to 200 distinct indicators in each of three categories —environmental, social, and governance— resulting in 557 total indicators. The following represents key observations and findings during this collection process.

B. Environmental Metrics

Environmental indicators are what we call the physical dimensions of sustainability—the traditional environmental sustainability metrics—including those such as greenhouse gas emissions per dollar of revenue or per product produced, amount of wastewater produced, amount of freshwater utilized, percent of materials recycled, etc. After exhausting our preliminary data sources, we categorized the environmental indicators by type, as follows (with number of metrics in parentheses): Energy (37) Emissions (35) Disclosure (30) Water (24) Materials (23) Effluents and Waste (19) Biodiversity (10) From this categorization process, we observed that "Energy" was the clear leader in sheer number of metrics. This category generates considerable attention from reporting organizations. It is widely considered one of the primary measurements for organizations engaging in efforts of environmental responsibility.

C. Social Metrics

In practice less than 20 are usually used in a single report. The total number of social metrics we found was 183, of which 60 are used by the private sector, and 123 by the government. Again, we categorized the metrics by similar characteristics (with number of metrics in parentheses):

Private Sector Human Rights & Resources (40) Performance in Products, Production & Supply Chain (20) Public Sector Safety & Health (84) Population (12) Infrastructure (11) Budget & Expenditure (9) Education (7) Social metrics track organizations' performance on equality, justice and other social impacts, but the metric and category boundaries are vague compared to environmental metrics.

D. Governance Metrics

Our research uncovered a total of 196 governance metrics. Governance indicators track how responsive a company is to its investors, the structure and function of the company's board, the rights of shareholders, the disparity between CEOs' salary and the average employee's salary, the transparency and organizational structure of a company, and prevalence of corruption. Our review of governance metrics found that many descriptions of governance indicators were either very limited or nonexistent, and even those with descriptions did not provide enough information to determine the type and quality of measurement. Some are just yes or no questions, seeking whether a company has a policy or not. Many governance indicators are simply a part of the company's mission statement or company profile. Except in the case of a handful of quantitative indicators, neither the database provider nor the computing entity has an effective method of measuring transparency and organizational structure. Based on the governance indicators that we found, we were created four categories based on similarities the indicator's description (with number of metrics in parentheses): Transparency (121) Equality & Fairness (36) Efficiency (21) Corruption (18) Transparency was the largest category, consisting of 121 indicators. Many of the common indicators center on board metrics, e.g. meeting attendance, composition of board, independence among members, and compensation of members.

E. Sustainability Metrics Frameworks & Composite Indices.

The ability to accurately measure sustainability is crucial to achieving sustainable development goals at every level, and the need to quantify concepts of sustainability into metrics or indicators has been well documented in the academic literature. (See Tanzil and Beloff 2006; Szekely and Knirsch 2005; and Azapagic and Perdan 2000 as examples.) Sustainability indicators are able to summarize a vast amount of information about our complex and complicated environment into concise, policy applicable and manageable information (Godfrey and Todd 2001; Warhurst 2002; Singh et. al 2012). Sustainability indicators are either presented in a structured framework that can be used to isolate and report on relevant indicators (Lundin and Morrison 2002), or aggregated towards a composite index or score/rating. Not surprisingly, the criteria for these types of indices are as diverse as the concept of sustainability itself (Mayer 2008). In general, sustainability frameworks provide qualitative presentation and grouping of large number of indicators and can be more revealing and accurate than aggregated indices, while indices tend to be easy to use and more easily understood by the general public.

F. The Ability to Accurately Measure Sustainability is Crucial to Achieving Sustainable Development Goals at Every Level.

Implementation of Sustainability Indicators A variety of organizations (private corporations, government agencies, consulting firms, non-profits, etc.) have developed scorecards, indices, ratings, tools, and programs to help organizations measure, track and report sustainability. In addition, significant work has been done to measure and track progress on sustainable development at the national level, with a wide variety of indices that rank and score countries' performance. Based on various frameworks and aggregation methodologies outlined in the academic literature, a number of organizations have attempted to select relevant indicators and develop all-encompassing indices or frameworks to measure sustainability. Just a few of those are discussed here: Since 1999, the Global Reporting Initiative (GRI) has been working towards establishing a credible set of sustainability indicators using four key areas of performance and impact: economic, environmental, social and governance. GRI's sustainability guidelines have become among the most commonly used for sustainability reporting, and it aims to become the universal standard – regardless of an organization's size, sector or location. GRI provides general indicator guidelines as well as sector-specific guidance, both of which are refined and updated over time.

The Sustainability Accounting Standards Board (SASB) is a non-profit engaged in the creation and dissemination of sustainability accounting standards for use by publicly-listed corporations in disclosing material sustainability issues for the benefit of investors and the public. SASB is developing sector specific standards that it hopes will allow all stakeholders to understand ESG metrics and ensure reliable comparison. By focusing on industry-specific standards, they expect to be able to compare "apples to apples." In 2010, Harvard University's David Wood, with Steve Lydenberg of Domini Social Investments and Jean Rogers of Arup, developed a methodology for determining industry-specific material issues and their associated, industry tailored performance indicators.

We've seen that there is a very large universe of indicators to measure the sustainability performance of an entity, but critical questions of which and how many indicators remain. While the development of these indicators is critical and must be continued, it is time to begin the process of settling on organizational sustainability indicators that everyone can use and understand. We need a generally accepted set of definitions and indicators for measuring sustainability

G. New Sustainability Metrics Take a Holistic Approach.

Sustainability metrics can be a difficult thing to measure.There are some new ways of measuring sustainability since the creation of the 3 pillars of sustainability that look at the economics vitality and environmental quality metrics to get a more holistic picture of what is going on. Sustainability has become one of the most important concepts in our society today. It refers to how we use resources responsibly, how we produce goods without harming the environment, and how we grow food without depleting natural resources. The issue is not just about protecting planet earth but also about safeguarding future generations from poverty and hunger as well as global inequality and injustice. Sustainability is more than just environmental concern. The main reason for developing new sustainability metrics is because of the complexity of measuring sustainability. It has moved away from looking at carbon emissions, forest over, and water quality to look at the economic vitality and environmental quality metrics

H. Measuring Sustainable Performance.

Organizations should consider the total impact on the economy, the environment, and society, not only relating to what is relevant for the company's internal stakeholders. The best way to ensure relevance is to use a formal standard that allows you to report in a structured and transparent way.

So far, there is no one globally accepted system for sustainability tracking and reporting. The GRI Standard is used by 73% of the world's 250 largest companies, across more than 100 countries. The GRI Standards are a modular system comprising three series of Standards: the GRI Universal Standards, the GRI Sector Standards, and the GRI Topic Standards. Each Standard begins with a detailed explanation of how to use it. As we move towards more standardization, making comparisons will be easier and transparency will increase.

Each organization will choose different metrics based on what is important or material to their business and their industry. Sustainable procurement can mean a lot of things, from measuring CO2 footprint to mitigating modern slavery. If you're not sure, check out our complete guide Sustainable Procurement 101. Let's break down some real performance metrics you can use.

I. Measuring Sustainable Performance.

Environmental sustainability metrics are the main area for tracking sustainability in most organizations. Environmental metrics cover a wide range of activities impacting climate, waste, and energy use.

Sustainability KPIs include:

- CO2 emissions reduction in kt
- Energy consumption in kWh
- Water usage in metric tons
- Waste reduction in cubic meters
- Plastic reduction in metric tons
- Material efficiency in material input per unit of service (MIPS)
- Noise pollution in decibels
- Compliance with chemical safety requirements
- Compliance with environmental standards
- Number of suppliers audited against environmental standards

Energy and emissions

The carbon emission and other pollutants resulting from the burning of fossil fuels are major factors contributing to climate change. Efforts to improve energy efficiency include migrating to more renewable energies to reduce harmful greenhouse gas (GHG) emissions. UK-based Carbon Disclosure Project (CDP) offers help and supports disclosing the environmental impact of major corporations. Its focus is on using carbon accounting principles to measure GHG greenhouse gas (GHG) emissions. Also, the International Integrated Reporting Council (IIRC) provides a comprehensive corporate reporting option that is useful when proving sustainable value to potential investors.

Scope 1 emissions, the direct emissions, are the simplest to track. Scope 2, the indirect emissions, resulting from the consumption of acquired electricity, steam, heat, and cooling. Organizations can use software and equipment, such as sensors, to accurately measure their energy consumption. Scope 3 emissions, the supply chain emissions, are harder to track and validate. Scope 3 is where procurement can bring visibility and transparency into supply chain GHG emissions. Reliable environmental reporting requires working closely with suppliers and setting common goals.

Water

Water is a key sustainability metric for most organizations, especially in manufacturing and the FMCG sector. Organizations can track their water usage, quality, the cost of water pollution on the environment as well as loss of water through leaks and evaporation. Leading companies are influencing suppliers to reduce and track their water use to reduce costs and save the environment.

Waste

Companies are beginning to focus on their contribution to the circular economy through waste management. Waste includes food and packaging waste, hazardous materials, debris and industrial waste, and final disposals. Plastic packaging and single-use materials can be replaced with recycled, recyclable, routable or circular materials.

Social and governmental metrics

Areas such as employee welfare, diversity, and inclusion that depend on numerical statistics can be monitored directly. Tracking other social metrics is less straightforward. Measuring performance against human rights goals such as improvement in living conditions and creating work opportunities in affected communities requires data and detailed analysis. The Anker Living Wage and

Living Income Research Institute provides a methodology as the basis for producing high-quality, consistent, objective information about living wages and wage gaps. The aim is to support wage improvement strategies and programs in ESG projects. This methodology has been used since 2017 to estimate living wages at Patagonia, a leading manufacturing company in ESG reporting.

In Governance, success is defined by the level of adherence to policy and regulations within the specific industry sector for both your own organization and the supplier base.

Corporate social responsibility KPIs include:

- Compliance with Code of Conduct
- Compliance with UN global conduct
- Share of suppliers audited against CSR standards
- Compliance with safety and security requirements
- Work-life balance, working hours
- People development, learning hours
- Community engagement, volunteering hours
- Share of diverse suppliers in the supply base
- Share of suppliers that filled in self-assessment questionnaire (SAQ)
- Diversity, equity, and inclusion (DEI) survey result

J. Case Study

The implementation of sustainability practices is related to changes in a company's strategy. Therefore, pursuing this strategy may influence how firms should measure performance.. A case study was conducted in a beverage company that has implemented sustainability practices since 2005. The empirical findings point to changes in characteristics of the company's performance measurement system. Hence, the implementation of sustainability practices acted as the external and internal trigger to change the performance measurement system.

Summary

There is a very large universe of indicators to measure the sustainability performance of an entity, but critical questions of which and how many indicators remain. While the development of these indicators is critical and must be continued, it is time to begin the process of settling on organizational sustainability indicators that everyone can use and understand. We need a generally accepted set of definitions and indicators for measuring sustainability.

Discussion questions

1. Please explain how you can measure sustainability performance in a certain industry?
2. Please explain the types of sustainability metrics in a certain industry?
3. Please explain what is the problem in measuring sustainability?

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CHAPTER 6: IMPACTS OF TECHNOLOGY ON SUSTAINABILITY

Sustainability is no longer a tick-box exercise, but an environmental, economic, and social aspect that is impacting our lives in almost every way. Understanding that no planet B exists for our youth and accomplishing 360° sustainability is imperative for all. Now more than before, people are focusing on social issues and sustainability. They are requiring that businesses step up and work under sustainability standards. Hence, the role of technology in sustainable development arises.

6.1 Industry 4.0 and Sustainability

Industry 4.0 is the abbreviation for the Fourth Generation Industrial Revolution. Industry 4.0 was coined in 2011 and drew the responsiveness of governments and business leaders all around the world for digital transformation. Industry 4.0 depicts a digital manufacturing revolution from traditional manufacturing in which new technical competence is introduced through the amalgamation of information technologies and automation that connect with one another to attain ideal performance. Following are the components that make up Industry 4.0: big data analytics, cyber-physical systems, Internet of things, additive manufacturing and cloud manufacturing. Industry 4.0 has enormous possibility for fostering long-term development and sustainable value formulation across social, economic and environmental domains enhancing effective use of resources.Researchers stress the significance of Industry 4.0 in guaranteeing sustainable "Triple Bottom Line" (ecological, economic and societal) .Organizational sustainability has grown in tandem with the advancements of Industry 4.0 in line with the incorporation of economic, social and environmental challenges into operations management.

6.2 Accomplishing Business Sustainability Goals

Latest studies have found that more than 70% of global consumers are willing to transform their consumption habits to mitigate their environmental footprint. For constantly striving in the competitive world, businesses are required to provide services that leverage not only consumers but also the environment. For instance, worldwide energy usage is projected to grow by nearly 50% by 2050. Investing in green energy that is accessible, clean, affordable, and sustainable, is now becoming a priority for organizations and the people.The role of technology in sustainable development is helping businesses with net-zero and other environmental, social, and governance goals.

Leading companies are already benefitting from technology accelerators to realize sustainability goals. For example, IoT, data analytics, and sensors are facilitating to decarbonize industry operations and solving issues by:

- **Networking and communicating**: Sharing information across networks, machines, and devices proficiently.
- **Monitoring and tracking**: Capturing Real-time data and reporting of operational performance within the connected devices.
- **Analyzing, improving, and forecasting**: Getting insights from data for improved decision-making on process efficiencies for the future.
- **Augmenting and automating**: Linking the digital and physical worlds with remote management and the construction of autonomous systems.

6.3 Accelerate Net-Zero Goals

- **Process optimization and digitization**: Creating sustainable operations that take stakeholder preference and enhance business resilience. Accepting advanced technologies, like cloud-native architectures for data-driven optimization of processes. It is helping businesses meet their emission reduction goals. As well as setting new industry standards. Such measures are having the potential to yield significant CO2 reduction.
- **Carbon data transparency**: Utilizing technology-led solutions that guide organizations with carbon accounting across the value chain IoT and blockchain-enabled sustainability solutions are facilitating transparency across all levels of an organization. Data and guidance are accessible and visible to all key stakeholders, which facilitates sustainable decision-making.
- **Circular products and services:** Building products and services that are reusable and sustainable with zero pollutants. The role of technology in sustainable development is involving the implementation of new types of product innovations and value chain solutions to fine-tune offerings. Engaging consumers and improving performance over time. Such solutions are enabling companies to create. Eventually, encouraging zero-waste products while improving ROI and building new revenue streams.
- **Data ecosystems and ventures**: Adopting cross-industry data-sharing ecosystems that are enabling compliance with sustainability regulations Data ecosystems are providing valuable, shared, and real-time insights into the environmental and societal impacts of a product or service. All while allowing organizations to meet their sustainability targets and compliance goals of TM become apparent and include product technology, process technology and information technology (IT)..

6.4 AI for Sustainable Outcomes

The role of technology in sustainable development like AI is essentially changing the way we think, live, work, and relate to one another and the external world. Business operations and processes can be optimized with such AI-enabled systems. While companies are using AI to augment efficiency and output and lower energy costs, training AI demands a lot of energy. Hence, to sustain an enterprise's efforts to mitigate its environmental footprint, it must also look at decreasing the carbon outputs of its AI/ML models. However, organizations are also using the power of AI to simultaneously reduce their carbon footprints and mitigate material risks.

AI models must be as efficient as possible so that training the AI model does not need large amounts of energy or computing power to augment accuracy and performance. Enterprises are requiring to conduct an efficiency vs accuracy test to determine if the resource utilized is justified from both a business and an environmental perspective.

6.5 The IoT and Sustainability

The IoT is expected to rocket in the years ahead, yet the benefits it promises will not come without environmental burdens, which are still being overlooked. In the meantime, the few life cycle assessments on IoT devices point out the risk of worsening the current environmental situation; they often conclude by stating the critical need for more life cycle analyses to ensure that decision-making processes focus on the benefits of the IoT without transferring impacts and causing the potential savings to backfire.

There is therefore a pressing need to consider the overall environmental benefits and costs in a multicriteria approach and to limit impact transfers when designing an environmentally friendly smart device. As more and more connected devices are manufactured, we have also seen that each device contributes to scattering some materials used to manufacture these devices, which are often not recyclable. both the number of connected device units and data traffic underlines the need to set priorities and limits to ensure that the IoT will not be a hindrance to achieving the objectives of reducing environmental impacts, such as global warming, that it will stay in line with the Paris Agreement and not in conflict with it.

But also to reduce the depletion of resources that are limited and critical; and finally, to address health and geopolitical sovereignty issues. Currently, most designers of connected objects do not take the environmental impact into account when designing the objects – or at least not systemically – sometimes even when these objects are intended to reduce humanity's environmental footprint. Eco-design may be a first prerequisite to limiting the environmental impacts of the IoT, but regarding the ongoing exponential rise of the IoT, even if eco-designing connected objects is a necessity will it be sufficient to limit climate change and critical raw material depletion?.

6.6 Technology for a Sustainable Future

The role of technology in achieving sustainability goals has become increasingly important. The United Nations' Sustainable Development Goals (SDGs) lay out a blueprint for a sustainable future for all. The goals cover a range of issues, including poverty, hunger, health, education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnerships for the goals. Technology plays a crucial role in achieving each of these goals. There are some of the ways in which technology can help achieve sustainability goals:

- **Renewable Energy:** One of the most significant challenges we face is the transition to renewable energy. The development of advanced renewable technologies such as solar, wind, and geothermal energy is key to reducing carbon emissions and mitigating climate change. In addition, smart grids and energy storage solutions are essential to ensure reliable and efficient distribution of renewable energy.
- **Sustainable Agriculture:** Technology can help improve food security and reduce the impact of agriculture on the environment. Precision farming techniques such as precision irrigation, precision fertilization, and precision pest management can reduce the use of water, fertilizers, and pesticides, while increasing crop yields. Additionally, new technologies such as vertical farming, hydroponics, and aquaponics can enable food production in urban areas and reduce the distance food travels to reach consumers.
- **Waste Management**: The rise of the circular economy and the adoption of sustainable waste management practices are critical to reducing waste and minimizing its impact on the environment. Technology can help with waste reduction, sorting, and recycling. For example, AI-powered waste sorting systems can accurately sort different types of waste, increasing the efficiency of recycling processes.
- **Water Management**: Water scarcity is a growing concern, and technology can help manage this precious resource. Advanced water treatment technologies can help increase the availability of freshwater, while smart irrigation systems can help reduce water usage in agriculture. Additionally, smart sensors can detect leaks and monitor water quality, helping to reduce waste and prevent contamination.
- **Sustainable Transport**: The transportation sector is a major contributor to greenhouse gas emissions. However, advances in electric vehicles, hydrogen fuel cells, and alternative fuels can help reduce emissions from transport. Additionally, smart transport systems that optimize traffic flow and reduce congestion can help reduce fuel consumption and emissions. Innovations in autonomous vehicles and drones can also improve the efficiency and safety of transport.

- **Sustainable Cities**: Cities are home to more than half of the world's population, and their sustainability is critical to achieving the SDGs. Technology can help make cities more sustainable by improving energy efficiency, reducing emissions, and enhancing mobility. Smart city technologies such as intelligent lighting, building automation, and traffic management can improve the quality of life for urban residents while reducing environmental impact.

6.7 Case Study

IoT and connected objects

The IoT is a young and complex technology area, regrouping a miscellany of connected electronic devices which are difficult to define and count and increasingly difficult to measure in terms of their environmental impact as they are diversifying ever more quickly and experiencing exponential growth. In the first section of this case study, we will explore what the IoT is and what kind of connected devices go to make it up. In the second section, we will provide an overview of the environmental issues related to the IoT and its exponential rise. With two concrete examples found in the literature we will see that one of the main IoT-related issues is the entropy of raw material resources used to manufacture electronical compounds as more and more connected devices are manufactured, and that even when smart devices can be used to limit greenhouse gas emissions, the question of impact transfer must be considered at least with regard to raw material resources. Since most IoT devices are intended for the consumer market or industry, and the proportion of connected devices that will serve to limit and reduce environmental impacts of human activities is still difficult to predict, can the IoT be designed to actively shape a sustainable future? Our recommendation section offers some leads.

Summary

The success of frontrunner companies is depending on leveraging technology from the very beginning. Through advanced technologies such as AI, IoT, or blockchain companies are analyzing, reducing, or optimizing their environmental impact. However, the role of technology in sustainable development is most definitely part of the solution.

Technology will play an increasingly crucial role in achieving sustainability goals in the future. From renewable energy to sustainable agriculture, sustainable transport to waste management, water management to sustainable cities, technology offers solutions to some of the most pressing sustainability challenges we face.

Discussion questions

1. Explain the role of technology in achieving sustainability goals?
2. How to accelerate the net zero goals?
3. Explain the pros and cons regarding the effect of technology on sustainable development?

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CHAPTER 7: SUSTAINABLE TECHNOLOGY INNOVATION AND TECHNOLOGY NEED ASSESSMENT

Numerous nations express concern about the issue of global warming and have pledged to address the threat. Since 2010, the Kyoto Protocol has been ratified by one hundred and ninety-three parties; however, only 37 countries (Annex I countries) have committed to meeting the specified greenhouse gas (GHG) emission reduction targets outlined in the treaty (UNFCCC). Although Thailand ratified the Kyoto Protocol in August 2002, it does not have a legally binding target for reducing or limiting its GHG emissions during the initial commitment period. Nevertheless, Thailand has the opportunity to participate in the carbon trading market through the Clean Development Mechanism (CDM).

To effectively address climate change, it is imperative to implement both mitigation and adaptation measures and technologies. In the context of climate change, the UN defines mitigation as human intervention aimed at reducing the sources or enhancing the sinks of greenhouse gases. Conversely, adaptation technology involves finding and implementing effective approaches to adjust to adverse effects resulting from climate change. The technology needs assessment (TNA) serves as a valuable tool, enabling a country to assess its requirements for new equipment, techniques, services, capacities, and skills for both climate change mitigation and adaptation.

The United Nations Environment Programme (UNEP), on behalf of the Global Environment Facility (GEF), is presently undertaking an extended set of Technology Needs Assessments (TNAs) with objectives extending beyond the sole identification of technology needs. These comprehensive TNAs aim to result in the formulation of a national technology action plan (TAP). The TAP will play a pivotal role by prioritizing technologies, proposing a supportive framework for the diffusion of these technologies, and aiding in the identification of feasible technology transfer projects connected to relevant sources of financing. The overarching objective of the TAP is to systematically address tangible measures essential for overcoming political, financial, and technological barriers, with the ultimate goal of effectively reducing or eliminating these obstacles (UNFCCC, 2022).

A Technology Needs Assessment (TNA) is a methodical procedure employed to appraise an organization's existing technological infrastructure, pinpoint gaps and inefficiencies, and ascertain the technological requisites essential for achieving its goals and objectives. This involves evaluating the organization's current technological capabilities, anticipating future needs, and formulating a plan to bridge the gap between the two.

The TNA process offers countries an opportunity to introspect on their requirements for attaining development goals, recognizing gaps, and determining technological solutions necessary to address these identified gaps or limitations. Additionally, the process furnishes recommendations regarding national strategies and policy frameworks indispensable for realizing key national priorities and development objectives.

7.1 Overall Objectives of the TNA

The objective of a Technology Needs Assessment (TNA) is to aid in the identification and analysis of critical technology needs, facilitating the transfer of environmentally sustainable technologies and programs to a specific country (UNFCC, 2011). A Technology Needs Assessment (TNA) allows a country to monitor its requirements for new equipment, techniques, services, capacities, and skills aimed at mitigating greenhouse gas (GHG) emissions and lessening the vulnerability of sectors and citizens' livelihoods to climate change. Furthermore, a TNA serves as a crucial component in advancing technology transfer. Technology transfer involves a range of processes facilitating the exchange of knowledge, experience, and equipment for both mitigating and adapting to climate change among diverse stakeholders, including governments, private sector entities, financial institutions, NGOs, and research and education institutions. (IPCC, 2002). Its purpose is to encourage the transfer of clean technology from developed nations to developing countries.

When people refer to the term "technology," the common association is with the application of science, scientific methods, and machines to accomplish a specific objective. However, it's important to note that the term "techno" also encompasses the concepts of "art, skill, and craft." Consequently, in this report, the term "technology" encompasses not only scientific knowledge and applications like machines, infrastructure, and equipment but also includes elements of art and management, such as domestic wisdom and practices.

7.1.1 TNA Methodology

Since its inception in 2001, the methodology of the Technology Needs Assessment has matured into a well-established process, evolving over the years through its application in various developing countries. This proven methodology may also offer valuable insights to developing nations as they endeavor to formulate and execute their Nationally Determined Contributions under the Paris Agreement. The Technology Needs Assessment process comprises three primary activities:

Identification and Prioritization: Identify and prioritize mitigation and adaptation technologies for specific sectors.

Barrier Analysis: Identify and analyze barriers that impede the successful deployment and diffusion of the prioritized technologies, including an examination of the enabling framework.

Technology Action Plans: Develop Technology Action Plans based on the inputs derived from the preceding steps. These plans, whether medium- or long-term, support the implementation of identified technologies. They outline activities that are further detailed in project concept notes (UNEP Copenhagen Climate Centre).

The process can be break down as follows:

Define the Purpose and Objectives: Clearly articulate the assessment's purpose and establish specific objectives, which may involve enhancing efficiency, improving security, reducing costs, or achieving specific business goals.

Engage Stakeholders: Involve key stakeholders from different departments or teams within the organization to gain valuable insights into their specific technology needs and challenges.

Inventory and Evaluate Current Technology: Document all existing hardware, software, networks, and systems in use. Assess their effectiveness, reliability, and alignment with organizational goals.

Identify Gaps and Weaknesses: Analyze gathered information to pinpoint areas where current technology may fall short of organizational needs or pose risks.

Explore Emerging Technologies: Research and identify emerging technologies that could address identified gaps or create new opportunities for the organization.

Conduct Cost-Benefit Analysis: Evaluate the costs associated with implementing new technologies or upgrading existing ones, comparing them to potential benefits in terms of improved efficiency, productivity, cost savings, or strategic advantages.

Perform Risk Assessment: Identify potential risks linked to the adoption of new technologies, including security vulnerabilities, compatibility issues, or disruptions to operations.

Consider Regulatory Compliance: Ensure that proposed technology solutions adhere to relevant industry standards and regulations, particularly in sectors with strict compliance requirements like healthcare or finance.

Prioritize and Develop a Roadmap: Based on the assessment, prioritize technology needs according to their impact on organizational objectives. Develop a comprehensive roadmap outlining the steps required for the implementation of recommended technologies.

The technology prioritization process involves five key steps, which include engaging stakeholders through focus group sessions and conducting a national public hearing on technology needs assessments.

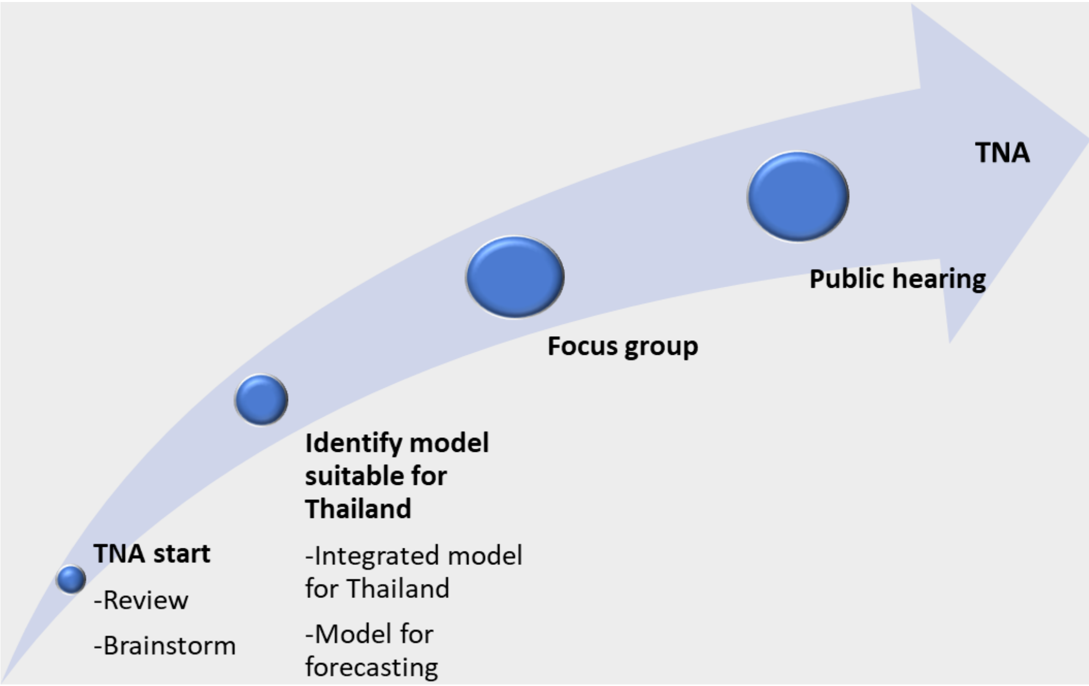

Figure 7.1 Technology prioritization process

The initial step involved a comprehensive review of potential technology categories and the generation of technology options through brainstorming. This process resulted in the identification of three overarching technology categories, which are summarized. In the second step, modeling tools utilized in various sectors were pinpointed as potential candidates for integration into a cross-sectoral modeling tool. Subsequently, experts from academic, governmental, and private sectors assessed the modeling candidates and technology options within each category during focus group sessions.

Following this, the preliminary list of selected technology options, arising from the focus group meetings, underwent scrutiny at the national public hearing workshop (see Figure 8.1). This workshop served to gather feedback from all stakeholders, ensuring the inclusion of all pertinent adaptation technologies. Criteria, weights, and scores were initially proposed by national consultants and later refined through stakeholder consultations.

Finally, a conclusive focus group session took place to consider expert comments on the technology options revised post-public hearing. The top-priority technology need in each category was then singled out for inclusion in the technology action plan.

Allocate Resources: Determine the budget, human resources, and time needed for implementing the identified technologies.

Implementation Plan: Develop a comprehensive plan outlining the step-by-step implementation of recommended technologies. This plan should encompass timelines, assigned responsibilities, and key milestones.

Monitor and Evaluate: Continuously track the progress of implementation and assess the impact of new technologies on the organization. Be prepared to make adjustments as necessary.

Documentation and Reporting: Maintain detailed records of the assessment process, recommendations, and implementation progress. Provide regular updates to stakeholders and decision-makers.

It's essential to recognize that a Technology Needs Assessment is an ongoing process. Given the rapid evolution of technology, periodic reassessment of your organization's needs is crucial to ensure that its technological infrastructure aligns with its goals and objectives.

7.1.2 Why do we need TNA?

A Technology Needs Assessment (TNA) stands as a vital process employed to identify and assess the technology needs of an organization, community, or society. Several compelling reasons underscore the importance of TNA:

Strategic Planning: TNA aids organizations in aligning their technological capabilities with overarching strategic objectives, ensuring that technology investments are in harmony with the organization's mission and goals.

Resource Allocation: By pinpointing critical technology needs, TNA facilitates the efficient prioritization and allocation of resources, enabling organizations to focus budgets and efforts on areas with the most substantial impact.

Risk Management: Through the evaluation of current and potential future technologies, organizations can identify potential risks and uncertainties, fostering the development of contingency plans and strategies to mitigate these risks.

Innovation and Competitiveness: TNA assists organizations in identifying emerging technologies and trends, fostering innovation and a competitive edge. This proactive approach allows organizations to adapt to changing technological landscapes.

Regulatory Compliance: TNA ensures that an organization's technology infrastructure and practices adhere to legal and regulatory requirements, a critical consideration in many industries.

Efficiency and Productivity: Organizations can identify opportunities to leverage technology through TNA, streamlining processes, enhancing efficiency, and boosting overall productivity.

Environmental and Social Considerations: TNA evaluates the environmental and social impacts of technology adoption, encompassing factors like energy consumption, waste production, and potential social implications.

Capacity Building: TNA identifies skill gaps and training needs within an organization, ensuring the workforce is equipped to effectively use and manage implemented technologies.

Sustainability and Long-Term Planning: TNA supports informed decisions about sustainable technology choices, considering the long-term implications and lifecycle of technologies to ensure continued viability and benefits.

Stakeholder Engagement: TNA often involves engaging stakeholders, promoting transparency and inclusivity in decision-making by incorporating input from employees, customers, and partners.

Avoiding Technological Obsolescence: TNA helps organizations avoid investments in rapidly obsolete technologies by facilitating informed decisions about technology adoption.

In summary, Technology Needs Assessment provides a structured and systematic approach to understanding, evaluating, and planning for the technological requirements of an organization. It ensures effective leveraging of technology to support the mission and objectives of the organization while minimizing risks and maximizing benefits.

7.2 TNA Thailand Case

In 2012, Thailand formulated a comprehensive technical document aimed at assessing the technology required for nationwide adaptation actions. The Technology Needs Assessment (TNA) report concentrates on the prioritization of technology within the agricultural, water resource, and modeling sectors. Additionally, Thailand has devised Technology Action Plans (TAPs) for the specific sectors identified in the TNA through a meticulous prioritization process. Section III of the document delves into the cross-cutting issues pertinent to the TNAs and TAPs across the various sectors in the nation.

The endeavor assists Thailand in identifying technological needs and fortifying its capacity in addressing climate change. As part of the six countries in Asia receiving support from the Global Environmental Facility (GEF) through the United Nations Environment Programme (UNEP) for climate change technology needs assessments, the Royal Thai Government designated the National Science Technology and Innovation Policy Office (STI) as the Thai TNA coordinator, with the Asian Institute of Technology (AIT) serving as the regional center for Asia.

This section expounds on the process and outcomes of the TNA, designed to pinpoint, evaluate, and prioritize diverse adaptation technologies crucial for Thailand's resilience to the impacts of climate change on the prioritized sectors. The insights and assessments provided in this section lay the foundation for Section II, which focuses on the Technology Action Plan (TAP).

In light of the impact of climate change on diverse sectors and stakeholders in Thailand, the first phase of the Technology Needs Assessment (TNA) involved identifying sectors significantly affected and urgently requiring adaptation technology. The inaugural session for the Thailand Technology Needs Assessment project took place on July 12, 2010, with the participation of the Office of National Resources and Environmental Policy and Planning (ONEP) under the Ministry of Natural Resources and Environment, and the Science, Technology, and Innovation Policy Office (STI) under the Ministry of Science and Technology. During this meeting, experts and stakeholders in climate change technology collectively determined the crucial need for adaptation technology in the agricultural sector, water resources management sector, and modeling sector.

As a result, the Steering Committee designated three technology workgroups for these sectors, each composed of national consultants. These workgroups, which involved institutions such as the National Center for Genetic Engineering and Biotechnology (BIOTEC) and the National Science and Technology Development Agency (NSTDA) for agriculture, the Hydro and Agro Informatics Institute (HAII) for water resource management, and the Center of Excellence for Climate Change Knowledge Management for modeling, assumed a crucial role in formulating the Technology Needs Assessment (TNA) for the specified sectors. The subsequent sections offer a concise overview of the assessment processes and outcomes for each sector.

1. Agricultural Sector

Thailand's agricultural sector is expansive, covering a range of subsectors. Nevertheless, this Technology Needs Assessment (TNA) specifically focuses on chosen subsectors rather than the entirety of the agricultural sector. This specific approach ensures the efficient translation and implementation of adaptation technologies. The initial phase of identifying target subsectors included evaluating their susceptibility to climate change and assessing their contributions to the nation's economic development, food security, and energy security.

In a meeting convened on May 11, 2011, with expert consultants and stakeholders, it was determined that field crops and aquaculture emerged as the two subsectors most susceptible to climate change, requiring immediate attention in terms of technology development and transfer. It is crucial to highlight that while this TNA addresses the specific needs of the target subsectors, many of the identified technologies have cross-cutting applications and the potential for use across various other agricultural subsectors.

During the development of the Technology Needs Assessment (TNA), initial proposals and discussions revolved around adaptation technologies in five distinct areas. These areas encompass climate forecast and early warning systems, crop improvement, precision farming practices, post-harvest technology, and animal nutrition and feed technology. The prioritization of adaptation technologies within the target subsectors relied on four criteria: 1) impact of technology, 2) technology capability, 3) policy and regulation, and 4) public perception and farmer acceptance.

After two stakeholder meetings using these criteria, experts expressed their preferences for three specific types of adaptation technologies: forecasting and early warning systems (37%), crop improvement technology (31%), and precision farming technology (17%). Forecasting and early warning systems aim to reduce the risk of damage from extreme climate events and pest/disease outbreaks, improving the ability to choose appropriate crops based on specific planting times and crop cycles. Crop improvement for climate resilience, employing techniques like Marker Assisted Selection (MAS) and genetic engineering, aims to decrease the risk of yield loss while maximizing resource efficiency. Lastly, precision farming technologies empower farmers to make well-informed decisions about their operations, reducing inputs while optimizing productivity and minimizing environmental impact.

Marker Assisted Selection (MAS) has been developed in the country and is ready for utilization and transfer to other nations through south-south cooperation. However, MAS is currently limited to specific rice varieties, namely jasmine rice KDML105 and glutinous rice RD6, with less research conducted on other crops. Expanding crop improvement for climate resilience necessitates increased expertise in molecular breeding, physiology, plant pathology, and entomology. Despite successful plant transformation in limited plant species, broader application faces challenges due to insufficient government support and resistance from local NGOs. The landscape is further complicated by the extensive patent coverage of genetic engineering, generating perceived intellectual property issues that impede technology transfer.

Precision farming in Thailand is currently in its early developmental phase. While certain technologies like drip irrigation systems, customized fertilizers, and closed systems for aquaculture have been introduced to innovative farmers, the adoption of these technologies is limited in number. Many ongoing projects and initiatives are still in the pilot or prototype-building stage.

Forecasting and early warning systems are employed to monitor and predict weather patterns and soil conditions, with the supporting software typically imported. However, the use of simulation models for predicting pest/disease patterns is not widespread, and several research institutes have recently commenced preliminary development work in this area. This highlights the necessity for technology and knowledge transfer from more technologically advanced countries.

2. Water Resource Management Sector

Thailand has grappled with a spectrum of water resource management issues, spanning from floods to droughts. The country's water resource management confronts a dual set of challenges, encompassing both natural factors and management-related issues. Natural challenges arise from inherent variability, including significant spatial and temporal fluctuations in rainfall. Certain regions experience recurrent bouts of drought and floods, sometimes within the same year. Additionally, the increasing severity and unpredictability of storms add to the natural challenges.

Management challenges, on the other hand, stem from the limitations of the existing infrastructure, characterized by insufficient flexibility and buffering capacity. Maintenance of infrastructure and stream channels is inadequate, and the handling of drought and flood issues occurs in isolation. Consequently, regions grappling with both problems necessitate redundant investments. Alterations in land use, notably deforestation and mono-crop plantations in headwater streams, contribute to changes in watershed runoff characteristics. Communication breakdowns and a lack of awareness within governmental agencies and the public further exacerbate the complexities of water resource management.

Hence, the analysis of Thailand's foremost challenges and objectives in water resource management draws upon the evolving water situation and the present state of water infrastructure management. This forms the foundation for outlining goals and objectives related to technology transfer and diffusion. Thailand's aspirations for water resource management center on achieving water security and agricultural security. The identified objectives for technology transfer and diffusion are as follows:

Enhancing Security in Capital Water Supply: Ensuring a secure and sustainable capital water supply is paramount.

Establishing Management Flexibility: Building flexibility to manage diverse supply and demand scenarios effectively.

Minimizing Disaster-Induced Damage: Mitigating the adverse impact of disasters on water resources.

Maximizing Water Usage Efficiency: Enhancing the efficiency of water usage to optimize resource utilization.

Inclusive Sectoral Management: Integrating all sectors into the water resource management framework.

Knowledge and Data Building: Developing knowledge, know-how, and data to bolster effective water resource management.

In essence, the prioritized technologies are expected to address challenges, improve the efficiency of infrastructure management, and contribute to the competence development of domestic human resources.

The process of technology prioritization involved three key steps, guided by stakeholder engagement through three focus group sessions and a national public hearing on technology needs assessment for water resource management. The initial step entailed a comprehensive review of potential technology groups, generating a list of technology options. A preliminary compilation of technologies, along with their contributions to Thailand's water resource management objectives as previously outlined, was prepared and deliberated upon in focus group sessions involving experts from academic, governmental, and private sectors. Subsequently, the preliminary list underwent a public review during the national public hearing workshop, seeking feedback from all stakeholders to ensure the inclusion of all relevant adaptation technologies.

The final list of potential adaptation technologies encompasses: 1) Environmental Observation 2) Weather and Hydrological Modeling 3) Flood and Drought Risk Management4) Operation of Water Infrastructures 5) Community Water Resource Management (CWRM) 6) Integrated Urban Water Resource Management (IUWRM) 7) Early Warning Systems

These technologies represent the culmination of a collaborative process that involved expert input, stakeholder feedback, and a comprehensive review to address the specific challenges and goals in water resource management for Thailand.

The prioritization of adaptation technologies involved the use of two distinct criteria categories—impact and capacity assessments—utilizing a multi-criteria decision analysis approach. The impact assessment aimed to measure the significance of technologies by evaluating their outputs and outcomes, while the capacity assessment focused on assessing Thailand's present technological standing and readiness for implementation through a SWOT analysis. Active stakeholder participation was integral in the review and scoring of all technology groups and individual technologies.

Identified as crucial for Thailand but not yet ready for development and implementation, high-impact technologies were selected and prioritized as "technology needs." The rankings included: 1) Networking (via pipes or canals) and Management of Infrastructures (including zoning) under Technology Group #4 (Operation of Water Infrastructure), 2) Seasonal Climate Prediction under Technology Group #2 (Weather and Hydrological Modeling), and 3) Sensor Web using Observation and/or Modeling Data under Technology Group #7 (Early Warning). These specific technologies play a vital role in improving the capacity and efficiency of water resource management and disaster management in Thailand. Furthermore, their selection aligns with the country's national policies and strategies.

Moving beyond individual technology needs and development, the creation of an inclusive system that integrates all technologies to facilitate decision-making emerges as the most crucial aspect of Thailand's success in water resource management. Implementing hard or structural technologies necessitates systematic engineering and a multi-objective approach to ensure an extended life cycle and maximize flexibility in addressing diverse scenarios of water supply and demands within the context of climate change.

3. Modeling Sector

The modeling sector plays a pivotal role at the intersections of climate change and various impacted domains, including agriculture and water resource management. It provides adaptive tools to mitigate the adverse effects of climate change, recognized as essential technology for both the agricultural and water resource management sectors. The primary goal of Thailand's modeling sector is to offer effective tools and integrated systems, enabling other affected sectors to develop dependable assessments and strategic plans for both mitigation and adaptation purposes. The affected sectors encompass climate, water resource management, natural disasters, transportation, industry, energy, agriculture, society, economy, and health, with special attention given to the water resource management and agricultural sectors due to their acknowledged national significance.

The technology prioritization process involves five fundamental steps, engaging stakeholders through focus group sessions and a national public hearing on technology needs assessments. The initial step involves reviewing potential technology categories and generating options through collaborative brainstorming. This process identified three categories of modeling sector needs: hardware, software, and database management.

Following that, in the subsequent phase, we recognized the modeling tools employed in diverse sectors, viewing them as potential options for integration into an all-encompassing, cross-sectoral modeling tool tailored for Thailand. The third stage entailed scrutinizing these modeling candidates and technology alternatives within each category during dedicated focus group sessions, with valuable insights provided by experts representing academic, governmental, and private entities in the affected sectors.

Advancing to the fourth phase, the initial roster of chosen technology alternatives, derived from the outcomes of focus group sessions, underwent scrutiny in a national public hearing workshop. This stage was designed to solicit input from all stakeholders, guaranteeing a thorough review and validating the inclusion of all relevant adaptation technologies. During the stakeholder consultation, national consultants proposed the criteria, weights, and scores, which were then subject to review and commentary by stakeholders. The Multi-Criteria Decision Analysis (MCDA) during the stakeholder consultation considered three criteria categories: performance efficiency, cost worthiness, and acceptability.

Performance efficiency was assessed based on ease of use and forecastability, while cost worthiness took into account further development and the transferability of technologies. The acceptability criterion evaluated the level of international and national acceptability of the technologies. Each criterion held equal weight for scoring, and three levels of scores—good, fair, and poor—were available for evaluation. Following the stakeholder consultation, a final focus group was conducted to consider and incorporate expert comments regarding the technology options that had been revised after the public hearing. Subsequently, the top-priority technology needs in each category were selected to be included in the Technology Action Plan outlined in Section II.

As per the technology prioritization process, the national data center emerged as the top-ranked technology within the hardware category. Simultaneously, the national data transfer/management process claimed the highest rank among technologies in the database management category. Ultimately, within the integrated model category, the WRF (ARW) model secured the highest ranking among the candidate models.

A data center encompasses essential hardware and houses an extensive collection of data sourced from various reputable channels. Beyond its role as a repository, it functions as a distributor of data to users and organizations, facilitating network utilization. The presence of a reliable data center is crucial for generating meaningful modeling results. Given the usefulness of modeling climate change impacts for the adaptation of diverse sectors—ranging from climate and health to economics—an integrated data center becomes highly desirable. Such a center streamlines user access to the comprehensive data needed for cross-sectoral modeling initiatives.

Although Thailand possesses a limited number of data centers, these establishments predominantly store data customized for specific purposes, adhering to the mandates of respective governmental agencies. This specialized approach poses challenges in accessing data for cross-sectoral modeling endeavors. In contrast to certain countries, Thailand currently lacks an integrated national data center. The establishment of such a center offers numerous benefits, including enhanced efficiency in domestic and international data collection and exchange, the creation of a unified data network for stakeholders and responsible entities, and its role as an official information distributor to all relevant parties. A national data center has the potential to catalyze advancements in both short-term and long-term data collection, application, and research efforts.

Various governmental agencies in Thailand, such as the Department of Meteorology, Royal Irrigation Department (RID), and Pollution Control Department (PCD), routinely monitor and document observed data related to weather, water, and air quality, respectively. These data primarily serve the purpose of developing domestic weather forecasts. However, as climate change is a global phenomenon, relying solely on observed data from Thailand is insufficient for modeling its impact. To adequately capture the complexities of climate change, it is imperative to incorporate data from other countries in Southeast Asia as inputs for modeling.

Unfortunately, Thailand currently lacks an official and effective mechanism for regional-level data collection, transfer, and database management. While a few research institutes in Thailand have made efforts to collect and manage data from diverse sources, both domestically and regionally, for modeling purposes, there is a significant gap in national data transfer and management. Establishing a robust national data transfer/management system is essential to furnish the national data center with credible and comprehensive data. Required data encompass Global Climate Model (GCM) data, climate data, weather data, and observational data from Southeast Asia.

Lastly, despite various governmental and public stakeholders in Thailand employing multiple modeling tools, each sector tends to utilize a specific model tailored to its particular application. Notably, the use of an integrated model that facilitates estimations of climate change impacts across sectors is absent. To enhance effectiveness, Thailand is encouraged to adopt an integrated model, enabling comprehensive analysis of climate change impacts spanning various sectors. Such a model can contribute to assessing how impacts from climate change in one sector may subsequently affect another sector. Based on expert opinions gathered in a group meeting, the WRF (ARW) model emerged as the top-ranked candidate model in the integrated model category, addressing the needs of both the agricultural sector and water resource management sector.

Summary

This chapter provides a comprehensive overview of the sustainable technology innovation and the assessment of technology needs. It begins by contextualizing the pressing global need for sustainable development and emphasizes the pivotal role that technological advancement plays in achieving this objective.

The chapter explains methodology and frameworks utilized in conducting technology need assessments, outlining systematic approaches for identifying, prioritizing, and evaluating technological requirements across various sectors. It underscores the significance of stakeholder engagement in this process, advocating for inclusive decision-making and diverse perspectives.

Moreover, the chapter explores Thailand TNA as examples to illustrate the practical applications of technology need assessments, demonstrating their efficacy in informing strategic planning and resource allocation.

Overall, this chapter serves as a valuable resource for understanding the intricate dynamics between sustainable technology innovation and technology need assessment. It equips readers with essential knowledge and tools to navigate the complexities of these processes and to contribute meaningfully to the pursuit of a more sustainable future.

Discussion Questions

What is the significance of sustainable technology innovation in addressing environmental challenges?

How can technology need assessment contribute to the development of sustainable solutions?

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PART III
EMERGING TECHNOLOGIES FOR IMPROVING SUSTAINABILITY PERFORMANCES

CHAPTER 8: SUSTAINABLE PRODUCTS AND SERVICES DESIGN AND DEVELOPMENT

Sustainability or the pursuit of sustainable development is currently a prominent and substantial focus of research. Manufactured goods exert influence on the three key aspects of sustainability—namely, the economy, environment, and society—across their entire life cycle, encompassing stages such as material extraction, manufacturing, transportation, usage, and disposal. Notably, research indicates that approximately 80% of the impacts on sustainability are determined during the product design phase (Ahmad et al., 2018). In the manufacturing sector, tackling this challenge involves recognizing the significance of designing and producing sustainable products as a crucial strategy to attain sustainability goals and promote cleaner production.

Within the framework of the triple-bottom line concept in product design, the primary goals of sustainable product design encompass minimizing a product's resource consumption and environmental emissions, while simultaneously enhancing its socio-economic performance across its entire life cycle, from inception to disposal (Gagnon et al., 2012). This chapter discusses Sustainable and eco-product design, Life cycle assessment eco-design tools, and Circular economy.

8.1 Sustainable and Eco-product Design

Understanding the concept of sustainable product design becomes accessible when we examine the term "design," which is a creative process involving the selection among various possibilities. Design is occasionally perceived merely as a good idea, sketch, or object, but it is, in fact, a comprehensive concept that involves the efficient and effective generation and development of ideas through a systematic process leading to the creation of a product. Traditionally, the typical design process consists of four stages. The initial stage involves planning and defining the problem, followed by conceptual design. In the second stage, the identification of the product's function occurs, alternative concepts are developed, and design specifications are established. The third stage encompasses preliminary design, involving the elaboration and evaluation of alternative concepts, leading to the selection of the most suitable concept. The final stage is detailed design, where the chosen alternative is thoroughly developed, further evaluation and optimization take place, manufacturing and maintenance requirements are identified, and documentation and communication are carried out.

Cooper et al. (2009) enhanced the traditional design process by integrating 'sustainability tasks' throughout all stages of design. The key sustainability tasks include: 1) Identifying and prioritizing sustainability issues to establish a 'sustainability agenda.' 2) Providing sustainability guidance during initial designs using pertinent tools and highlighting trade-offs between sustainability concerns 3) Assessing the design's performance against the sustainability agenda 4) Formulating a strategy for sustainability monitoring.

Sustainable product design involves strategic considerations that highlight the significance of the complete life cycle of a product. This encompasses aspects such as the selection of raw materials, conceptual and structural development, manufacturing processes, product usage, and extends to the product's end-of-life phase, emphasizing reuse and recycling (Gagnon et al., 2012).

Furthermore, both sustainable design and eco-design emphasize the life cycle concept, advocating for products to be designed with consideration for all phases of their life cycle. This perspective can be integrated into product design, particularly in the context of eco-friendly product designs.

8.1.1 Case of plastic packaging eco-design

Nestle

Nestlé is actively increasing the utilization of recycled plastics in its packaging to contribute to the circular economy for plastics. As of the conclusion of 2022, 7.7% of the company's plastic packaging incorporated recycled content, with a targeted increase to nearly 30% by the close of 2025. Notably, Nestlé's waters business in the UK has successfully transitioned its entire Buxton Natural Mineral Water range to 100% recycled PET. The company is dedicated to ensuring that 100% of its packaging is designed to be compatible with recycling systems, and currently, 81.9% of Nestlé's total plastic packaging meets this criterion. Nestlé is committed to achieving a goal of more than 95% of its plastic packaging designed for recycling by the end of 2025 (Nestle, 2023).

Coca Cola

In 2018, The Coca-Cola Company (TCCC) announced its ambition to contribute to a "world without waste" through the launch of a global initiative bearing the same name. This initiative aimed to significantly diminish the environmental footprint of packaging. Subsequently, in January, the Coca-Cola system in Japan affirmed its dedication to the 2030 Packaging Vision, outlining a series of environmental objectives that are in harmony with TCCC's overarching global initiative.

Roadmap to 2030

The specific packaging objectives set for the Coca-Cola system in Japan encompass incorporating sustainable materials, such as recycled PET, in all PET bottles by 2025; aiming to recover a volume of PET bottles equivalent to the products sold in Japan by 2030; and actively collaborating with partners to establish more robust packaging collection and recycling initiatives (Coca-Cola Bottlers Japan Holdings Inc., 2022).

Design Goals:

• Achieve 100% usage of sustainable materials, including recycled PET plastic through "Bottle to Bottle*" and bio-based PET plastic, in all PET bottles for products sold in Japan by 2025.

*In bottle-to-bottle recycling, used PET bottles are collected, processed, and remade into PET bottles for beverage packaging.

• Attain 100% utilization of sustainable materials by 2030, aiming for the complete elimination of packaging dependent on fossil fuels.

• Reduce the amount of PET plastic in each product by 35% by 2030 (compared to 2004) (See Figure 8.1)

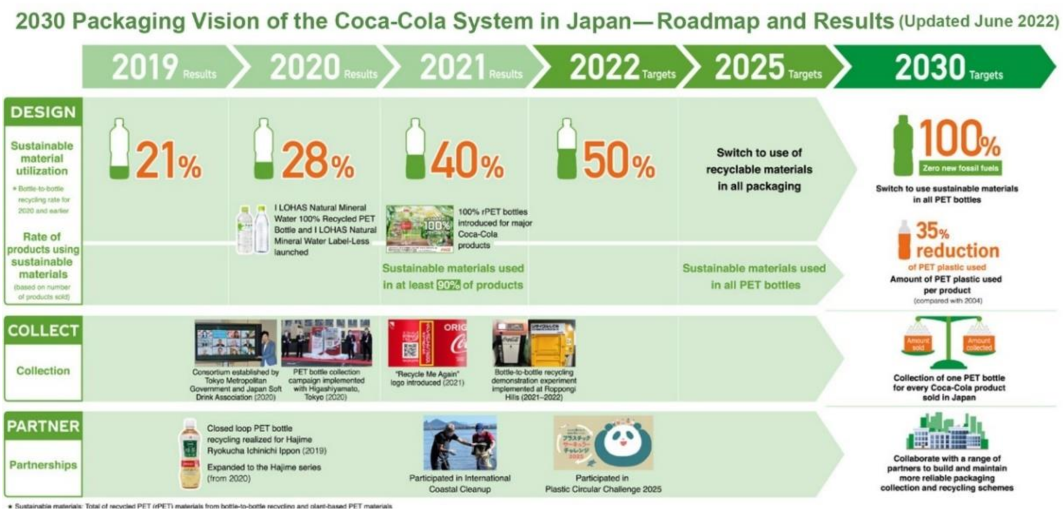

Figure 8.1 2030 Packaging Vision of the Coca-Cola System in Japan
Source: Coca-Cola Bottlers Japan Holdings Inc. (2022)

An illustration of designing products for durability and prolonged use involves the creation of items that endure over time, diminishing the necessity for frequent replacements and, consequently, minimizing environmental impact. The following examples exemplify this approach:

Fairphone: Fairphone is a company specializing in the design of modular smartphones, aiming to extend the device's lifespan. The modular design enables users to effortlessly replace specific components like the battery or camera, eliminating the need to replace the entire phone. This promotes product longevity and contributes to the reduction of electronic waste (Fairphone, 2023).

IKEA's "Buy Back" Initiative: IKEA has introduced a "Buy Back" program that allows customers to return used furniture in exchange for store credit. The returned furniture is subsequently resold or recycled. This program encourages customers to choose furniture with the assurance that it can be returned, reused, or recycled, fostering a circular economy (IKEA, 2023).

8.2 Life Cycle Assessment Eco-design Tools

There exists a wealth of eco-design tools to assist designers at various stages of product development. Design for Environment (DfE) and eco-design are terms often used interchangeably to describe this category of tools. DfE is the preferred term in the United States of America (USA), while eco-design is more commonly used in Europe. Moreover, DfE typically focuses on incorporating environmental considerations for a specific phase of the product life cycle, whereas eco-design extends its scope to encompass the entire product life cycle (Baumann et al., 2002).

Eco-design tools span a spectrum from basic and general forms to intricate, quantitative, and time-intensive instruments. Some of these tools conduct thorough analyses, quantifying sustainability impacts and consequently offering specific and detailed solutions to enhance the overall sustainability performance of a product.

Devanathan et al. (2010) Categorized approximately 30 eco-design tools into three distinct groups: tools based on life cycle assessment (LCA), those relying on checklists, and tools grounded in quality function deployment (QFD).

In eco-design, Life Cycle Assessment (LCA) stands out as the most widely utilized methodology. At the core of eco-design, LCA empowers us to evaluate not only the carbon footprint but also all potential environmental impacts of a system—be it a product, commodity, or service—throughout its entire lifecycle. From raw material extraction for design to end-of-life treatment, our production and consumption choices can profoundly affect the environment and our well-being. Through a comprehensive analysis of material flows at each stage, LCA enables the identification of crucial points, facilitating improvements in the system's environmental performance without compromising or enhancing its service. This standardized approach harmonizes ecological, social, and economic considerations.

LCA furnishes quantitative insights into the environmental footprint of a product throughout its life cycle, spanning from cradle (material extraction and production) to grave (end-of-life), using various environmental indicators. Adopting a systemic life cycle approach, LCA encompasses stages such as raw material extraction, production, distribution, use, and disposal. This method employs a multi-criteria analysis, quantifying both input flows (raw materials, water, energy) and output flows (emissions into air, water, or soil, waste generation) at each stage to assess their impacts comprehensively. For instance, when insulating a building, energy consumption decreases, but the insulation process entails material use, energy, and transportation. The "life cycle" perspective aids in determining solutions with minimal impact while maintaining or enhancing the product's functions. Standardization is ensured through ISO 14040-44 standards, providing a foundation for harmonizing methodologies and evaluating environmental impacts against reference values in LCA (Kong et al., 2022; Pollutec, 2023).

Simplified LCA is a simple and easy way to perform an assessment in less time and with fewer resources and data, but provides uncertain results (Ahmad et al., 2018). There are several softwares that allow to estimate LCA of products and services.

Simapro: Simapro is a widely used software tool for conducting LCA. It helps in modeling and assessing the environmental impacts based on various environmental indicators of products throughout their life cycle. Scenario analysis and sensitivity testing can be estimated.

GaBi: GaBi is another LCA software tool that supports environmental performance assessment and sustainable product development for LCA modeling products and processes.

OpenLCA: OpenLCA is an open-source software for life cycle assessment. It provides a platform for creating and analyzing life cycle models. The software provides flexible modeling capabilities and integration with various databases.

8.3 Circular Economy

Bio-Circular-Green Economic Model (BCG) leverages a whole-of-society strategy, including the government, private sector, academics, and society which have collectively successfully integrated this philosophy into practice. BCG is a combination of the bioeconomy, the circular economy, and the green economy. Bioeconomy is defined as the manufacturing of renewable biological resources and the transformation of these resources into value-added products. Circular economy aims to reuse and recycle resources. Green-economy focuses on balancing the economy, society, and the environment, resulting in sustainable development.

The BCG model is expected to enable Sustainable Development Goals (SDGs) by promoting sustainable agriculture, clean energy, and responsible consumption and production, ensuring biodiversity conservation and sustainable utilization, and preserving the environment and ecosystem (Figure 8.2).

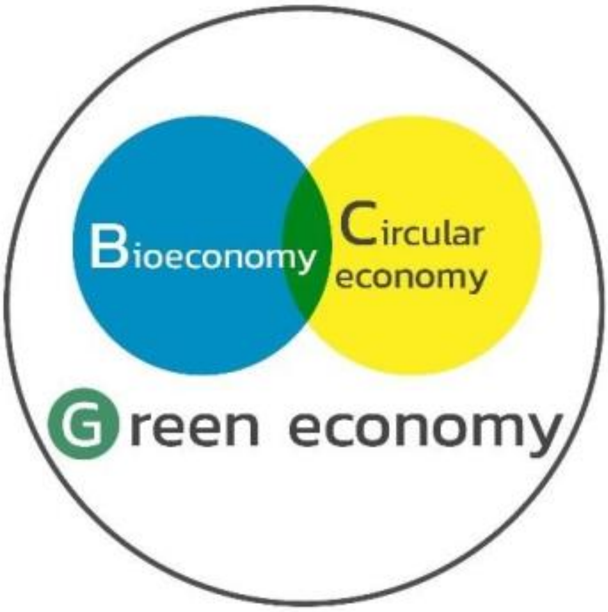

Figure 8.2 The BCG model
Source: National Science and Technology Development Agency (2020)

Circular Economy in Plastics Packaging Trend

Circular economy of plastics packaging in many countries is summarized and showed in Figure 8.3. Figure 8.3 showed the target of plastic packaging policies. The European create a strategy for plastic in circular economy in 2017 and set the target in 2025 that plastic packaging will be recycled at 50% by 2025. In 2020, China starts to launch ban plastic bag policy in major cities and set target that in 2020. Plastic bag is banned in shopping malls, supermarkets, pharmacies, bookstores, and food takeout services. In 2022, Canada announced that they will ban single use plastic [eg. Checkout bags, Cutlery, Foodservice ware, Stir sticks and straws] and Pepsi's European set target to create 100% recyclable in 2022. In 2023, England will ban single use plastic by October 2023. In 2025 many countries have plastics waste circular economy target such as China has target to reduced plastics waste straw by 30%. In USA, 100% 0f 100% of plastic packaging will be reusable, recyclable, compostable by 2025. Coca Cola and nestle will change all packaging to recyclable material. In 2026, China will ban degradable plastic bags. In 2027, Thailand will be 100% recycled plastics waste. In 2030 Malaysia and South Korea will be zero plastics waste country, Vietnam will ban single use plastics bags, Japan will be 60% of recycling rate, EU will have Plastic Packaging recycling at 55% and all P&G packaging will be100% recyclable Material. In 2035, Japan will be 100% effective use of plastics.

The circular economy trend of plastics packaging are widely used in many countries in the world. Countries that do not have policies or laws to save the environment or prevent plastic pollution from plastics packaging will face obstacle of trade to other country. ASEAN countries should study and create more sustainable policies for managing plastic packaging and plastics waste. Circular Economy is one of the solutions that can make countries in ASEAN create laws and policies about plastics (Table 8.1).

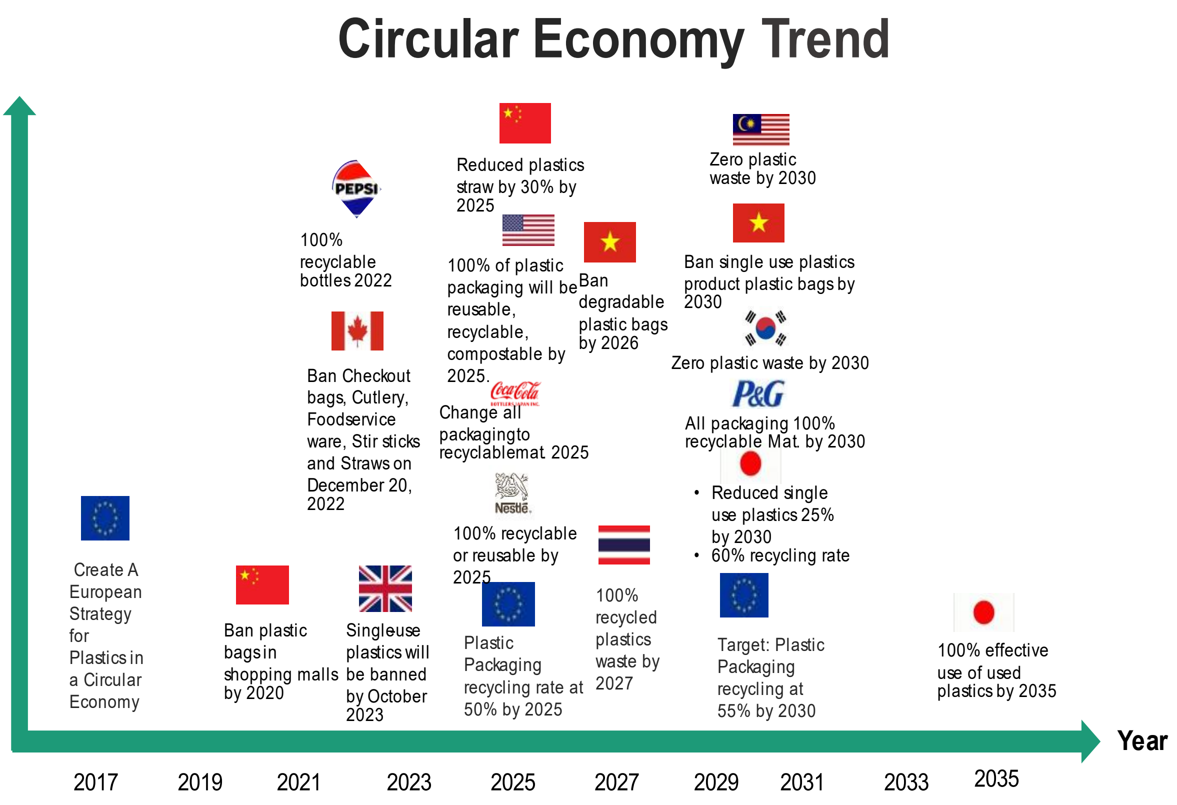

Figure 8.3 Target of plastics circular economy in the global trend

Table 8.1: Summary status quo of CE and plastic choice

	CE	Plastic choice	System
EU	2025: 50% plastic packaging recycling 2030: increase recycling rate to 55%		
The Netherlands	No data		
French	2025: recycle 100% of plastics 2040: phase out single-use plastics		
Italy	2023: plastic packaging tax		
Australia	2025: phase out single-use plastics 2025: all packaging 100% reusable, recyclable, or compostable, 70% of plastic packaging is recycled or composted, 50% of average recycled content is included in the packaging.		
Canada	2030: zero plastic waste		
Japan	2025: reusable and recyclable design for all containers and packaging/products 2030: -25% reduction of single-use plastics and -60% recycling rate of plastic containers and packaging -maximum introduction (2 million tons) of biomass plastics 2035: 100% effective use of used plastics including circular economy measures		
China	No data	Biodegradable plastic	
South Korea	2030: zero plastic waste		EPR system for packaging waste
Cambodia	No data		
Laos	No data		
Myanmar	No data		
Vietnam	No data	Biodegradable plastic	
Thailand	2027: 100% CE of plastic waste	Recyclable plastic	No
India	2022: ban single-use plastics	Biodegradable plastic	

Summary

This chapter provides a detailed exploration of the principles, methodologies, and practices involved in the design and development of sustainable products and services. It begins by outlining the critical importance of sustainability in today's market landscape, emphasizing the need for businesses to adopt environmentally and socially responsible approaches to product and service creation.

This chapter explores pivotal elements guiding sustainable design, including life cycle assessment, eco-design principles, and circular economy principles. It investigates their seamless integration into the design and development phases to mitigate environmental impact, maximize resource efficiency, and augment social value. Additionally, numerous cases are introduced throughout the chapter.

In conclusion, this chapter serves as a comprehensive guide for businesses and practitioners seeking to embrace sustainability in product and service design and development. By integrating sustainability principles into their practices, organizations can create value for both society and the environment while remaining competitive in the marketplace.

Discussion Questions

1. Find example of Eco-design product in your country
2. Draw a life-cycle of a product your are interested
3. What examples are provided to illustrate the impact of regulations on sustainable product development?
4. What role does consumer awareness play in the success of eco-design initiatives?
5. Explain any challenges or trade-offs associated with implementing eco-design practices?

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CHAPTER 9: BIG DATA ANALYTICS

Fundamentally, data constitutes raw facts encompassing numbers, letters, symbols, images, or sounds. Once a dataset undergoes processing, the resultant structured and contextual output is referred to as information. Addressing a common yet challenging question, the disparity between data and information lies in the structured context that imparts meaning to the latter. Notably, information is the outcome of processing multiple data sets, facilitating effective communication. To illustrate, consider the storage of digital data with values like 10, 60, 20, 50, 40. Computer processing of this data to produce a line graph transforms the raw data into information, providing insights into the dataset through visual representation.

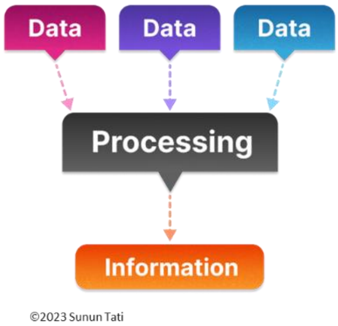

Figure 9.1 Data vs. information

Data:
- Sets of facts or content representing something.
- Can be communicated in various formats: digital, photo/video, sound.
- Different data types: character, Boolean, numeric.
- Source of data depends on the type.

Information:
- Processed data with context and meaning.
- Obtained from raw data through processing and communication.
- Example: digital data processed as a line graph.

Difference between data and information:
- Data is raw, unprocessed facts.
- Information is processed data with meaning and context.

Data structures organize information efficiently for specific purposes. Instead of simply storing individual pieces of data, it creates a structured relationship between them. Imagine collecting people's names: unorganized, it's just a list. But with a data structure like a queue, names are connected, allowing "first in, first out" access like a movie ticketing line. This organized approach makes data readily available and simplifies its use.

Algorithms are a fundamental concept in computer science, providing a systematic approach to problem-solving. They can be broken down into a series of well-defined steps, each of which is executed in a specific order. Algorithms can be used to solve a wide range of problems, from simple tasks like sorting a list of numbers to complex tasks like training a machine learning model. Algorithms play a vital role in our modern world, enabling computers to solve complex problems and perform tasks that would be impossible or impractical for humans to do manually.

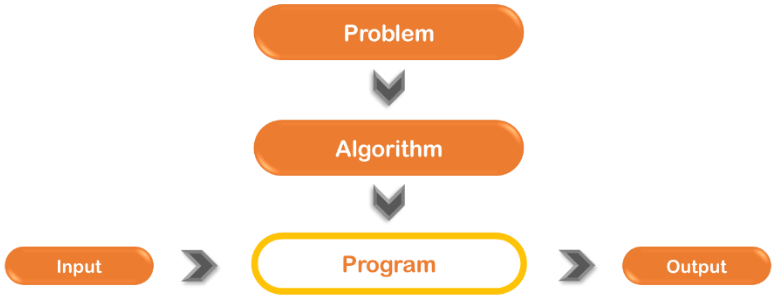

Figure 9.2 Algorithm

9.1 Data Science Workflow

Business Understanding marks the initial and pivotal step in any data-driven project. In this phase, the focus is on comprehensively understanding the problem that needs to be addressed. This involves defining the problem, setting clear goals for the project, and identifying the primary stakeholders or supporters.

- Problem Definition (Find): Clearly define the problem to be solved, including its context, challenges, and potential solutions.
- Goal Clarification/Scope (Goal): Setting clear goals for the project, outlining desired outcomes, specifying the project scope, and determining key performance indicators (KPIs) for success.
- Identifying Stakeholders or Supporters (Get): Understanding the key stakeholders or supporters of the project, including individuals or groups with a vested interest in the project's outcome and those who can provide essential support or resources.

The workflow involves a systematic process to derive meaningful insights and build effective models.

- Selecting the required information, a crucial step where relevant data is identified through concrete questions, defined product goals, and a deep understanding of the business or activity. Subsequently, collecting appropriate information involves gathering comprehensive data from diverse sources like databases, APIs, and open data, ensuring a representative dataset.
- Understanding the information follows, as insights are gained through the exploration of data characteristics, patterns, and potential challenges. Data preparation is integral at this stage to ensure the quality and accuracy of the dataset. The next step, preparing data to build a model, involves cleaning, preprocessing, and organizing the data to make it suitable for model construction, often necessitating the retrieval of additional data or joining datasets based on specific criteria.
- Choosing the most appropriate data analysis method comes next, where the selection of algorithms aligns with the nature of the data and the goals of the analysis. The process proceeds to evaluating the results of model implementation, assessing the model's performance post-deployment. Feedback obtained during this phase is crucial and is used to enhance and refine the model further.
- Embracing an iterative approach, the cycle repeats continuously. This iterative nature ensures ongoing improvements and adaptations to changing requirements, incorporating insights gained from continuous feedback.

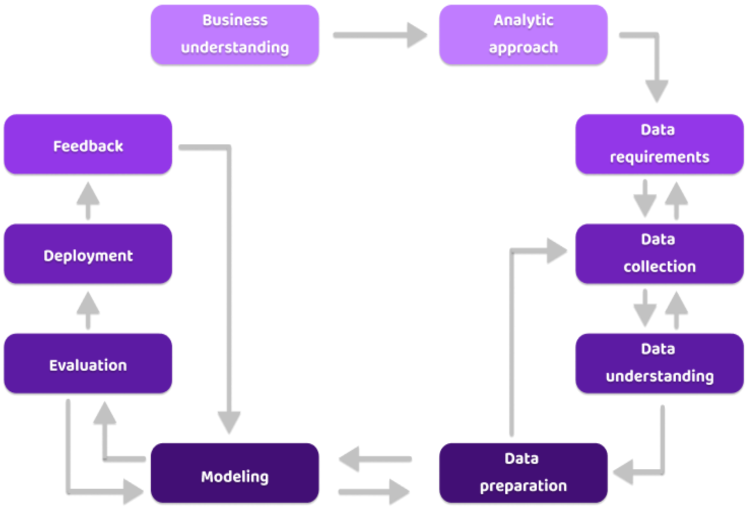

Figure 9.3 Data science workflow

9.2 Data Analytics

Data analytics lies at the heart of this process, transforming raw data into actionable knowledge. This approach employs various techniques and tools, spanning from basic statistical analysis to intricate machine learning algorithms. Data analytics involves employing a variety of methods and approaches aimed at addressing three fundamental questions.

Descriptive Analytics: What has happened? Descriptive analytics focuses on understanding the past performance of an organization or system. This involves analyzing historical data to reveal trends, patterns, and insights. Common techniques include data visualization, dashboards, and reporting.

Predictive Analytics: What will happen? Predictive analytics uses historical data and statistical models to predict future outcomes. This can be used to forecast sales, identify potential risks, and optimize operations. Common techniques include machine learning, deep learning, and regression analysis.

Prescriptive Analytics: What can we do to make _______ happen? Prescriptive analytics goes beyond simply predicting the future by recommending actions to achieve specific goals. This involves using optimization algorithms and simulation models to identify the best courses of action.

Table 9.1 Type of Data Analytics

Type	**Descriptive Analytics**	**Predictive Analytics**	**Prescriptive Analytics**
Focus	Past performance	Future outcomes	Actionable insights
Techniques	Data visualization, dashboards, reporting	Machine learning, deep learning, regression analysis	Optimization algorithms, simulation models
Purpose	Understand what happened	Predict what will happen	Recommend what to do

9.3 The Importance of Data Collection and Preparation

Data collection and preparation are the most important steps in data analysis. They ensure accurate and insightful results. By carefully collecting and preparing data, you eliminate inconsistencies, missing values, and errors that could distort your analysis. In machine learning, quality data is essential for training effective models.

Understanding Data Types

Data can be broadly categorized into two main types: qualitative and quantitative. Each type serves a distinct purpose in research and analysis. Here's a simplified breakdown:

1) **Qualitative Data** provides insights into opinions, experiences, and perceptions.
   - Focus: Words and descriptions
   - Subcategories
     - Nominal: Used for labeling variables, no order or meaning (e.g., plant types: Perennial, Shrub, Herbaceous)
     - Ordinal: Data has order, but exact comparisons are unknown (e.g., survey responses: Strongly Agree / Agree / Disagree / Strongly Disagree)
   - Example: Analyzing interview transcripts or customer reviews
2) **Quantitative Data** allows for statistical analysis, calculations, and predictions.
   - Focus: Numbers and measurements
   - Subcategories:
     - Discrete: Whole numbers, not divisible (e.g., average number of children per family)
     - Continuous: Numbers divisible into smaller units (e.g., height, weight, temperature)
     - Ratio: Has zero as a true reference point, allowing all mathematical operations (e.g., weight)
     - Interval: Has order and known differences, but zero point is arbitrary (e.g., temperature in Fahrenheit)
   - Example: Analyzing survey responses with numerical ratings or temperature measurements

Well-organized and cleaned data.

Data cleaning is an essential step in any data analysis project. It involves identifying and correcting errors, inconsistencies, and missing values in your dataset.

Why Do We Need Data Cleaning?

- Incomplete information: Missing data points can skew your analysis and lead to inaccurate results.
- Incorrect information: Errors such as typos, inconsistencies, and outliers can distort your findings.
- Multiple tables mixed into one: Merged tables may contain duplicate entries or conflicting information.

Common Causes of Data Inconsistency:

Inconsistent Representation of the Same Information

- The same information may be recorded differently in different formats (e.g., "two" vs. 2).
- Inconsistent abbreviations: Different abbreviations may be used for the same word (e.g., "February", "Feb", "Febr").
- Misspellings: Information may be spelled incorrectly or inconsistently (e.g., "color color").
- Varying capitalization: Data may have varying capitalization (e.g., "spring", "Spring").

Outliers and Errors

- Data points that deviate significantly from the norm can distort your results. Cleaning involves investigating and removing outliers or correcting errors.

9.4 Big Data Characteristics

Big data refers to a collection of data gathered from various origins, characterized by its sheer volume and complexity, presenting challenges for conventional processing methodologies. The characteristics of big data, often described by the 3Vs, 5Vs or 6Vs, significantly impact the challenges and opportunities associated with managing and utilizing this vast amount of information.(Balusamy et al., 2021)

Table 9.2 Comparison of Big Data Vs

Characteristic	Gartner 3Vs	IBM 4Vs	Microsoft 6Vs
Volume	/	/	/
Variety	/	/	/
Velocity	/	/	/
Veracity	X	/	/
Variability	X	X	/
Visibility	X	X	/

The table includes the following features:

- Volume: Stands for the scale of data.
- Velocity: Denotes the analysis of streaming data.
- Variety: Indicates different forms of data.
- Veracity: Focuses on trustworthiness of data sources.
- Variability: The number of variables in data sets (refers to the complexity of data set).
- Visibility: Emphasizes that you need to have a full picture of data in order to make informative decisions.

9.5 Unlocking Big Data Insights with Data Visualization

Data visualization involves presenting data in the form of common graphics, such as charts, plots, infographics, and even animations. It serves the purpose of communicating complex data relationships and data-driven insights in a manner that is easily comprehensible. An infographic, defined as a picture or diagram or a group of pictures or diagrams showing or explaining information, is often utilized in this process. The representation of data involves using visual variables like lines, bars, circles, or other elements to construct various chart or graph types based on the data. The presentation of data in visualization is focused on delivering additional meaning, intuitiveness, and depth of insight. It incorporates aspects like color use, interactivity, annotation, and the thoughtful arrangement of all visual elements.

A dashboard integrates charts, graphs, and reports into a unified screen, providing a snapshot overview of data. In comparison to business intelligence (BI) reports, dashboards serve as a means for users to comprehend intricate reports more easily. They are particularly beneficial for stakeholders requiring quick, at-a-glance summaries of performance. On the other hand, BI reports cater to stakeholders seeking more in-depth information and the ability to analyze data comprehensively to reveal insights.

In summary, dashboards offer a concise summary of data using charts, graphs, and reports on a single screen, making them perfect for quick overviews. BI reports provide more detailed information and analysis for deeper insights.

9.6 Case Study

Demand Forecasting and Resource Optimization Through Advanced Analytics by IBM

Every business, whether large, medium, or small, must match supply and demand as efficiently as possible. To ensure efficient production and reduce costs, businesses must accurately predict demand and plan production accordingly. Historical data, forecasts, and real-time analysis are crucial for accurate demand prediction. Firstly, historical data is examined, revealing a decline in sales since

March. Forecasts, based on the past three years' transactions, provide a detailed view of each product. Real-time adjustments to demand forecasts can be made by the marketing team. The production plan is then created to meet the escalating demand, considering default capacity limits. Adjustments to production units and capacity limits are made to prevent inventory shortages. The manufacturing plan is optimized by recalculating based on additional capacity, ensuring positive planned inventories. Crucially, operations planning is linked to the financial plan, reflecting the impact of production changes on the income statement for each scenario. The solution facilitates simulation scenarios for diverse inputs, allowing quick creation, comparison, and evaluation of alternative situations to optimize demand, production, and inventory.

Table 9.2 Roadmap of Demand Forecasting and Production Planning

Step	**Description**
1. Historical Data Analysis	Review past sales data (Dec-past year) by product and region. Identify trends and patterns.
2. Forecast	Generate forecasts based on the past 3 years of data. View forecasts as a summary or drill down for product details.
3. Real-time Adjustments	Marketing edits data for real-time analysis. Product managers adjust production plans.
4. Updated Forecasts	Updated forecasts reflect adjustments and new information.
5. Production Limits	Capacity limits determine allowable production levels. Limits can be adjusted based on potential and maintenance schedules.
6. Manufacturing Plan	Production plan ensures sufficient inventory to meet demand. Initial plan might show potential shortages.
7. Increased Capacity	New shift policy increases production capacity for the first two months.
8. Recalculated Production Plan	Optimization ensures positive planned inventories throughout the period.
9. Financial Plan Integration	Analyze the impact of production changes on income statements. Evaluate revenue and cost changes for profitable growth.
10. Simulation for Different Scenarios	Easily create new situations as test cases. Compare alternatives to assess their impact on demand, production, and inventory.

Data-Driven Fashion: Zara's Success Story

Zara's use of data is a key factor in its success. Zara's operational prowess hinges on its strategic utilization of real-time data gleaned from a vast network of over 6,000 stores spanning 80 countries. The company uses RFID microchips to track inventory and tailor its collections to customer demand. The implementation of RFID microchips plays a pivotal role in this strategy, enabling Zara to meticulously track inventory movement from warehouses to stores. The wealth of real-time data gathered through this process informs Zara's design team and facilitates the allocation of inventory to stores based on immediate demand. What distinguishes Zara is its unique strategy of tailoring collections to specific zip codes and demographics, ensuring a personalized shopping experience for customers. This localized customization has become a key driver of Zara's success, emphasizing its commitment to meeting customer demands with precision.

Zara's dedication to diversity is apparent in its remarkable annual production of over 11,000 distinct items. The brand's competitive advantage lies in its unique data-driven approach, setting it apart in the fast fashion industry and contributing significantly to its outstanding success. The seamless integration of real-time data into Zara's operations not only keeps the brand abreast of industry trends but also positions it as a trendsetter. This underscores the transformative influence of leveraging data in the dynamic landscape of fashion retail.

Summary

In summary, the distinction between data and information lies in the processing that transforms raw facts into meaningful, contextualized insights. The data science workflow, comprising business understanding, data collection, model building, evaluation, and iteration, is essential for deriving meaningful insights and building effective models. Data analytics plays a pivotal role in transforming raw data into actionable knowledge, with descriptive analytics focusing on past performance, predictive analytics foreseeing future outcomes, and prescriptive analytics recommending specific actions. Data collection and preparation, involving cleaning and addressing two main data types (qualitative and quantitative), ensure accurate and insightful results. Big data's characteristics pose both challenges and opportunities for managing vast amounts of information. Data visualization is crucial for conveying complex relationships, with common types including charts, graphs, infographics, and dashboards. Case studies, such as Zara's success story and demand forecasting, exemplify the power of data science across various industries. Ethical considerations in data collection and analysis, especially regarding privacy and security, must be addressed.

Discussion Questions

1. Discuss the differences between descriptive, predictive, and prescriptive analytics.
2. How can data analytics be used to inform decision-making and solve complex problems?
3. How can businesses leverage big data to gain a competitive advantage?
4. How can data visualization be used to effectively communicate complex information to non-technical audiences?
5. Analyze the case studies of demand forecasting and Zara's success story. What are the key takeaways from each case study?

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CHAPTER 10: ARTIFICIAL INTELLIGENCE (AI)

In the process of data-driven decision-making (Marr, 2015), a systematic approach to data management is imperative. Beginning with data collection, the objective is to amass relevant and comprehensive data that directly addresses the defined problem and aligns with the project goals. This involves sourcing data from diverse channels, including databases, APIs, and open data, ensuring a representative dataset. Moving forward, the focus shifts to data preparation, where the emphasis lies in guaranteeing the quality and accuracy of the data to establish a reliable foundation for AI models. This step involves meticulous cleaning, preprocessing, and organization, addressing any discrepancies or missing values. Subsequently, in the visualization and pattern recognition phase, the goal is to gain valuable insights by exploring the characteristics, patterns, and potential challenges within the data. Employing data visualization techniques becomes crucial in uncovering trends, correlations, and the underlying structure of the data.

Figure 10.1 The process of data-driven decision-making
Source: Marr (2015)

The final stage involves generating new information with AI, wherein machine learning and other AI techniques are applied to analyze the data and derive meaningful insights or predictions. This may include training models for predictive analytics, classification, or clustering, all tailored to meet the specific objectives of the project. Artificial intelligence (AI) is the science and engineering behind the creation of intelligent machines, particularly intelligent computer programs, according to John McCarthy's 2004 definition. It involves utilizing computers to understand human intelligence without being limited to biologically observable methods. Its development focuses on creating computer systems or software that can perform tasks typically requiring human intelligence. This encompasses the simulation of cognitive functions such as learning, reasoning, problem-solving, perception, and language understanding in machines.(Gupta & Mangla, 2020; Kristensen, 2021)

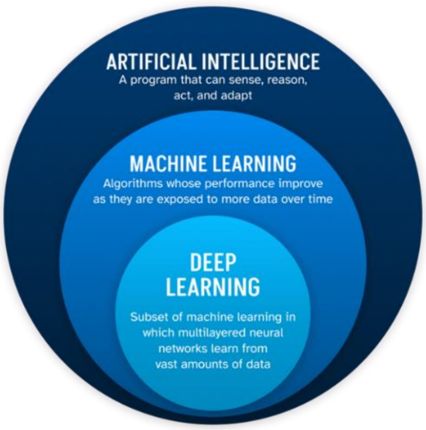

Figure 10.2 Artificial intelligence Structure
Source: Oracle Poland (2019).

10.1 Machine Learning vs. Deep Learning

Machine learning (Randolph, 2021) is a process by which computers autonomously recognize patterns and make decisions without explicit programming. Learning from vast datasets, including images, videos, audio, or text, ML develops the ability to recognize patterns and make predictions based on its learned experiences. The effectiveness of ML is contingent on the quality and diversity of the data used for training. The risk of bias arises when the training data favors certain attributes, potentially resulting in inaccurate predictions, especially if the data collection process is not diverse and inclusive. Those working with ML need to be mindful of potential biases in the training data, as these biases can lead to skewed predictions. The quality of the training data essentially shapes the algorithm's performance, highlighting the pivotal role of responsible data selection in ML development.

Deep learning, as a subset of machine learning, distinguishes itself by its reliance on large amounts of training data for predictions. Unlike traditional machine learning, deep learning autonomously learns high-level features from data and creates new features without user intervention. The learning approach in deep learning is characterized by an end-to-end resolution of problems, emphasizing a holistic and comprehensive understanding of the underlying data patterns.

Table 10.1 Comparison of Machine Learning and Deep Learning

	Machine Learning	**Deep Learning**
Definition	Process where computers autonomously recognize patterns and make decisions without explicit programming	Subset of machine learning that utilizes large amounts of data for predictions
Data Requirements	Relatively smaller datasets	Large amounts of data
Learning Approach	Requires feature engineering	Learns high-level features and creates new features autonomously
Problem Resolution	Focuses on specific aspects of the problem	Emphasizes an end-to-end solution with a comprehensive understanding of underlying data patterns
Examples	Regression algorithms, decision trees, support vector machines	Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs)

10.2 Case Study

AI-Powered Route Optimization

Telematics technologies, such as GPS tracking and sensors, were integrated into delivery trucks, laying the foundation for the development of mobile applications. This system relies on real-time data collection to optimize route instructions through a dynamic algorithm. The algorithm updates directions for drivers in real-time, enhancing navigation based on changing factors. The routing system, built upon the static route provided to drivers in the morning, continually updates directions during their deliveries. This real-time adaptation is crucial for addressing changing conditions and commitments.

The Dynamic Optimization system is particularly focused on providing accurate delivery time estimates, contributing to a more precise and reliable service for customers. The detailed turn-by-turn directions provided by the routing system guide drivers not only to addresses but also to specific package drop-off and pickup locations, including concealed spots like loading docks. This approach enhances driver efficiency by improving daily commitment management and responsiveness to rapidly changing customer needs.

Table 10.2 Features of the Dynamic Optimization Delivery Routing System

Feature	Description
Telematics Integration	Integration of telematics technologies like GPS tracking and sensors into delivery trucks for real-time data collection.
Dynamic Algorithm	Utilization of a dynamic algorithm to optimize route instructions based on real-time data, considering changing factors and commitments.
Real-time Route Updates	Continuous updates to route directions throughout the day, adapting to changing conditions and ensuring accurate delivery time estimates.
Turn-by-turn Directions	Provision of detailed turn-by-turn directions, including specific package drop-off and pickup locations.
Enhanced Driver Efficiency	Improvement in daily commitment management and responsiveness to customer needs through optimized routing.

Summary

A systematic approach to data management is crucial for effective data-driven decision-making. The process involves data collection, preparation, visualization and pattern recognition, and generating new information with AI. AI techniques, such as machine learning and deep learning, are used to analyze data and derive meaningful insights or predictions. AI focuses on creating intelligent machines that can simulate human intelligence. Machine learning is a subset of AI where computers autonomously learn from data and make predictions. Deep learning is a subfield of machine learning that utilizes large amounts of data for predictions and autonomously learns high-level features. The effectiveness of AI models relies heavily on the quality and diversity of the data used for training. AI technologies have diverse applications across various industries, including logistics, healthcare, and finance.

Discussion Questions

1. Discuss the importance of data quality and data governance in ensuring reliable and unbiased outcomes from AI models.
2. Discuss the potential applications of AI in other industries beyond logistics, such as healthcare, finance, and education.
3. Consider the role of government regulation in shaping the development and deployment of AI technologies.

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CHAPTER 11: ROBOTICS AND INTERNET OF THINGS (IOT)

Mechanization and automation (Radziwill & Knovel, 2020) have been replacing manual labor since the onset of the first industrial revolution. The key distinction between manual labor and automation lies in the method and extent of human involvement in performing tasks. While manual labor relies on the active participation of human workers, automation seeks to replace or augment human involvement with technological solutions. Mechanization, as a form of automation, introduces machinery to assist in physical tasks but still requires human input for cognitive and sensory aspects of the work. Complete automation, on the other hand, envisions processes that can be accomplished without direct human intervention, representing a shift toward greater technological autonomy in performing tasks.

11.1 Robotics

A robot is delineated as a structural entity endowed with the capacity to execute diverse tasks utilizing tools or objects, including manipulation at its extremities. Its salient attribute lies in its programmability, enabling adaptation for a myriad of operational functions.(Durrant-Whyte et al., 2012). In the industrial sector, traditional robots are recognized for manipulator arms dedicated to repetitive tasks. Robotic structures now possess intellectual capabilities, particularly in decision-making and memory of past experiences, through the application of artificial intelligence and expert systems. However, many existing industrial robots lack such intelligent features, as their control units efficiently execute assigned tasks in industrial settings. The control systems used in robots fall into categories like units with pneumatic logic, PLC (Programmable Logic Controller) units, electro-mechanical sequencer units with end-stroke stops, electronic units with logic, minicomputers, computers, and microprocessors.(Gacovski, 2020)

Table 11.1 Type of Robot

Type of Robot	**Purpose**	**Characteristics**
Industrial Robots	Designed for specific industrial tasks	Typically operate in controlled environments, often fixed in place, perform repetitive tasks with high precision and accuracy
Service Robots	Perform tasks that are useful to humans	Can operate autonomously or with human guidance, often found in public spaces or homes
Field Robots	Operate in complex and unstructured environments, often outdoors or in remote locations	Designed to be robust and adaptable to handle challenging conditions

Overall, robots are becoming increasingly sophisticated and are being used in a wider range of applications.

Industrial robots

Industrial robots are advanced machines that are used to carry out a variety of tasks in manufacturing and industrial environments. These robots are equipped with cutting-edge sensors, control systems, and mechanical components, enabling them to automate processes, boost efficiency, and improve overall productivity across a wide range of industries. (Elangovan, 2019)

Table 11.2 Types of Industrial Robots

Subtype	Purpose	Examples
Assembly Line Robots	Assemble components, weld, and paint on production lines	Automotive robots, electronics manufacturing robots
Material Handling Robots	Handle and transport materials within manufacturing facilities	Robots used for picking and placing parts in warehouses
Inspection Robots	Perform quality control and inspection tasks, using sensors and cameras to detect defects in products	Robots used for inspecting welds on pipelines
Collaborative Robots (Cobots)	Work alongside human workers, performing tasks that may be hazardous or repetitive for humans	Robots used to assist in assembly tasks in automotive manufacturing

Service robots

Service robots are a type of robot designed to carry out tasks and provide assistance in various environments outside of manufacturing and industrial settings.

Table 11.3 Service Robots

Subtype	Purpose	Examples
Domestic Robots	Perform household tasks such as vacuuming, cleaning floors, and mowing lawns	Vacuuming robots, lawnmowers, and robots that can assist with laundry and meal preparation
Healthcare Robots	Provide assistance in hospitals, clinics, and rehabilitation centers	Robots used to dispense medication, assist with patient care, and provide companionship
Logistics and Delivery Robots	Handle goods and materials in warehouses, distribution centers, and delivery services	Robots used for sorting, packing, and transporting goods in warehouses
Educational Robots	Engage students in learning and provide personalized instruction	Robots used to teach coding, math, and other subjects
Entertainment Robots	Designed for entertainment and companionship	Companion robots, robots used for gaming, and robots that can perform tricks

Field robots

Field robots, designed to execute military and exploratory missions, are constructed with resilient materials to endure harsh environments.

Table 11.4 Field Robots

Subtype	Purpose	Examples
Construction Robots	Assist in construction tasks, such as bricklaying, painting, and demolition	Robots used for bricklaying, painting, and demolition work
Agricultural Robots	Perform tasks in agriculture, such as planting, harvesting, and weeding	Robots used for planting seeds, harvesting crops, and weeding fields
Exploration Robots	Used for scientific research and exploration, often in hazardous or inaccessible environments	Robots used to explore the ocean floor, mars rovers, and robots used to map underground tunnels
Military Robots	Used for military purposes, including surveillance, reconnaissance, and combat operations	Drones, robots used for mine detection, and robots used for explosive ordnance disposal
Rescue Robots	Used in search and rescue operations, assisting in locating and rescuing people in disaster zones or other dangerous environments	Robots used to locate survivors in collapsed buildings and robots used to rescue people from floods and other natural disasters

11.2 Internet of Things (IoT)

The term Internet of Things (IoT) refers to a network of physical objects, encompassing devices, vehicles, buildings, and various items. These objects are equipped with sensors, software, and other technologies, enabling them to establish connections and exchange data with other devices and systems through the internet or other communication networks.

Key Aspects of the Internet of Things:

- Connectivity: Devices are linked to the internet, facilitating communication between themselves and other systems.
- Sensors and Data Collection: Devices gather data related to their environment and functioning, providing valuable insights.
- Interoperability: Devices possess the capability to communicate and interact with each other, irrespective of the manufacturer or technology involved.
- Automation: Devices can execute tasks automatically, enhancing efficiency and reducing the need for human intervention.
- Analytics: Data acquired from these devices can undergo analysis, offering insights and contributing to improved decision-making processes.

Internet of things (IoT) example

- RFID utilizes radio waves for object identification and is used in asset tracking, inventory management, etc.
- GPS provides location and time information using satellites and is used for navigation, tracking, and mapping.
- NFC enables contactless communication between devices and is used for payments, access control, data exchange, etc.

11.3 Case Study

Integrating IoT into Bus Information Systems

As illustrated below, the integration of IoT into the Bus Information System (BIS) revolutionizes public transportation. A Bus Information System (BIS) with IoT and a cloud data center is a modern solution for enhancing bus transportation. It involves placing IoT devices on buses to collect real-time data on location, passenger load, and more. This data is transmitted to a cloud data center, enabling real-time processing and analysis.

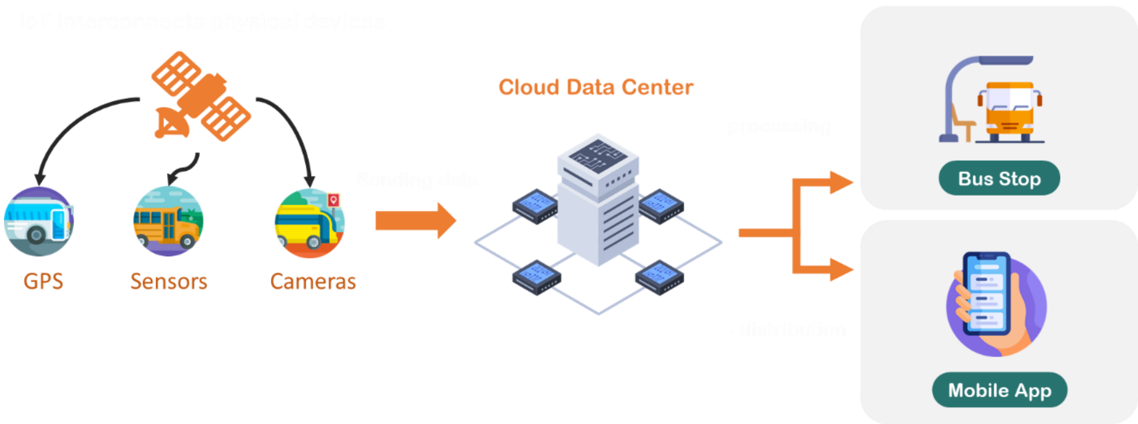

Figure 11.1 Bus Information System

Summary

Mechanization and automation have steadily replaced human labor since the Industrial Revolution. Where manual labor relies on human effort, automation seeks to replace or augment it with technology. Mechanization, a form of automation, utilizes machinery for physical tasks while still requiring human input for cognitive aspects. Complete automation aims for processes to run without direct human intervention, signifying a shift towards greater technological autonomy.

Robotics takes automation a step further, introducing robots capable of diverse tasks. These robots possess programmability and adaptability, enabling their use in various fields. Industrial robots excel at repetitive tasks in controlled environments, while service robots assist humans in everyday life. Field robots, designed for harsher environments, perform tasks like construction, agriculture, and exploration.

The Internet of Things (IoT) further amplifies automation by connecting physical objects to the internet. These objects collect and exchange data, leading to innovative applications like asset tracking, navigation, and contactless payments. Integrating IoT into systems like Bus Information Systems demonstrates its potential to improve efficiency and enhance public services.

In conclusion, automation and robotics are transforming industries, replacing manual labor and leading to innovative applications. The integration of IoT further expands the possibilities, connecting objects and enabling them to exchange data for improved efficiency and functionality across diverse sectors.

Discussion Questions

1. How are robots being used to solve real-world problems in various industries?
2. What are the potential challenges and risks associated with the widespread adoption of IoT?
3. The case study on integrating IoT into Bus Information Systems highlights the potential improvements in public transportation. What are the key advantages and considerations when implementing IoT in public service systems?
4. How do you envision the future of automation, robotics, and IoT in shaping various industries, and what challenges might arise as these technologies become more prevalent?
5. Considering the transformative impact of automation and IoT, how can policymakers and industries work together to ensure responsible and ethical deployment of these technologies?

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CHAPTER 12: BLOCKCHAIN TECHNOLOGY

In a centralized system, a singular entity or organization holds complete control over the network, making it more efficient and scalable. However, this centralized structure poses challenges to security and resilience, as it is susceptible to single points of failure and manipulation by the central authority. Conversely, in a decentralized system, no single entity governs the network, rendering it more secure and resilient. Despite these advantages, decentralized systems can be less efficient and scalable, demanding consensus among participants before transactions can be confirmed. In a distributed system, data and processing are dispersed across multiple nodes, ensuring the highest level of security and resilience. However, this increased security comes at the expense of efficiency and scalability, as coordination among all nodes is essential to maintain consensus.

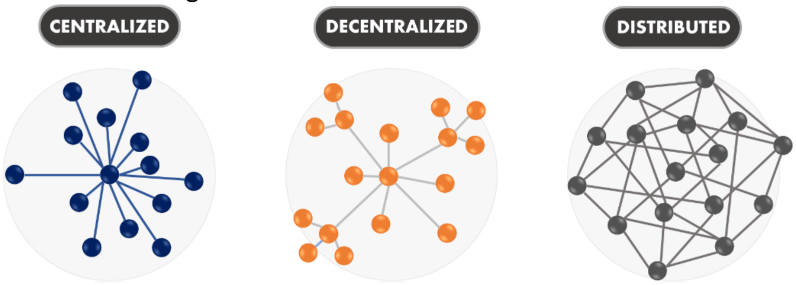

Figure 12.1 The differences between centralized, decentralized, and distributed systems

12.1 Blockchain Architecture

Blockchain technology is most associated with decentralized and distributed architectures, which provide features like decentralization, transparency, and immutability.(Bashir, 2018) Decentralized blockchains, like Bitcoin and Ethereum, distribute control among multiple participants, making them more secure and resilient than centralized systems. Distributed ledger technology (DLT), a type of blockchain, spreads data across multiple nodes, further enhancing security and resilience. Consensus mechanisms ensure agreement on the state of the ledger.

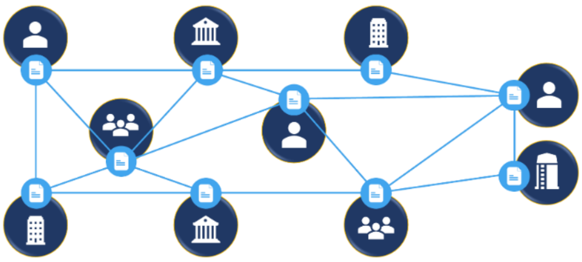

Figure 12.2 Distributed Ledger Technology

A block is a fundamental building block of a blockchain, containing transactions, the hash of the previous block, a timestamp, and nonce. Hash functions play a crucial role in securing ownership information within the blockchain. It transforms any data into a fixed-length numerical representation, creating a unique and consistent digital fingerprint for each distinct set of information. The uniqueness and consistency of hash values for each transaction contribute to maintaining data integrity and preventing unauthorized modifications. The application of these functions fortifies the integrity and confidentiality of data, serving as an integral component in safeguarding against unauthorized access and ensuring the robustness of ownership protection mechanisms.

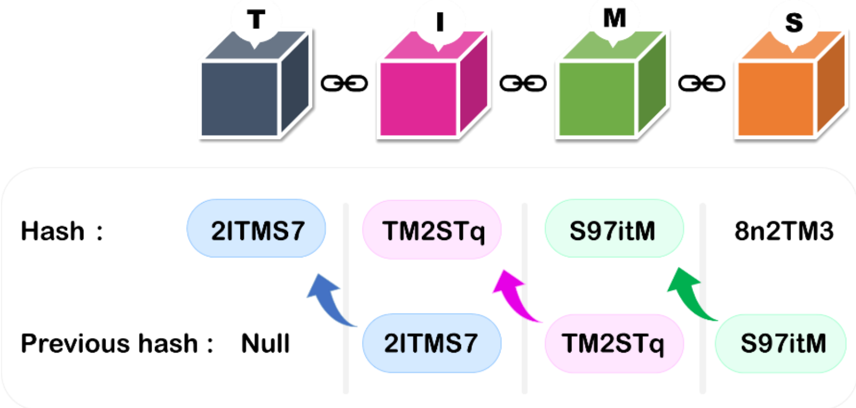

Figure 12.3 The role of hash functions in securing ownership information within a blockchain

Blockchain technology harbors transformative potential across diverse industries. Blockchain can be used to create smart contracts, authorize transactions, and trace the origin and movement of goods.

12.2 Smart Contracts

Smart contracts are essentially programs housed on a blockchain, and they execute when specific predetermined conditions are satisfied. It provides a transparent, secure, and efficient way to document and transfer ownership of assets.(Richard Ma, 2019)

Authorizing transactions is a critical process that involves confirming the identity of the transaction initiator and expressing their agreement with the content of a document, thereby granting authorization for its execution. Authorizing transactions involves confirming the identity of the transaction initiator and expressing their agreement with the content of a document. Handwritten signatures were traditionally used to authorize transactions, but digital signatures are now the standard. Digital signatures uniquely identify the author and express their agreement with the document's content.

In the context of blockchain, digital signatures are cryptographic hash values of transaction data encrypted with the private key of the account transferring ownership. This evolution underscores the secure and traceable nature of transaction authorization in blockchain technology.

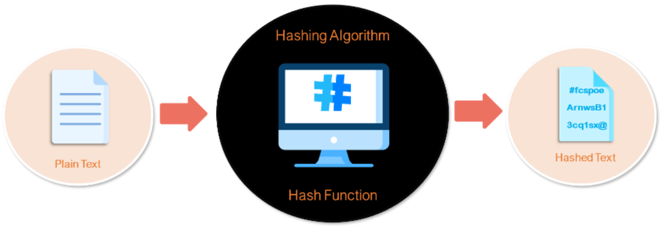

Figure 12.4 Hashing: an ownership verification mechanism

12.3 Supply Chain Traceability

Traceability is a key feature of blockchain technology that allows for the tracking of the origin, movement, or location of something. Traceability in blockchain-based systems is more comprehensive than traditional ledger-based systems because it captures transaction-level data, including information flows (state of products or actors), inventory flows (transfer of ownership/custodianship of products), and financial flows (transfer of cash or liquid assets).(Calum Handforth et al., 2021; Ellahi et al., 2023)

Case Study: Walmart

Walmart, a prominent leader in adopting Blockchain technology, strategically addressed challenges in food traceability. Recognizing the vital need for transparency in the food supply chain, Walmart partnered with IBM to create a food traceability system based on Hyperledger Fabric. This system allowed Walmart to trace products within seconds, revolutionizing the speed and accuracy of information retrieval. The company collaborated with various stakeholders, including JD, IBM, and Tsinghua University, to build a Blockchain ledger, ensuring the movement of pork in its Chinese supply chain was transparent and secure. Walmart's pioneering initiatives, such as the Walmart Food Safety and Collaboration Center, underscore its commitment to leveraging Blockchain for enhancing food traceability, a critical aspect of the food industry.

12.4 Smart Government

Blockchain technology's transformative potential for governments lies in its ability to address several key challenges and enable a more efficient, secure, and transparent system. By reducing fraud and corruption, improving procurement processes, automating tasks, facilitating secure data sharing, and streamlining transactions and asset management, blockchain can help governments save money, improve service quality, and build trust with citizens.

Case Study: Dubai Blockchain Strategy

The Dubai Blockchain Strategy embraces blockchain technology as a revolutionary force shaping the future of the Internet. It highlights the simplicity, security, and reliability of blockchain-based transactions, making it a cornerstone for a streamlined and efficient city experience. This transformative strategy contributes to Dubai's vision of becoming the world's happiest city. It envisions a surge in economic opportunities and digital advancements that will positively impact all sectors of the city. Dubai aims to solidify its position as a global technology leader by becoming the first blockchain-powered government. This pioneering move will pave the way for other cities to adopt this transformative technology, fostering entrepreneurship and propelling global competitiveness.

- Government Efficiency: To save 5.5 billion dirhams annually in document processing alone.
- Industry Creation: To create a new industry around blockchain technology.
- International Leadership: To become the first blockchain-powered government and drive the future economy.

12.5 Healthcare

Blockchain can be used to store patient records, track the movement of pharmaceuticals, and automate tasks, such as processing insurance claims. This can lead to improved patient outcomes, reduced costs, and increased efficiency.(Ghosh et al., 2023)

Table 12.1 Blockchain Applications in Healthcare (Healthcare Engineering, 2023)

Objective	Description
Patient Management	enables researchers to analyze patient data on a large scale using secure and verified access, leading to improved patient group management.
Pharmaceutical Delivery	empowers pharmaceutical firms to gather real-time data, facilitating the precise delivery of prescription drugs and services.
Patient Data Storage and Sharing	ensures secure and transparent storage of patient details, enabling healthcare providers to easily verify and access patient data generated throughout different clinical study phases.
Transaction Validation	validates transactions, ensuring authenticity and preventing unauthorized access, promoting safety and transparency in healthcare operations.
Patient Monitoring	enables timely access to medical equipment, remote patient monitoring, and enhanced supply chain traceability, improving overall safety and patient care.
Health Record-keeping	excels in health record-keeping, offering functionalities such as secure data sharing, electronic health record management, and administrative task automation.

Overall, blockchain technology has the potential to transform the healthcare industry by making it more efficient, secure, and patient-centered.

Summary

Blockchain technology has the potential to revolutionize diverse industries by offering increased security, transparency, and efficiency. It utilizes decentralized and distributed architecture for features like immutability, while smart contracts enable secure and efficient ownership transfers. Digital signatures ensure secure transaction authorization, and blockchain offers comprehensive tracking of goods for improved supply chain traceability. Case studies like Walmart and Dubai demonstrate the potential of blockchain for food traceability, government efficiency, and international leadership. In the healthcare industry, blockchain can be used for patient records, pharmaceutical delivery, automation, and improved outcomes. Overall, blockchain technology possesses the potential to transform the world by fostering a more efficient, secure, and transparent future.

Discussion Questions

1. Discuss the advantages and disadvantages of centralized, decentralized, and distributed systems.
2. What role do hash functions play in securing ownership information within a blockchain, and how do they contribute to data integrity and prevention of unauthorized modifications?
3. How do these case studies demonstrate the potential of blockchain technology?

4. Consider the applications of blockchain technology in various industries, as discussed in the chapter. How can blockchain address specific challenges and contribute to increased efficiency, security, and transparency?

5. Explore the concept of "smart government" enabled by blockchain. In what ways can blockchain help governments reduce fraud, improve procurement processes, and build trust with citizens?

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CHAPTER 13: DIGITAL TWINS TECHNOLOGY

Digital Twins are virtual counterparts of physical entities, processes, or systems, synthesized through the amalgamation of real-time data, sensors, and diverse information sources. It offers solutions to real-world challenges and augments operational efficiency through virtual simulations. Due to the intricate nature of digital twin technology, systematic step-by-step implementation is imperative, encompassing components like machine learning algorithms, data analytics, and advanced visualization. (Fuller et al., 2020)

Layer 1 – Digital Virtualization (Mirroring):

At this initial stage, the focus is on the digital representation and objectification process of components constituting the real world. This involves duplicating a physical object into a digital twin, creating a mirrored digital counterpart.

Layer 2 – Digital Twin Synchronization (Monitoring):

Advancing to the second layer, the emphasis is on real-time mutual synchronization between real-world and virtual-world components. This synchronization includes both static elements, such as things and space, and dynamic elements, encompassing behavior, processes, and predictions. This stage aligns with the monitoring and control of the physical object based on the analysis of the digital twin.

Layer 3 – Modeling and Simulation (Modeling and Simulation):

Moving to the third layer, the focus shifts to analyzing and predicting the real world through the simulation of changes in virtual twin objects in response to conditional changes. This stage corresponds to optimizing the physical object through the simulation results of the digital twin.

Layer 4 – Federated Digital Twin (Federation):

Advancing further, the fourth layer introduces the concept of federated digital twins. This involves configuring federated digital twins, optimizing complex physical objects, and inter-operating federated digital twins with complex physical objects.

Layer 5 – Intelligent Digital Twin Services (Autonomous):

The final layer encompasses managing the digital twin service lifecycle based on intelligent and autonomous technologies and related platforms. This stage corresponds to autonomously recognizing and solving problems in federated digital twins and optimizing physical objects according to the federated digital twin solution.

A digital twin stands as a virtual representation of an object or system throughout its lifecycle, continually updated through real-time data. Its unique capabilities leverage simulation, machine learning, and reasoning to enhance decision-making processes.

Table 13.1 Difference between Digital Twins and Simulation Models

Feature	Digital Twin	Simulation
Purpose	In-depth study of complex systems	Analyze specific processes
Scope	Multiple processes	Single process
Data Flow	Two-way (real-time)	One-way (pre-defined)
Complexity & Cost	High	Lower
Integration with Physical World	Essential	Optional
Applications	Product development, process optimization, predictive maintenance	Training, testing, design optimization

13.1 Types of Digital Twins

Digital twins are broadly categorized into two main types. Observer Digital Twins closely monitors and understands the operations of physical objects and systems. Their primary application lies in efficient asset management, offering real-time insights into the current state of the corresponding physical entities. This type of digital twin is commonly employed in various industries, with notable examples being wind turbines, jet engines, and generators within manufacturing facilities.

On the other hand, Virtual Digital Twins are designed for the creation and testing of new elements before their physical counterparts are produced. This category finds applications in the development of intricate systems such as aircraft, rotating machinery, automobiles, and integrated circuits. Virtual Digital Twins allow for thorough testing and analysis in a simulated environment, facilitating refinement and optimization before actual implementation. (Jeong et al., 2022)

Digital twins exhibit varying characteristics depending on the level of product magnification, allowing different types to seamlessly coexist within a single system or process. The diversity in these twins is highlighted through categories such as Component Twins or Parts Twins, which serve as the foundational units representing the smallest operational components. Parallelly, Asset Twins come into play when two or more components collaborate, forming an asset and enabling the study of their interactions. At a higher level of magnification, System or Unit Twins provide insights into the amalgamation of diverse assets, forming an entire functioning system. Notably, these twins offer visibility into asset interactions and may suggest enhancements for improved performance. Lastly, the macro level is embodied by Process Twins, revealing the intricate collaboration of systems to establish an entire production facility. Their role extends to determining synchronization and timing schemes crucial for overall operational efficiency. The flexibility for different types of digital twins to coexist underscores their adaptability within dynamic systems and processes. (IBM, 2022)

Table 13.2 Types of Digital Twins

Type	Description
Component/Parts Twins	• Component twins are the basic units of digital twins, representing the smallest functioning components. • Parts twins are similar but refer to components of slightly less importance
Asset Twins	• When two or more components work together, they form an asset. • Asset twins allow the study of component interactions, generating performance data for actionable insights.
System/Unit Twins	• System or unit twins involve a higher level of magnification, showing how different assets come together to form an entire functioning system. • They provide visibility into asset interactions and may suggest performance enhancements.
Process Twins	• Process twins, at the macro level, reveal how systems collaborate to create an entire production facility. • They help determine synchronization and timing schemes that impact overall efficiency.

The application of digital twins is not universally suitable for every manufacturer or product. The need for the continuous flow of sensor data, a fundamental requirement for digital twins, is not warranted for every object, and the substantial resources required for their creation may not always be justified from a financial standpoint. Notably, the creation of a digital twin, being an exact replica of a physical object, can incur significant costs.

Limitations

- Not suitable for every manufacturer or product due to:
  - Cost involved in creating and maintaining a digital twin.
  - Need for continuous sensor data, which may not be practical for all objects.
- Complex and expensive to create a high-fidelity replica.

Benefits:

- Valuable for large-scale, complex projects or products, such as:
  - Buildings and bridges (structural integrity)
  - Jet turbines, automobiles, aircraft (complex machinery)
  - Power generation and transmission equipment
  - Manufacturing with co-functioning machine systems
- Streamlines processes and improves efficiency.

Industries engaged in large-scale products or projects witness the greatest success with digital twins. This includes sectors such as engineering (systems), automobile manufacturing, aircraft production, railcar design, building construction, manufacturing, and power utilities. The digital twin market is poised for substantial growth, reflecting the increasing demand across various industries. In 2022, the global digital twins market was projected to reach USD 73.5 billion by 2027, indicating a significant and sustained expansion in the utilization of digital twins. (IBM, 2022)

13.2 Case Study

The Digital Twin of a City has emerged as a revolutionary framework for effective urban management. These digital replicas operate in real-time harmony with urban infrastructure, drawing insights from a diverse array of data sources, such as traffic information, environment parameters, open-source data. From an array of data sources, simulation of transportation network digital twin, infrastructure digital twin, and ecology digital twin takes place.(Lehtola et al., 2022)

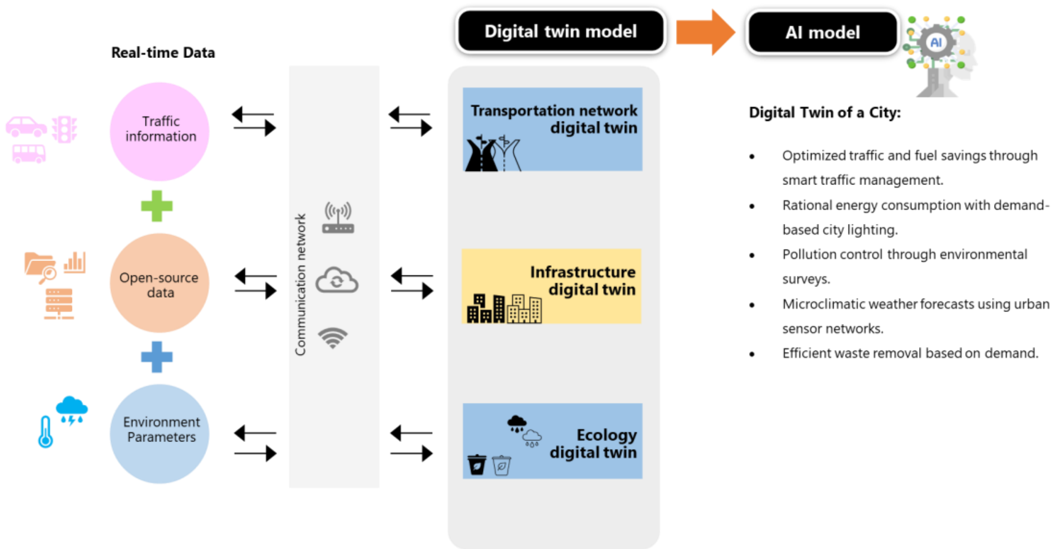

Figure 13.1 The Digital Twin of a City

One success story that exemplifies the power and potential of digital twins is the case study of Takamatsu City in Japan. The City in Japan has implemented digital twins for monitoring and preventing emergencies, especially flooding, and for enhancing the city's tourist attraction. The flood monitoring system provides real-time data analysis from water level sensors, ensuring timely alerts to residents and efficient emergency response. Additionally, the tourist attraction digital twin utilizes data from rented bicycles to map and enhance tourist-frequented areas, aiding in targeted marketing campaigns. The application of digital twin technology transforms urban management, offering comprehensive solutions for city challenges and enhancing the overall quality of life.(Ivanov et al., 2020)

Utilizing the capabilities of digital twin technology, Terminal San Giorgio in Genoa, Italy effectively tackled challenges related to the restructuring of its layout and operations, leading to significant enhancements in throughput and safety. To test proposed changes, a digital twin, or port simulator, was created using modeling software. The simulator incorporated real-time data collected from the terminal, including the movement of 20,000 interconnected objects. The simulation was used to stress-test the terminal's layout, simulate evacuation scenarios, and optimize truck boarding and disembarking operations. Additionally, the digital twin was connected to AI (Artificial Intelligence) development platform for AI-based decision-making. The result was an effective tool for testing, optimizing, and predicting the impact of operational changes in the container terminal. (Anylogic, 2023)

Summary

Digital Twins, as virtual counterparts of real-world entities, offer solutions through real-time data analysis and virtual simulations. Their systematic implementation encompasses data virtualization, synchronization, modeling & simulation, federation, and intelligent services. Two main types exist: Observer (monitors physical objects) and Virtual (designed for testing new elements). The Digital Twin of a City represents a powerful framework for urban management, drawing insights from diverse data sources to simulate traffic, infrastructure, and ecology. Case studies like Takamatsu City (flood monitoring & tourism) and Terminal San Giorgio (port optimization) demonstrate the transformative potential of Digital Twins in various fields. The power of Agent-Based Simulation and Digital Twins, showcasing their applications in diverse areas like urban planning, industrial optimization, and emergency response.

Discussion Questions

1. Describe the five layers involved in the implementation of Digital Twin technology. What are the key considerations at each layer?
2. Discuss the benefits of using Digital Twins for urban management. How does the Digital Twin of a City enable data-driven decision-making?
3. Analyze the case study of Takamatsu City and Terminal San Giorgio. How did Digital Twins contribute to improved efficiency and problem-solving in these situations?
4. How do you think Agent-Based Simulation and Digital Twins will shape the future of various industries and fields? What are the potential limitations and challenges associated with this technology?

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GLOSSARY

Term	Definition	Chapter Reference
Adaptive Technologies	Technologies designed to adapt to changing conditions, needs, and challenges, promoting resilience and flexibility in various applications.	7
Agent-Based Simulation	A computer simulation that models the behavior of individual agents within a system.	13
Algorithm	A sequence of well-defined instructions for solving a problem.	9
Artificial Intelligence (AI)	Systems that exhibit human-like intelligence, capable of learning, reasoning, and problem-solving.	3,9
Automation	Replacing or augmenting human involvement with technology for tasks.	11
Big data	A collection of data characterized by its volume, velocity, and variety.	9
Big Data Analytics	A specialized field that deals with the processing and analysis of large, complex datasets, often beyond the capabilities of traditional systems.	3
Bus Information System (BIS)	A system that provides information about bus routes, schedules, and arrival times to passengers.	11
Business sustainability goals	Sustainability in business defined. Sustainability in business refers to a company's strategy to reduce negative environmental impact resulting from their operations in a particular market. An organization's sustainability practices are typically analyzed against environmental, social, and governance (ESG) metrics.	6
Circular Economy	An economic system that emphasizes the importance of managing limited or scarce resources wisely and responsibly with regeneration rather than consumption principles to reduce or even eliminate wastes to achieve a sustainable life cycle.	1,8
Clean Development Mechanism (CDM)	Definition: A market-based instrument under the Kyoto Protocol that allows developed countries to invest in emission reduction projects in developing countries as a way to offset their own greenhouse gas emissions.	7
Cloud Computing	A model for on-demand access to computing resources, such as virtual servers, storage, and applications, over the internet.	3
Cloud Data Center	A large, centralized data storage and processing facility.	11

Term	Definition	Chapter Reference
Competitive Advantage	What differentiates the companies with others and makes them win the market.	1
Complex Innovation	Innovation involving certain technologies which are not easy to be replicated, preventing other companies within the industry to enter the market.	1
Consensus Mechanism	A process used by nodes in a decentralized system to agree on the state of the ledger.	12
Continuous Incremental Innovation	Innovation in which novelty in products or services is created along the way and by increasing efficiency or improving performance of the companies' business processes.	1
Cradle-to-Cradle Design	An approach that emphasizes designing products so that their materials can be continually recycled or safely returned to the environment at the end of their life cycle.	8
Dashboard	A visual display of key metrics and performance indicators.	9
Data	Raw facts representing facts, figures, symbols, images, or sounds.	9
Data Analytics	A subset of data science focused on analyzing historical data to identify trends, make predictions, and support decision-making.	3
Data Science	A field that encompasses various techniques for extracting insights from structured and unstructured data.	3
Data structures	Organized structures for storing and accessing data efficiently.	9
Data visualization	The process of presenting data in a visual format.	9
Decentralized	A system without a single central authority.	12
Deep Learning	A subset of ML that leverages artificial neural networks to learn complex patterns and representations from data, enabling applications like image recognition, natural language processing, and speech recognition.	3
Demand forecasting	The process of predicting future demand for a product or service.	9
Descriptive Analytics	The process of using data to understand what has happened in the past.	9
Digital Signature	A cryptographic method used to verify the authenticity of a document or transaction.	12
Digital Technologies	Electronic tools, systems, devices, and resources that generate, store, or process data. Examples include social media, online games, multimedia, and mobile phones.	Introduction

Term	Definition	Chapter Reference
Digital Transformation	The strategic integration of digital technologies across all aspects of a business to improve efficiency, customer experience, and unlock new opportunities.	2
Digital Twin	A virtual replica of a physical entity, process, or system that is synchronized with the real world.	13
Digital Twin Technology	The creation of virtual replicas of physical entities, systems, or processes, enabling applications like predictive maintenance and simulations.	3
Disruptive Innovation	Innovation that completely changes the competitive game by offering a new value proposition to the market.	1
Distributed	A system where data and processing are spread across multiple nodes.	12
Dynamic Algorithm	An algorithm that adapts to changing conditions and updates its output in real-time.	10
Dynamic Optimization Delivery Routing System	A system that uses real-time data to update delivery routes and provide accurate delivery time estimates.	10
Environmental metrics	Environmental condition metrics seek to provide information on the health of the environment and how it is changing. Ideally, these metrics would link specific industrial activities or emissions to environmental impacts.	5
Field robot	A robot designed to operate in complex and unstructured environments, such as construction sites, farms, and disaster zones.	11
Genetic Engineering	Genetic engineering, also called genetic modification or genetic manipulation, is the modification and manipulation of an organism's genes using technology.	4
Global Positioning System (GPS)	A satellite-based navigation system that provides information about location and time, enabling applications like navigation, mapping, and tracking.	3
GPS	Global Positioning System, a satellite navigation system that provides location and time information.	11
Hash Function	A mathematical function that converts data into a unique and fixed-length string of characters.	12
Health Record-keeping	The process of maintaining a patient's medical records.	12
Human Factors	Refers to the study of how humans interact with elements of a system or environment, aiming to improve product design, operations, and safety.	Introduction

Term	Definition	Chapter Reference
Human-Machine Collaboration	The collaborative work between humans and machines, leveraging the strengths of both to achieve better outcomes.	3
Humanoid Robot	A humanoid robot is a robot resembling the human body in shape. The design may be for functional purposes, such as interacting with human tools and environments, for experimental purposes, such as the study of bipedal locomotion, or for other purposes	4
Hyperledger Fabric	An open-source blockchain platform for business use.	12
Industrial Robot	A robot designed for specific industrial tasks, such as assembly, welding, and painting.	11
Industry 4.0	Industry 4.0 is revolutionizing the way companies manufacture, improve and distribute their products. Manufacturers are integrating new technologies, including Internet of Things (IoT), cloud computing and analytics, and AI and machine learning into their production facilities and throughout their operations.	6
Information	Processed data with context and meaning obtained by processing raw data.	9
Innovation	The successful exploitation of new ideas.	1
Internet of Things (IoT)	A network of interconnected devices embedded with sensors, software, and connectivity, enabling them to collect and exchange data over the internet.	3,6,11
Inventory	The stock of goods or materials that a business holds.	9
Kyoto Protocol	An international treaty adopted in 1997 that sets binding emission reduction targets for developed countries and establishes flexible mechanisms, including the CDM, to help them meet their commitments.	7
Life Cycle Assessment (LCA)	A comprehensive analysis of the environmental impact of a product or service throughout its entire life cycle, including raw material extraction, production, use, and disposal.	8
Machine Learning (ML)	A subset of AI that uses algorithms to learn from data without explicit programming, enabling tasks like prediction, classification, and clustering.	3
Mechanization	Replacing human labor with machines for physical tasks.	11
Mitigation	The process of reducing or preventing the severity, impact, or occurrence of something undesirable. In various contexts, mitigation often refers to efforts to minimize the impact of risks, disasters, or negative effects.	7

Term	Definition	Chapter Reference
Near Field Communication (NFC)	A short-range wireless communication technology that facilitates contactless data exchange between NFC-enabled devices, enabling applications like contactless payments, data exchange, and access control.	3,11
Observer Digital Twin	A digital twin used to monitor and understand the operations of physical objects and systems.	13
Open Innovation: Inside-out	Innovation in which companies offer their unused or idle facilities to support innovation from external parties.	1
Open Innovation: Outside-in	Innovation that is driven by external parties including customers, other companies, and the wider society.	1
Operations	A process of transforming inputs into outputs to meet customers' needs.	2
Operations Management	A transformation process that is planned, organised, led, and controlled effectively and efficiently to achieve business goals.	2
Patient Management	The process of managing patient records and data.	12
Patient Monitoring	The process of tracking a patient's health status using medical equipment.	12
Port Simulator	A digital twin of a port that can be used to test and optimize port operations.	13
Predictive Analytics	The process of using data to predict what will happen in the future.	9
Prescriptive Analytics	The process of using data to recommend actions to achieve specific goals.	9
Product Lifecycle Management (PLM)	The process of managing the entire lifecycle of a product from inception, through engineering design and manufacture, to service and disposal of manufactured products.	Introduction
Quantitative Data	Data that allows for statistical analysis, calculations, and predictions.	9
Radical Innovation	Innovation that offers novel products or services with relatively premium prices.	1
Radio-Frequency Identification (RFID)	A technology that uses radio waves to identify objects equipped with RFID tags, enabling applications like asset tracking, access control, and contactless payments.	3
Resource optimization	The process of planning and allocating resources efficiently.	9
RFID	Radio Frequency Identification, a technology that uses radio waves to identify objects.	11
RFID microchip	A small chip that can be used to track the movement of goods and materials.	9

Term	Definition	Chapter Reference
Robot	A machine capable of performing tasks independently or with human guidance.	11
Sensors	Devices that collect data about the environment.	11
Service robot	A robot designed to assist humans in various environments, such as homes, hospitals, and public spaces.	11
Smart Contract	A self-executing program that runs on a blockchain.	12
Stakeholder	An individual, group, or organization that has an interest or concern in the activities, outcomes, or success of a project, organization, or system.	7
Supply Chain	A collaborative value delivery process from suppliers to customers involving multiple organizations.	2
Supply Chain	The network of organizations involved in the production and distribution of a product.	12
Sustainability	The practice of maintaining processes or states in a manner that avoids depleting natural resources, thereby supporting long-term ecological balance.	Introduction
Sustainability indicators	A sustainability indicator is a measure used to assess the environmental, social, and economic aspects of a particular system or organization, with the aim of evaluating its overall sustainability.	5
Sustainability Metric	a standard of measurement, based on assessment criteria and indicators, used for measurement, comparison or to track performance.	5
Sustainable Design	The practice of designing products with consideration for environmental, social, and economic sustainability throughout their entire life cycle.	8
Technology	Something that helps humans do their jobs and meet their need easily, effectively, and efficiently.	1
Technology and Innovation Management	The discipline that deals with the planning, development, and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization.	Introduction
Technology Need Assessment (TNA)	A systematic process of identifying and evaluating technological requirements and gaps within a specific context, often to inform decision-making and strategic planning.	7
Telematics	The integration of telecommunications and informatics, used in vehicles to collect real-time data.	10
Traceability	The ability to track the origin, movement, or location of something.	12

Term	Definition	Chapter Reference
Transhuman	Transhuman, or trans-human, is the concept of an intermediary form between human and posthuman. In other words, a transhuman is a being that resembles a human in most respects but who has powers and abilities beyond those of standard humans	4
Turn-by-turn Directions	Detailed directions that guide drivers to specific locations, including drop-off and pickup spots.	10
Value Chain	Processes involving managerial functions within an organization that work together to deliver value to customers.	2
Virtual Digital Twin	A digital twin designed for creating and testing new elements before they are physically produced.	13
WRF-ARW Modeling System	The Weather Research and Forecasting (WRF) Advanced Research WRF (ARW) Modeling System, a numerical weather prediction system used for atmospheric research and operational weather forecasting.	7
3D Printing	A process of making three-dimensional solid objects from a digital file, by laying down successive layers of material until the object is created.	Introduction