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DASHBOARDS IN SMART CITY'S SUSTAINABILITY PERFORMANCE MEASUREMENT THROUGH BUSINESS INTELLIGENCE

by

André Ricardo de Carvalho Mota

Project Work report presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Knowledge Management and Business Intelligence.

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DEDICATION

My parents are illuminated souls who honestly worked all their lives abdicating their dreams to provide me a supportive environment and motivation to grow and strive for an honest and better future.

The opportunity to share a life with them based on the values of affection, attention, brotherhood, humility, honesty, and altruism makes me feel blessed. I will follow their example throughout my life, hoping to make a difference in a world where there are so many people in need, having my father's legacy left in favor of the less fortunate people as a source of inspiration and guiding light.

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ABSTRACT

People's concentration in urban areas is causing our society significant challenges because of a high populational density in mega-cities. These mega-cities cannot meet and balance their inhabitants' needs, making it hard to develop an economy to increase their quality of life and improve cities' surrounding environment and social communities. For cities to grow, considering the three pillars proposed by the sustainable development concept, which traces back to 1980 and supported by OECD, these cities building must meet today's society's needs without risking future generations' needs. Following the smart city concept means that decisions taken now must consider the impact on the economy, environment, and society altogether to avoid putting at risk the needs of today's society, especially its future generations' well-being. OECD expects this concept to change society's view on its relationship with the world, hoping the community understands that our planet is an ecosystem that provides vital services. These critical services comprise food, clean water, oxygen, bacterial waste processing, citing a few, and conclude that its survival depends on the environment. The smart city concept aims to address these issues through the simultaneous management of these three pillars and is gaining strength with the latest technological development because it leverages information and communication technologies to collect data to monitor cities' growth. Besides, smart cities can play a vital role in the world's climate change by reducing carbon footprint and the usage of cities' non-renewable energy sources while socially developing its communities and promoting equity between its inhabitants. However, for smart cities to realize all the benefits it proposes, the data collected must support informed decisions. This master project uses business intelligence methods, technologies, and tools to create a strategic performance dashboard using a correlational study based on data made available at European Commission's Eurostat portal. Business performance management principles guide the strategic dashboard creation to monitor smart city strategic performance under the light of the triple bottom line concept.

KEYWORDS

Smart cities; Performance Dashboards; Sustainability; Business Intelligence; Sustainable Development; Balanced Scorecard; Performance Measurement System; Corporate Sustainability

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LIST OF ABBREVIATIONS AND ACRONYMS

BI	Business Intelligence
BSC	Balanced Score Card
DSS	Decision Support Systems
DW	Data warehouse
EIS	Enterprise Information Systems
EU	European Union
EU2020	European Union 2020
ERD	Entity Relationship Diagram
ETL	Extract Transform and Load
GDP	Gross Domestic Product
GUIs	Graphical User Interfaces
ICT	Information and Communication Technology
KPIs	Key Performance Indicators
MIS	Management Information Systems
MS	Management Science
MSA	Measurement Sampling Adequacy
OECD	Organization for Economic Co-operation and Development
OLAP	Online Analytical Processing
OR	Operational Research
R&D	Research and Development
SBSC	Sustainability Balanced Score Card
SQL	Sequel Query Language
TTL	Triple Top Line
TBL	Triple Bottom Line
WCED	World Commission on Economic Development

1. INTRODUCTION

Before analyzing the smart city concept's purpose, it is vital to review the OECD's goals, the definition of sustainable development concept, and possible ways to measure it. For Strange and Bayley (2008), OECD is an organization that helps governments to address different issues and work together on new developments. These issues and recent events comprise economic, social, and environmental challenges of globalization, corporate governance, information economy, and to compare and share policy experiences aiming the solution of its members' everyday issues.

OECD also supports and defines the sustainable development concept, a challenge attracting attention recently, which is a process of developing growth to meet today's society needs without risking future generations' well-being. In other words, sustainable development is a conceptual framework tracing back to the Brundtland Report's appearance. It is based on indicators to measure growth by structuring the well-being analysis of sustainable development's people, environment, and economic aspects between the current and future generations.

This reflection on the sustainable development concept reveals that its foundation on the environment, society, and economy means it is a multidimensional challenge. Decisions must balance between these three aspects or dimensions by measuring all of them to some extent. To enable the sustainable development measurement through the use of indicators, Strange and Bayley (2008) advise the use of the "Capital Approach" concept to define the society's capital base types of financial capital, economic wealth, produced money, surrounding infrastructure, natural capital, natural ecosystems, human capital, and social capital.

Contrasting Strange and Bayley's (2008) vision of this concept with the definition of the sustainable city proposed by Ahvenniemi et al. (2017) helps to understand what it means to citizens' daily lives. A sustainable city is "achieving a balance between the development of the urban areas and protection of the environment with an eye to equity in income, employment, shelter, basic services, social infrastructure, and transportation in the urban areas" (Hiremath et al., 2013, cited in Ahvenniemi et al., 2017, p. 235).

According to Ahvenniemi et al. (2017), the smart city concept embraces all the ideas exposed above. It declares that its assessment builds on "the previous experiences of measuring environmentally friendly and livable cities, embracing the concepts of sustainable development and quality of life, but with the important and significant addition of technological and informational components" (Marsal-Llacuna et al., 2015, cited in Ahvenniemi et al., 2017, p. 235).

However, through their extensive literature review, Ahvenniemi et al. (2017) found no universal definition for sustainable development leading to no standard to select a balanced set of environmental, social, and economic indicators to fulfill it. Science for Environment Policy (2018) shares this concern. It adds that explanatory, pilot, and performance assessment tools do not capture how the pillars of sustainable development link together.

Regardless of it, for Kourtit and Nijkamp (2018), balanced scorecards are a measurement system or a performance assessment tool, as stated above, which can aid in steering an organization by supporting the definition of its vision, mission, values, and strategy, making it measurable through key performance indicators. They believe that dashboards can assess smart city performance because they embrace the balanced scorecard concepts. However, Kourtit and Nijkamp concern that there is no consistency in the linkage between strategic goals and objectives in designing such tools.

Nevertheless, Figge et al. (2002) have a contradictory view on this subject, who believe that a balanced scorecard can simultaneously manage improvements of social, environmental, and economical business goals. They declare that such a tool is a suitable candidate to fulfill sustainable development’s main requirement of integrating ecological, economic, and social aspects.

On the one hand, Petrini and Pozzebon's (2009) work aims to improve the definition, gathering, analysis, and dissemination of socio-ecological-economic information, who believe that properly using BI’s lifecycle methodologies, processes, methods, and tools can help with this task. However, Petrini and Pozzebon’s primary concern is implementing business intelligence (BI) solutions designs aligned with the organization’s strategic purposes and, consequently, integrating such solutions into performance management systems such as the balanced scorecard framework.

On the other hand, Eckerson (2011) believes that business performance management can align BI solutions with corporate management systems on the strategic level, which is not well understood because it involves processes and techniques already used by organizations. However, methods and applications such as strategic planning, financial consolidation and reporting, planning and budgeting, forecasting and modeling, dashboards, and scorecards are rarely applied and implemented coherently.

This project’s goal is to answer the following research and hypothesis questions, respectively, using a correlational study (Cooper & Schindler, 2014):

- How can smart cities’ sustainability strategic performance be measured?
- Do the measures of environmental, social, and economic dimensions influence each other?

This work uses a deductive cognitive process to answer the research question, which results in a strategic performance dashboard to measure the smart city’s strategic performance by monitoring its sustainable development targets.

The design of this dashboard plans to fill the research gap proposed by Hu et al. (2017) by displaying correlational information alongside performance measures to answer the hypothesis question using an inductive cognitive process.

The following sections comprise this work: introduction, smart sustainable cities, corporate performance systems, sustainable corporate performance systems, business intelligence, business performance management, performance dashboards, data and research methodology, results and discussion, and conclusion.

2. SMART SUSTAINABLE CITIES

This section brings the line of thought of Ahvenniemi et al. (2017) and Kummitha and Crutzen (2017) about smart and sustainable cities concepts, aiming to clarify how they relate to each other and present their different perspectives. Besides, Kourtit and Nijkamp's (2018) work discusses ways to approach smart and sustainable cities assessment.

2.1. DIFFERENCES BETWEEN SMART AND SUSTAINABLE CITIES

Sustainability means that cities should simultaneously manage environmental, social, and economic aspects. According to Ahvenniemi et al. (2017), the smart city concept definition presented in the introduction does not exist without modern technologies. The concept has, at its core, the sustainable city and sustainable development concept ideas and values. Their work compares assessment tools frameworks based on these two concepts, finding no universal definitions for any of them.

The outcome of this lack of definition is several smart city and sustainable city assessment tools focusing on distinct indicator sets. Besides, these assessment tools do not reflect systemic interaction between environmental, social, and economic measures, nor the frameworks provide a normative indication of what indicators to use.

When comparing these smart and sustainable cities' assessment frameworks, Ahvenniemi et al. (2017) found that sustainable city assessment tools reviewed have more environmental indicators. In contrast, smart city assessment tools lack this kind of measure, having more social and economic indicators. For them, cities themselves need to be understood as ecosystems to adequately capture the interaction between the economic, social, and environmental dimensions and must have output and impact indicators.

In addition to the differences in indicator sets found when comparing smart and sustainable assessment tools, Ahvenniemi et al. (2017) identify two mainstreams views regarding the smart city concept. One is oriented to information and communication technologies and employs infrastructures, applications, services, and analytic capabilities to develop the hard infrastructure. While the other is geared to people to improve social and human capital, knowledge, and equity to develop the soft infrastructure.

2.2. SMART CITIES' SCHOOLS OF THOUGHT

Kummitha and Crutzen (2017) also recognize two main approaches to deal with the smart city concept in their work. On the one hand, the technology-driven method advocates that every city activity should use information and communication technology to better its inhabitants' living standards to achieve sustainable development.

On the other hand, the human-driven method emphasizes that ICT usage is a by-product of human capabilities. These capabilities allow the community members to be agents of change to build a knowledge society. They can help find solutions to the urbanization issues they face in their everyday life by applying technology.

Through an extensive literature review, Kummitha and Crutzen (2017) identified many definitions for the smart city concept and perspectives on how to implement it. Their work builds a framework to group these perspectives into the restrictive, reflective, rationalistic, and critical schools of thought using technology and human-driven adoption methods as a means of classification to present the evolution of ideas and values of such concepts.

The restrictive school values the connectivity and data provided by the city’s infrastructure, mainly based on the internet of things and the ICT-based solutions built on top of it to provide citizens services. This sort of technology and solutions stimulate the interactions between citizens, and the service providers, including government agencies whose main goal is to address citizens’ issues and needs.

Even though such ideas stimulated knowledge and created better ways to advance citizens' quality of life, they failed to articulate how ICT promotes social inclusion, resolves income and education differences, and stimulates employment. Failing to provide answers to support such vital aspects of modern society raised criticism leading the proponents of this school of thought to explore other methods to integrate ICT and technology into the city infrastructure to achieve higher ends.

These essential aspects concerning our society are the basis of the reflective school of thought, which still believes in ICT’s power, but integrates human elements in its construction. Its goal is to improve human capital using ICT to enhance citizens’ skills enabling them to innovate and promote social order to solve their everyday issues.

Furthermore, this school of thought believes that the smart city concept can help create a new socio-economic environment, promote social participation, and improve citizens' way of living in other contexts such as mobility, governance, living, and energy. More importantly, by enabling sensors’ data to enhance the macro-planning for cities to share it within and between themselves.

The promotion of this new socio-economic environment attracted further critique by allowing powerful ICT companies to play a central role in the smart city building because it can stimulate the power relations between them and the government turning public spaces into private ones. Moreover, the reflective school of thought still does not show how ICT can improve citizens' capabilities, believing that enhancing human capital is a by-product of technological advancements.

These concerns gave rise to the rationalistic school of thought, which believes that community members should drive the smart city building. It argues that enhancing the community members’ skills and capabilities reduces the gap between technology development and its usage because capabilities development can drive the technology usage by applying it to solve everyday problems.

To improve citizens’ abilities and bridge the gap between technology development and its usage, the rationalistic school of thought proposes the jointing action of universities, industry, and the government to create an inspiring environment and build the needed infrastructure to support the creation of a smart city driven by the community.

This joint action, known as a triple-helix model, attracts young and well-educated students to this innovative environment, fostering a knowledge-based economy rather than a labor-intensive one. This kind of environment improves the city’s human capital to promote its “smartness” through education, social learning, culture, and knowledge sharing.

In other words, this school of thought believes that technology is a by-product of human capital, which is the foundation of a knowledge-based economy. Such type of economy fuels entrepreneurship and innovation, allowing citizens to become agents of change by conceiving, designing, building, and maintaining their smart cities by creating innovative technological solutions. This environment transforms how people live and interact with each other, leading to more ICT and technology progress.

According to Kummitha and Crutzen (2017), despite the efforts of the rationalistic school of thought in emphasizing human capital rather than technology to approach smart city building, there is still criticism raised by its opponents. They argue that there are not enough references explaining how citizens participate in planning activities of the smart cities' construction.

This objection and dissatisfaction around the smart city concept are the foundation for the critical school of thought. It believes that the power relations between government and corporations turn public spaces into private ones. Their proponents argue that the smart city concept is a neoliberal project aiming to control various players' power relations with different interests and expectations.

2.3. SMART CITY DECISION SUPPORT AND DASHBOARDS

According to Kourtit and Nijkamp (2018), the gradual movement to urban centers has turned cities into centers of economic, social, cultural, political, and technological attraction, which raises challenges, opportunities, and negative externalities. Kourtit and Nijkamp concern if each of these urban centers' economic, environmental, social, cultural, and technological performance serves its inhabitants.

Neto and Rego (2019) share this concern and declare that governments are under pressure to efficiently use the city's resources and go through a digital transformation process to turn towns into a platform that uses analytics and real-time data to support urban planning and management. Most importantly, Kourtit and Nijkamp (2018) believe that smart cities should be part of a globally connected network, which provides new opportunities and urban strategies by combining complementary and rival activities from several towns in this worldwide network.

For Kourtit and Nijkamp (2018), information and communication technologies have added value to public and private stakeholders through the vast and unlimited volumes of data collected, stored, shared, and used in modern cities in this worldwide network. To exploit the advantages and deal with the threats brought by introducing advanced technologies to support smart cities' management and its challenges calls for a new way to use all this data.

An appropriate toolkit is needed to manage the complex city ecosystem and develop smart urban dashboards to measure the smart city's performance, organizing and synthesizing its data. These dashboards allow monitoring the city's social, economic, and environmental performance and raise early warnings in the case of misalignment between critical urban conditions and the city's vision and strategy.

Digital technologies facilitate the creation of these dashboards and aid in the transformation of data into knowledge. Such visualizations quickly display the data in the form of graphics as city's performance KPIs in one screen, revealing the linkage between strategic goals and the city's conditions and status.

These one-screen dashboards enable stakeholders to understand the real story within this data at a glance and consequently make better decisions based on this understanding to increase the chances of meeting the smart city stakeholders' needs. In other words, accurate and accessible up-to-date information at the right time and the right amount must support the smart city's decision making.

These dashboards must have a multidimensional approach by adding social and ecological assessments to the economic perspective. Such a practice is needed because the old gross domestic product metric to analyze a city's socio-economic development and manage its internal and external dynamics is no longer enough, which today must include the quality of life.

Dashboards' data visualizations include balanced scorecards, which provide monitoring and communication to stakeholders involved by sharing smart cities' achievements. These tools enable the tracking of strategic performance systems that is a "supporting process where steering of the organization takes place through the systematic definition of mission, strategy, and objectives of the organization, making these measurable through critical success factors and key performance indicators, in order to be able to take corrective actions to keep the organization on track" (De Waal, 2007, cited in Kourtit & Nijkamp, 2018, p. 27).

Although Kourtit and Nijkamp (2018) recognize the use of dashboards' user-friendly data visualizations to communicate information to stakeholders about smart cities' performance, they concern about the inexistence of consistency in the linkage between strategic goals and objectives in its design.

2.4. A BRIEF DISCUSSION OF SECTION TWO

Ahvenniemi et al. (2017) compare assessment tools based on smart and sustainable city concepts, finding at one hand that ICT gears smart city assessment frameworks with a predominance of social and economic indicators. On the other hand, people guide sustainable city assessment frameworks containing more environmental indicators.

Such a difference in the assessment tools' indicator focus is related to the lack of a universal definition for smart and sustainable city concepts, leading to an explosion in assessment tools indicators. These assessment tools do not reflect the systemic interaction between their measures, nor the frameworks provide any advice on what metrics to use, according to Ahvenniemi et al. (2017) work.

On top of this, Ahvenniemi et al. (2017) also identified two main approaches to implementing the smart city concept. One is oriented to information and communication technologies to develop the hard infrastructure, while people gear the other to create the soft infrastructure.

On the other hand, Kummitha and Crutzen (2017) further analyze these two main approaches by presenting an evolutionary perspective of the restrictive, reflective, rationalistic, and critical schools of thought's purpose, values, and ideas. My opinion is that the rationalistic school of thought reflects today's smart city approach.

This school of thought approach tries to harmonize the smart city concept by putting people in its center, arguing that human capital must drive technology to solve common everyday issues by the community's members to build a knowledge society.

Despite giving valuable insights on the smart city concept evolution and its approach, Kummitha and Crutzen (2017) also do not provide instructions on what indicators to use. Besides, it does not give directions on which kind of tools can simultaneously evaluate environmental, social, and economic aspects.

The work conducted by Kourtit and Nijkamp (2018) recognizes the recent usage of dashboards to measure smart city's performance through balanced scorecards. It uses a different framework called the "pentagon model" to link smart cities' strategic and operational objectives and associated metrics. However, they point out the importance of considering the systemic interaction between environmental, social, and economic measures by mentioning the importance of verifying the linkage between metrics instead of objectives.

3. CORPORATE PERFORMANCE SYSTEMS

This section presents Kaplan and Norton's (1992, 1996, 2000, 2007, 2008) balanced scorecard work, starting with its traditional perspectives, which support the connection between short-term actions to long-term strategic goals and the role of balanced scorecards and dashboards in monitoring the execution of a strategic management system. The recent evolution in technology allowed such visualizations to incorporate advanced analytics, according to Larson and Chang (2016).

Within this context, Wehde (2018) believes that evaluating strategy separately from operations can lead to better results, while Hu et al. (2017) found empirical evidence that one of the several types of balanced scorecards presented by Franco-Santos et al. (2012) can improve decision-makers' understanding of business strategy.

3.1. THE BALANCED SCORECARD

According to Kaplan and Norton (1992), the balanced scorecard helps answer questions on different aspects by grouping financial and non-financial measures in a single report. It organizes these measures into the financial, customer, internal business processes, and innovation and learning perspectives, enabling the linkage of tangible and intangible assets critical for companies to remain competitive in the market.

The innovation and learning, or fourth perspective, regards the company's ability to make continual improvements to its existing products and services. In other words, the capability to innovate, improve, and learn is directly related to the company's value.

In the internal business process or third perspective, managers must focus on the business processes that help meet customers' expectations and customers' concerns, usually cycle time, quality, employee skills, and productivity. Focusing on these concerns means that the customer or second perspective tends to fall into four categories: time, quality, performance and service, and cost.

The financial, or first perspective, usually involves goals such as profitability, growth, and shareholder value. Operational improvements, such as quality and cycle-time, can create excess capacity. Managers must put this extra capacity to work or get rid of it. This spare capacity can boost revenues or reduce expenses by eliminating it, resulting in financial improvements.

By simultaneously managing tangible and intangible assets through all four perspectives, the balanced scorecard puts the whole organization's focus on the strategy established by taking actions to meet its goals.

3.2. STRATEGY AND THE BALANCED SCORECARD

For Kaplan and Norton (1996), a balanced scorecard is not a controlling tool to evaluate past performance. Still, a means to communicate the strategy of business aiming to align organizational and cross-departmental initiatives. For these financial and non-financial measures to represent a strategy, they should incorporate the cause-and-effect relationships among objectives and critical variables, including lead, lag, and feedback loops.

A strategy is a group of hypotheses about cause and effect relationships represented by a sequence of if-then statements. The measurement system should tell the business strategy and make the relationships between the objectives and measures explicit in the four perspectives to be managed and validated.

Moreover, for a balanced scorecard to adequately represent this strategy, it should communicate how to achieve outcome measures by defining performance drive measures. However, if the balanced scorecard only depicts them, it is impossible to understand if the short-term improvements translate into overall business expansion.

In other words, the purpose of a balanced scorecard is to articulate the theory of business through the causal chain of performance drivers and outcomes. A qualitative approach initially establishes these relationships, and after companies accumulate more data, they can objectively build this kind of relations.

More importantly, it must not replace the organization's daily measurement system because balanced scorecard metrics must draw the decision-makers' attention to factors leading to its competitive advantage.

3.3. Mapping the Strategy

Kaplan and Norton (2000) declare that the balanced scorecard strategy should describe how a company plans to meet its customers' and shareholders' needs. The customer perspective establishes the value proposition, and the internal business processes perspective describes the innovation used to enhance the customer management and operational processes. Lastly, the learning and growth perspective builds the employee abilities and information technology capabilities to deliver such value.

A strategy map can visually describe and document the strategy's intangible assets an organization uses to achieve its goals informing the knowledge, skills, and systems that the company's employees need to build to innovate. By enabling the correct strategic capabilities and efficiencies to deliver specific value to the market, eventually leads to higher shareholder value measured through key performance indicators.

Such a tool is the foundation of any management system, which helps an organization implement its growth initiatives effectively and rapidly. A strategy implies the organization's movement from its current position to a future situation in which it has not been before.

A strategy map specifies the cause-and-effect relationships between objectives, showing the pathway to this future position as a group of linked hypotheses, making them continuously explicit and testable, enabling the use of the results to adapt the strategy and correct exposed gaps. When aligned with the balanced scorecard, the strategy map describes the approach needed to successfully implement it by achieving the targets established in the context of an organization's vision, mission, and values through the balanced scorecard.

3.4. STRATEGIC MANAGEMENT SYSTEMS

For Kaplan and Norton (2007), a strategic management system can put an established strategy in motion by linking short-term actions to long-term goals. This system comprises four new processes transforming the balanced scorecard in a business framework.

The first process, translating the vision, helps organizations turn their vision and strategy into goals, objectives, and targets. The second process, communicating and linking, helps to inform the organization's strategy throughout the company. The third process, business planning, helps integrate organizations' business and financial plans. The fourth process, feedback, and learning allow organizations to monitor short-term results in the light of recent performance to evaluate their strategy.

A balanced scorecard helps managers cycle through this strategic management system to improve and reengineer the most critical processes related to the organization's strategy success, primarily because it aligns actions with the strategy through the established business performance drivers.

Senior management can rely on the balanced scorecard to verify at any point of strategy's implementation whether it is working, and if not, why. It enables the double-loop learning in this fashion, which produces changes in decision-makers' assumptions and theories about cause-and-effect relationships to reformulate the strategy if deemed necessary.

Budget reviews and other financially based management tools do not enable this sort of learning. Such tools only address one perspective and do not allow strategic knowledge, consisting of gathering feedback and testing hypotheses. A strategic feedback system should allow testing, validation, and modification of the strategy.

3.5. THE STRATEGIC MANAGEMENT SYSTEM AS A BUSINESS FRAMEWORK

Kaplan and Norton (2008) believe that a strategic management system is an integrated set of activities and tools that a company uses to develop its strategy, translate it into operational actions, and monitor it to improve both. Its successful execution involves understanding the management cycle that links it to operations and applying appropriate tools at each stage of this process.

Studies in the last 25 years show that 60% to 80% of companies fall short in achieving the success predicted by their strategy because of tensions between strategy and operations, usually by mixing the review of such distinct activities, which result in operations issues blocking strategy evaluation and development. Wehde (2018) suggests that organizations review their operational processes monthly and analyze their strategy quarterly to allow corporations to identify and include innovations crucial to the business.

Kaplan and Norton (2008) declare that such a strategic management system comprises developing the strategy, translating the strategy, planning operations, monitoring and learning, and testing and adapting it. This kind of management system enables strategic planning, operational execution, feedback, and learning to avoid the shortfalls described in the previous paragraph using the strategic plan to guide the formulation of the operational policies and plans.

On the one hand, balanced scorecards and strategy maps support the translation of vision and strategy into goals, measures, and targets. On the other hand, dashboards aid in monitoring strategy implementation.

Dashboards play a vital role in monitoring the operations to aid its planning in such a process. According to Larson & Chang (2016), the latest technological development of business intelligence tools enables performance dashboards to test and adapt strategy, using several kinds of analysis. Kaplan and Norton (2008) believe that such visualizations can include correlations among the strategy's performance measures, which can also feature strategic themes to organize performance metrics and targets for each strategic objective to assess its execution quantitatively.

Analyzing the correlations between the strategy's performance measures allows strategy assessment by validating and quantifying the relationships between these performance metrics, leading to questioning or partially rejecting the entire process if a link is not occurring.

Franco-Santos et al. (2012) extensive research on such performance systems reveals three types of balanced scorecards (BSC). The BSC type II groups financial and non-financial measures into perspectives with the addition of describing the organization´s strategy using sequential cause-and-effect logic to link tangible and intangible assets.

Most importantly, Hu et al. (2017) found empirical evidence that visually depicting the links between the strategic theme measures in a balanced scorecard improves decision-makers' understanding of organizations' strategy in a BSC type II. They also suggested varying BSC design displays by equalling the number of performance metrics and strategic themes.

3.6. A BRIEF DISCUSSION OF SECTION THREE

The balanced scorecard framework that started as a tool to describe an organization's strategy by linking tangible and intangible assets critical for companies to remain competitive has evolved over the years. Other tools, such as the strategy map, emerged to complement it by enabling the visualization of these links and outlining the strategy's value proposition to its primary stakeholders. Visualizing and understanding the connections between a balanced scorecard's non-financial perspectives is crucial for achieving its financial targets.

Kaplan and Norton (2008) established a closed-loop process to implement a strategic management system comprising various tools to help decision-makers turn vision and strategy into goals, measures, and targets. Performance dashboards monitor these measures and targets to verify any gap in the strategy's implementation. The technology evolution enabled such tools to incorporate advanced analytics, allowing business theory validation by testing the cause and effect relationships exposed by them, allowing the double-loop strategic learning.

4. SUSTAINABLE CORPORATE PERFORMANCE SYSTEMS

This section brings Figge et al.'s (2002) work that extends Kaplan and Norton's research by integrating sustainable development's environmental and social aspects into the business through a sustainability balanced scorecard. Edgeman and Eskildsen (2014) and Dyllick and Hockerts (2002) present the definition of sustainable enterprise excellence, triple top line, and triple bottom line corporate sustainability concepts. They explain their relation to the idea of "people, planet, and profit" and how the corporate sustainability criteria can support them.

4.1. SUSTAINABLE ENTERPRISE EXCELLENCE

According to Edgeman and Eskildsen (2014), after the Brundtland Commission declaration named "Our Common Future" (WCED, 1987) and the sustainability movement raised by the United Nations, many organizations and businesses embraced the triple bottom line concept due to the severe non-compliance penalties defined in its policies, practices, and guidelines. The TBL concept and its societal, environmental, and financial performance components are also known as "people, planet, and profit," which United Nations endorsed as a Standard for Urban and Community Accounting in 2007.

To adopt this TBL concept, an organization needs an equitable, ecological, and economically viable strategy supported by an ethical, effective, and efficient governance to achieve positive "people, planet, and profit" enterprise performance. For Edgeman and Eskildsen (2014), sound policy and responsible production result in performance when integrated with governance. Sustainable enterprise excellence guides organizations to derive benefits from acting in a transparent, ethical, relevant, and reliable way towards their primary stakeholders.

The resulting benefits by acting ethically and transparently towards the organization's stakeholders support its economic sustainability. The responsible strategy, governance, and actions on behalf of society and the environment support social and ecological sustainability, addressing "people, planet, and profit."

In other words, the sustainable enterprise excellence concept establishes a process using a strategy driven by equity, ecology, and economic values, known as the triple top line. This strategy based on ethical, effective, and efficient governance guides the implementation of the triple bottom line concept to achieve "people, planet, and profit" enterprise performance through policies, people, and partnerships.

Its implementation continuously changes the organization by continually improving its sustainability aspects focused on the refinement of its human capital, innovation, and financial aspects. This process aims to increase an organization's sustainability maturity level to become continuously relevant and responsible.

The triple top line strategy balances both competing and complementary interests of organizational stakeholders and includes depth and breadth consideration of social and environmental responsibility and performance.

Such a strategy's values drive the triple bottom line concept or "people, planet, and profit" implementation, targeting explicitly ecological and social considerations, called green innovation. This innovation is regular, systematic, and systemically embedded in companies culture, contributing to the refinement of its financial, human capital, and sustainability aspects, consequently leading to the concept of sustainable change.

Enterprises aiming at corporate sustainability performance must appropriately tailor their plans to implement the triple bottom line concept and its green innovation by focusing on organizational design, methods, and procedures. The sustainable enterprise excellence concept guides this tailoring by distinctively emphasizing innovation, organization design, business intelligence, and analytics through policies, people, and partnerships. Triple top line strategy comprising equity, ecology, and economy is the foundation of such tailoring.

"People, planet, and profit" or triple bottom line concept requires a regular assessment of all organization's results and activities against the criteria established, which needs subsequent integration of the knowledge gained from this assessment into the company's strategy and processes. Evaluating the company's strategy produces new opportunities for innovation, aiming to improve performance using current best practices and develop new procedures, leading to the next best practices and competitive advantage.

4.2. THE CORPORATE SUSTAINABILITY CASES

The sustainable enterprise excellence system explained previously is an extension of the corporate sustainability criteria and other concepts presented by Dyllick and Hockerts (2002). According to Dyllick and Hockerts, organizations should satisfy eco-efficiency, socio-efficiency, eco-effectiveness, socio-effectiveness, sufficiency, and ecological equity criteria to achieve sustainable development.

Enterprises cannot reach sustainability by only linking it to business through eco-efficiency criterion, which currently relates to indicators such as energy, water, and resource efficiency, alongside waste and pollution intensity. Corporate sustainability means meeting the needs of the organization's direct and indirect stakeholders without putting at risk the needs of future stakeholders by simultaneously addressing economic, natural, and social capital.

Corporate sustainability means that corporations must maintain and grow their economic, social, and environmental capital. Economic sustainability alone contributes to sustainability in the short run. Still, to achieve overall sustainability, in the long term, all three dimensions must be satisfied. However, due to irreversibility, non-linearity, and non-substitutability aspects of the social and environmental capital, organizations cannot use these aspects according to orthodox management theory, which translates any input production factor into monetary units.

There is a chance for the next generations to find substitutes for natural resources using technology. However, these generations are unlikely to find ways to substitute ecosystems such as the ozone layer or the climate stabilizing amazonian forest. It is also essential to consider if the ecosystem's carrying capacity is close or not to a system breakdown in the case of any other emission.

On the other hand, a socially sustainable organization should minimize negative impacts such as human rights, work accidents and maximize the positives effects by boosting human capital by creating employment and corporate giving. Besides, it must add value to the societal capital by improving the community's public services quality because adequate infrastructure is paramount to building a society with enough education and health pre-conditions for economic activity.

In other words, for organizations to achieve long-term sustainability, they need to manage environmental, social, and economic capitals altogether by developing not only the "business case" but also the "natural case" and the "social case." Such management is necessary because of the irreversibility, non-linearity, and non-substitutability aspects of the real-world controlling any of these three types of capital.

Business links to the economic capital, on the one hand, through eco-efficiency, which relates to the organization's economic value added to the ecological impact caused by the business. On the other hand, the connection to the economic capital is also made by socio-efficiency, representing the relationship between an organization's value added to the social impact. These two criteria are guiding principles leading to relative improvements in economic capital, and both are critical to achieve economic sustainability and make the "business case."

It is essential to consider if the ecosystem's carrying capacity is close or not to a system breakdown in the case of any other emission due to irreversibility, non-linearity, and non-sustainability aspects mentioned previously. Companies' processes must effectively produce their eco-efficient products and services to fulfill the eco-effectiveness criterion.

The consumption choice of eco-effective products or services is in the hands of customers and out of the organization's control, leading to the criterion of sufficiency. Eco-effectiveness and sufficiency are vital criteria to achieve environmental sustainability to make the "natural case."

To achieve social sustainability, companies cannot focus only on the socio-effectiveness criterion because it can lead to social excellence islands. To avoid it, they need to make their eco-efficient products and services affordable to the masses, leading to the criterion of ecological equity. This criterion avoids current generations consuming most of the existing natural resources and degrading the remaining ecosystems, making both criteria essential to develop the "social case."

In summary, strategic decisions are only possible in sustainability by managing all three capitals together. Developing the "business, social, and natural cases" and articulating its corporate sustainability criteria allows such management and helps decision-makers select a set of indicators to build their strategy.

4.3. SUSTAINABILITY BALANCED SCORECARD

For Figge et al. (2002), the balanced scorecard is a strategic management tool capable of aligning organizations' operational and non-financial activities to their long-term strategy, delineating the strategic relevance of such activities for the corporation. It avoids the short-term focus and past orientation by defining a hierarchic system comprised of four perspectives. Each perspective has strategic objectives involving lagging and leading indicators aligned with the financial aspect.

These objectives, and consequently, their measures, are linked by a cause-and-effect chain through all four perspectives to enable alignment between the company's strategy and its long-term plans with its short-term non-financial activities at the operational level. Such alignment makes the contribution and transformation of intangible assets into long-term financial success explicit and controllable.

Lagging indicators represent the achievement of strategic objectives, and leading indicators show how to achieve the results targeted by lagging indicators. This structure indicates that Figge et al.'s (2002) work relates to the first of the four critical strategic management processes described by Kaplan and Norton (2007), helping to converge vision and strategy into goals and measures.

For this reason, Figge et al. (2002) believe that the balanced scorecard is a suitable tool to manage the companies' contribution to sustainable development because it can fulfill sustainable development's main requirement of integrating environmental, social, and economic dimensions. However, the market system does not fully integrate social and ecological scarcities, in which scarcities usually reflect on prices. Nonetheless, it is paramount to align such non-financial activities at an operational level with its business strategy to manage such aspects.

Because of this lack of full integration in the market system, they propose three approaches to integrating the mainstream business´s social and environmental aspects. The first combines the social and ecological elements into the measures of the four traditional perspectives. The second includes an additional view to account for social and ecological issues. Finally, the third approach creates a specific environmental and social scorecard.

The first option available to build a sustainability balanced scorecard integrates environmental and social aspects into the four perspectives through its lagging and leading indicators, making it useful when these aspects are strategically relevant and integrated into the market system. In other words, this option does not consider exchange processes outside the market mechanism, focusing mainly on the economic sphere.

The second option to develop a sustainability balanced scorecard adds a non-market perspective to account for sustainable development's environmental and social aspects, mainly because companies do not exclusively operate in the socio-economic spheres. Many ecological and social aspects have their origins outside the market exchange process as social constructs. They are usually treated as externalities, meaning that such aspects and their related scarcities are not an integral part of the market system, meaning they do not have market prices assigned to them.

Such externalities can become strategically relevant to the organizations by directly influencing the financial perspective or indirectly the other non-financial perspectives. For this reason, it becomes paramount for enterprises to integrate the environmental and social aspects outside of the market system into the business strategy through a cause-and-effect chain towards the financial perspective. Figge et al. (2002) declared that "Kaplan and Norton also point out that firm-specific formulation of a BSC may involve a renaming or adding of perspectives" (Kaplan & Norton, 1997, p. 33, cited in Figge et al., 2002, p. 274).

The third option to create a sustainability balanced scorecard is to derive an environmental and social balanced scorecard, which cannot occur in parallel with the conventional BSC because of the necessity of integrating ecological and social aspects into the mainstream business before creating it. In other words, a derived sustainability balanced scorecard for the sustainable development's social and environmental aspects is not an independent alternative but an extension deduced from one of the first two options.

The design of the other two approaches for developing a sustainability balanced scorecard identifies the ecological and social aspects' strategic relevance position in the cause-and-effect chain, which delineates if such aspects are inside or outside the market exchange process. The derived sustainability balanced scorecard serves as a coordinating control system of all the strategically important environmental and social elements.

To develop a sustainability balanced scorecard based on one of the three options presented, companies must first select a strategic business unit, meaning that a strategy is already in place. Second, it should identify the sustainable development's social and environmental concerns for this business unit. Third, it is to determine the relevance of these sustainable development's social and environmental aspects to the business unit.

Based on such a formulation process, it is possible to use a sustainability balanced scorecard no matter whether a conventional balanced scorecard exists before integrating sustainable development's social and environmental aspects.

The primary reason for this is that choosing a business unit presupposes a strategy, reflecting the previous establishment of the specific needs regarding environmental and social aspects affecting this business unit. The strategic relevance is determined through the cause-and-effect hierarchical linking of all perspectives independently of the structure adopted based on the three options above.

For Figge et al. (2002), "it is important to note that the BSC is not a tool for the formulation of strategies. Rather, the BSC serves to describe and translate an existing strategy consistently in order to enhance the successful execution of the strategy" (Kaplan & Norton, 1997, p.36, 2001, p. 104, cited in Figge et al., 2002, p. 277).

4.4. A BRIEF DISCUSSION OF SECTION FOUR

Corporate sustainability is the process guided by governance and based on a strategy for helping an organization become continuously responsible and relevant through ethical and transparent actions towards its stakeholders, society, and the environment.

Developing "business, natural and societal cases" supported by the six corporate sustainability criteria to address the triple bottom line concept or "people, planet, and profit" can enhance the process established by the sustainable enterprise excellence system to support corporate sustainability.

The six corporate sustainability criteria based on responsible strategy and governance, in practice, enable organizations to realize the benefits of acting ethically and transparently towards their shareholders, society, and environment to support economic, social, and ecological sustainability.

This process can help decision-makers develop a strategy that incorporates sustainable development aspects into the business, supporting an indicator set selection comprising environmental, social, economic goals and measures aligned with organizations' vision, mission, and core values. Such a strategy can be coherently described by a sustainability balanced scorecard, enabling the sustainable development aspects' simultaneous management.

5. PERFORMANCE MANAGEMENT SYSTEMS

This section presents the disciplines of business intelligence and business performance management, which convergence, according to Eckerson (2011), led to the performance dashboards' appearance. In Eckerson's vision, such dashboards are performance management systems that can help organizations rapidly adapt to market changes by automating performance management. Business performance management can guide performance management with data and metrics provided by the business intelligence methods, processes, tools, and technology.

5.1. BUSINESS INTELLIGENCE

This subsection presents Mortenson et al. (2015) work that explains the scientific management history by showing its evolution and the predominant disciplines and technologies through time, which describes where the business intelligence discipline positions itself in this context. Kimball and Ross' (2013) technical guidelines to build a data warehouse and their proposed business intelligence technical reference architecture complement the section's content.

5.1.1. The evolution of scientific management

"Management training through education, opposing the tradition of coming up the ranks from apprentice to master-craftsmen, a practice he argues as being without applied science" (Locke, 1989, cited in Mortenson et al., S., 2015, p. 585). According to Mortenson et al. (2015), the management paradigm through education led to a shift in management attitudes, which uses discursive reasoning instead of intuition. Their work segmented the new management paradigm in six periods to better understand what are the predominant disciplines and analyze them through the years.

The first period, known as scientific management, started in 1910 and ending after the second world war, saw innovations brought by the technological revolution impacting the managerial theory process. The scientific management led to a domino effect of interactions between different disciplines and society, resulting in changes to the working life and practices, inspiring new approaches in the new management paradigm.

After the second world war in the mid-1960s, the second period started and witnessed the scientific method's dawn. The operational research (OR) and management science (MS) discipline pioneers and the nascent computer technologies found new applications to their tools and methodologies. Even with the limited decision-making discipline development, this period did see the formalization of behavioral and ergonomics fields.

However, the commercial application of computers by the OR and MS disciplines was the most significant aspect of this period, demonstrating that the scientific methodology could benefit business and decision making.

The growth in management information systems (MIS) characterizes the third period between the mid-1960s and early-1970s. Despite the advances in hardware and software, making the information system and data more pervasive and integrated into the business, there was a gap between the potential and the value these systems could bring to quantitative analysts and decision-makers.

The fourth period saw the prominence of decision support systems (DSS) between the early-1970s and late-1980s. The creation of expert systems and decision support systems (DSS) bridged the gap from the previous period and integrate different computer systems, business processes, and decision making. Even though both systems were fundamentally different, they had the same goal of assisting in decision-making.

Expert systems and decision support systems were based on computer technologies and used quantitative methods in the algorithms and models to analyze the data. The development of graphical user interfaces (GUIs) influenced by the decision-making discipline complement these systems. This convergent period did see the consolidation in the evolution of technology, quantitative methods, and decision-making into single systems to maximize their impact, showing the decision-making discipline's influence on technological and quantitative subjects.

Business intelligence architecture and techniques were the primary concern in the early 1990s and mid-2000, characterizing the fifth period, which saw the creation of data warehouses through DSS, databases, market research's blended architecture, and the transactional data collected using barcode scanners. The increasing data volumes presented technological challenges and stimulated new quantitative and decision-making approaches, resulting in data mining discipline to deal with large datasets available in this period.

The data mining discipline creates credible and effective solutions by combining statistics, SQL, and machine learning. Dashboards that are mostly GUIs, if compared to DSS systems, could rapidly disclosure necessary business performance measures because they are pre-populated with key performance indicators popularized by Kaplan and Norton's balanced scorecard management tool.

The combination of Kaplan and Norton's framework and dashboard technologies in this period created a culture of management by metrics, whereby KPIs determined staff bonuses, strategic and operational decision making. In a nutshell, the BI period introduced new architectures and procedures, making the storage, management, and delivery of data inside an organization efficient and consistent.

The sixth period, extending from the mid-2000s to the present days, is marked by the prominence of analytics and has seen a growth in data supported by the internet usage on such a scale that limited the BI architecture and relational databases, creating in this way, the demand for new architectures and technologies. The data complexity brought challenges for the quantitative analyst because of the prevalence of unstructured data, leading to text mining, network analysis, and natural language processing.

These large datasets require a more inductive approach, in which correlations are more critical to the process than model building that seeks data reduction in the interest of performance and parsimony. To sum up, the sixth period has seen new changes to the scientific approach in modern architectures and processing techniques.

This history presents scientific management from basic calculators to computerized models, automating millions of decisions every second. The understanding of decision-making and effective communication of information has seen similar progress. Crucial to this new management paradigm’s history is the simultaneous development of the quantitative decision-making disciplines and the related technology to build what Mortenson et al. (2015) call an analytics ecosystem.

5.1.2. Kimball data warehouse toolkit

According to Kimball and Ross (2013), the information generated in an organization serves operational record-keeping and analytical decision-making purposes. Transactional systems, characterized for not maintaining history, keep the data generated by the organization’s day-to-day business processes optimized to deal with one transaction at a time in a rapid fashion.

On the other hand, data warehouses (DW) and business intelligence (BI) systems watch for the organization’s day-to-day business processes performance, for instance, by comparing this month's sales orders to last month's sales orders. These systems answer business users’ questions by searching it over thousands of transactions and require this historical data to have its context preserved to evaluate the organization’s performance over time accurately.

Designing DW and BI solutions over business needs to lay the ground for logical and physical structures is paramount to perform such analyzes. The tools and technology comprising a DW and BI system must enable its content to be easily accessible, secured, consistently, and promptly presented for the decision-making process. It needs to be immune to disruptions caused by business changes over time to be considered successful and be embraced by the business community.

For a DW and BI system to meet such requirements, analytic data must be quickly at the disposal of business users and allow fast querying. Dimensional data modeling is a technique advocated by Ralf Kimball, which can simultaneously address these two requirements and make databases simple. This simplicity ensures that the users understand and navigate the data to deliver fast, easy, and efficient results.

Even though relational databases management systems instantiate dimensional data models, in which third normal form data models usually are held, they are a different type of data model. Third normal form data models, known as normalized models, are designed to reduce data redundancies by dividing data into discrete entities, each of which becomes a relational table. These normalized models optimize one-time transactions, such as inserts, updates, and deletes for transactional systems mentioned earlier, but are too complicated for BI queries.

Entity-relationship diagrams (ERD) represent both data models, the dimensional and the normalized models, to communicate the relationship between tables. Still, the difference between the two types of data models is the degree of normalization. Dimensional models do not reach the third normal form, aiming to trade data redundancy by query performance and data understandability.

Another dimensional data model trait is that they comprise fact and dimension tables to hold information about an organization’s business process performance. The information about business process events stored in a fact table must be the lowest data level for one business process in a single-dimensional model.

In other words, each row in such a fact table must correspond to a business process measurement event and be at a specific and unique level of detail, called grain. Fact tables can store additive, semiadditive, and non-additive measures categorized as a transaction, periodic, and accumulating snapshot fact tables.

These tables have two or more foreign keys to connect their rows to the dimension tables to satisfy referential integrity. In other words, a fact means business measure and must be kept in a single repository for access throughout the enterprise by business users, avoiding replication to ensure consistency.

These dimension tables contain textual context associated with the business process measurement event and describe the “who, what, where, when, how, and why” associated with it. Dimension tables joined to the fact table make their data accessible and are defined by a single primary key, being the basis for the referential integrity with the fact tables mentioned earlier. Crafting attributes carefully in a dimension table provides sensible query constraints, groupings, and report labels, delivering in this way robust analytic slicing-and-dicing capabilities.

To summarize, the structure containing a fact table with the business event’s measurement connected to the dimension tables giving it context is called star schema and represents a single business process. This structure should contain atomic data as the foundation of any fact table design to support any business user question and withstand time because it is easily extensible.

Beyond these technical guidelines, Kimball and Ross (2013) propose a DW and BI technical reference architecture. It comprises the four distinct components of transactional source systems, ETL system, data presentation area, and business intelligence applications.

The transactional source systems keep the operational records mentioned previously in this section and do not maintain historical data. The DW and BI environment can relieve these systems from the burden of representing the past. Because such transactional source systems are outside of the DW and BI environment, their data format is also out of DW and BI environment’s control.

In a DW and BI environment, the ETL system is a set of processes and data structures responsible for delivering data to the dimensional data models in the presentation area. It adds value to the data by extracting the data from operational source systems to enhance it through cleansing processes, combining data from multiple sources, and de-duplication. These conforming and cleansing tasks can create diagnostic metadata and eventually lead to business process reengineering to improve the transactional source systems’ data quality.

The DW and BI presentation area contains queried data by the business users, report writers, and analytical BI applications. Dimensional data structures must keep this data, such as star schemas or online analytical processing (OLAP) cubes containing atomic data. Business process events drive this data organization and adhere to the bus architecture using conformed dimensions, which is the key to build distributed DW and BI systems iteratively.

The last of these four Kimball and Ross’ (2013) DW and BI architectural components are the BI applications that leverage the data in the presentation area and refer to the business users’ systems capabilities, including ad hoc queries, application modeling, or sophisticated data mining applications. Some of these applications can upload data back to the transactional source systems or even to the presentation area.

Overall, business intelligence practitioners put a great effort into developing the star schema dimensional data model by following these technical guidelines described so far. The primary reason for this is because they drive the building of robust data warehouses to provide business users a powerful business analysis experience through the technical reference architecture presented.

Drilling down is the most fundamental data analysis activity, which involves adding a row header in an existing SQL query by including a dimension attribute in the GROUP BY command. This kind of analysis does not require the predefinition of hierarchies or drill-down paths.

Drill-across reports enable consistent analysis and data integration in a data warehouse, allowed by conformed dimensions. Conformed dimensions have attributes in separate dimensions tables with the same name and domain contents, enabling a single report to combine the information in different fact tables.

Following Kimball and Ross' (2013) approach to building a data warehouse to provide such analytic capabilities is complex. Its implementation follows an incremental approach by decomposing its planning process into manageable pieces based on business processes through standard conformed dimensions to deliver integration, enabling the reuse of dimension tables across business processes.

Enterprise data warehouse bus architecture is an architectural framework that enables such an incremental approach using conformed dimensions by addressing its rows. It serves as a design and communication tool with its rows representing business processes and its columns dimensions. Scanning this matrix shaded cells through columns indicates the dimensions taking part in the business process. Going through the rows with the same shaded column reveals the conformed dimensions at each business process.

This tool prioritizes the implementation of DW and BI projects by implementing one matrix row at a time, guided by the organization's natural flow of business processes known as the value chain. The value chain's steps of any organization generate transactions with metrics at different time intervals with unique granularities. Transactional source systems produce such transactions, making each business process spawn at least one fact table.

5.1.3. A brief discussion of the business intelligence subsection

The Business Intelligence discipline emerged in 1990 to support business decision-making in the context of scientific management. Kimball and Ross (2013) developed the framework for building DW and BI solutions to support business decision-making in such context through its processes, tools, and technologies.

This support is related to the fact that Kimball and Ross' (2013) framework provides several technical guidelines to build the star schema dimensional data model by first selecting a business process before deciding which performance metrics and dimensions to describe in the data model. Designing a dimensional data model based on vital business processes can provide crucial business process information aligned with the organization's strategic goals for any kind of performance measurement system.

5.2. BUSINESS PERFORMANCE MANAGEMENT

This section presents Eckerson's (2011) work on performance management, implemented through a closed-loop process to improve business management and turn strategy into action by measuring performance throughout an organization. Eckerson believes that the business intelligence discipline is vital to provide a data infrastructure for such performance management.

5.2.1. The BPM four-step closed-loop process

For Eckerson (2011), business performance management (BPM) is a concept that has different meanings and reflects everything vendors have to offer their customers in terms of applications and technologies that do not represent the discipline of business performance management.

The goal of BPM is to help organizations to become more focused, aligned, and productive. To achieve it, organizations must identify the key activities that contribute to their success in achieving their strategic objectives through a series of processes and technologies, which can help optimize their business strategy.

In other words, business performance management bridges the gap between strategy development and its execution by focusing on activities that contribute to the long-term health of an organization. The outcome is improved communication of strategy throughout the organization via dashboards and scorecards, boosting coordination through the exchange of ideas and information virtually at all organizations' levels and across business units to focus on the refinement of the right processes and products.

Bridging the gap between strategy development and its execution can provide business management automation by executing a four-step, closed-loop process consisting of strategizing, planning, monitoring and analyzing, acting and adjusting. This closed-loop process has integrated data and metrics as its foundation, alongside a shared vocabulary to provide the means for measuring performance across all organization's dimensions.

On the one hand, strategize and plan steps create vision, goals, and plans to complete these steps and constitute the "strategy" part of performance management. On the other hand, monitor and analyze, and act and adjust steps represent the "execution" of strategy to monitor and analyze performance and adapt plans and targets as necessary.

In the first step of this closed-loop process, strategize, companies defined their mission, vision, values and set the goals to achieve short- and long-term objectives. The best strategies establish critical drivers of business and ways to measure these drivers. Organizations can depict their strategy by arranging it in a strategy map to organize strategic goals in a single page using cause-and-effect logic, evidencing which objectives influence others.

The closed-loop process's second step, plan, allocate resources, people, knowledge, and technology to carry out new initiatives, projects, and procedures or refining existing ones, which usually involves breaking down corporate objectives into discrete targets for every group across the organization.

Monitor and analyze performance constitutes the closed-loop process's third step and enables business users to understand the business and proactively achieve the goals. Performance dashboards provide the users this ability visually and consist of business intelligence tools for reporting and analyzing information based on data integration infrastructure for collecting and integrating data from different sources.

Lastly, in the closed-loop process's fourth step, act and adjust, performance dashboards play a crucial role because they alert business users to potential issues and provide them with further detail to help them make better decisions.

5.2.2. A brief discussion of the business performance management subsection

The business performance management concept and its proposed BPM framework is a discipline that leverages the Kaplan and Norton balanced scorecard framework and other tools already applied in strategic management. At first glance, it resembles Kaplan and Norton's (2008) five-step closed-loop process aiming to reduce the tensions between strategy and operations presented earlier.

Despite the different number of steps observed in each of these two frameworks' closed-loop processes, both pursue the organization's long-term health. However, Kaplan and Norton's (2008) strategic management system focus on the alignment of strategic and operational plans. In contrast, business performance management pursues the identification of critical business activities based on consistent data and metrics. In other words, BPM focus on the organization's essential business processes when defining and executing the strategy.

5.3. DASHBOARDS

This section presents Eckerson's (2011) work on performance dashboards, which uses Few's (2006) dashboard design techniques to address the different stakeholders' needs by providing the right information to each specific audience.

5.3.1. Dashboards design

For Few (2006), dashboards can support any goal worth monitoring and use different data to build it, having its visual design and functionality determining its role. These dashboards can be strategic, analytical, or operational and have their layout characteristics adjusted accordingly to each function.

Dashboards have a primary purpose in the strategic role. Any dashboard aiming to support managers at any level in the company must provide them a quick overview of the business opportunities and overall health. Usually, these dashboards present high-level performance measures. Even though contextual information can help clarify the meaning of such measures by comparing them to targets and using brief histories, this kind of information can distract the decision-maker.

Strategic dashboards benefit from simple visual displays, and because their goal is showing long-term direction, monthly, weekly, or daily data snapshots work better than real-time data. As the strategic manager rarely has the responsibility to conduct further analysis, this dashboard should not provide interaction, making it a unidirectional display that only presents its status.

Primarily, dashboards display quantitative measures, usually expressed in summary form and less often as averages. Measures of distribution and correlation, such as standard deviation and linear correlation coefficient, respectively, are rarely used. The limited space of a single screen and the dashboard's role determines how to use summary expressions of quantitative data in various timeframes.

Comparison and evaluation enrich the measure's presentation, making comparisons expressed graphically an effective way to communicate the differences between measures, instead of using text alone. Time series is an example that provides context to understand what is happening and how well some aspect of the business is performing.

On the other hand, evaluation gives the dashboard reader the ability to quickly understand if a measure achieved the target or not by encoding this information in special visual techniques and artifacts, such as traffic lights or visual attributes. These visual features can use colors to alert the reader about the state of specific measures.

Although these visual artifacts and techniques can be helpful, they should be parsimoniously used to not affect the readers' visual perception by respecting their short-term visual memory. Gestalt principles of proximity, closure, similarity, continuity, enclosure, and connection lower the stress on the reader's optical sensing and visual encoding.

5.3.2. Performance dashboards

According to Eckerson (2011), business performance management comprises several management disciplines, processes, and tools to improve any organization's strategy execution. On the other hand, business intelligence is the infrastructure that allows the measurement, monitoring, and management of business processes driving business performance. For this reason, there is not a specific BPM solution that reflects the BPM discipline.

Nevertheless, organizations monitor business performance by developing and deploying dashboards and scorecards, which also have a comprehensive definition and purpose. Enterprises have used business intelligence and data integration tools to build dashboards and scorecards.

Performance dashboards are a specific dashboard, a performance management system providing business users the capability to monitor critical business processes and activities by triggering alerts when performance is below predefined targets. These performance dashboards also provide the ability to analyze the root cause of issues by exploring information at different levels of detail and perspectives to steer the organization by managing processes and people to improve decisions and enhance performance.

There are performance dashboards designed to enhance operational and tactical processes. However, the most popular one is the strategic performance dashboard, which is usually bound to the balanced scorecard methodology for monitor and manage business strategy.

The top management's need to monitor the organization using a dashboard, known as the executive cockpit, gave rise to the performance dashboard. The executive information systems (EIS) is an example of this kind of dashboard back in 1980. These systems faded away for being highly costly to address a few people's needs in the company.

Later in the 1990s, organizations experimented with different ways to give executives direct access to integrated information quickly, starting the field known today as business intelligence. At the same time, executives turned to new techniques and methods to manage strategy and enhance performance, a discipline broadly defined as business performance management.

As a result, many companies started using business intelligence to provide the technical infrastructure for business performance management initiatives, and after 2000 started the convergence of BI and BPM disciplines to create the performance dashboard.

For Eckerson (2011), a performance dashboard is “a layered information delivery system that parcels out information, insights, and alerts to users on-demand, so they can measure, monitor, and manage business performance more effectively” (Eckerson, 2011, p. 15 chapter 1).

Such a definition clearly states that a performance dashboard is not about screens displaying graphics but brings a performance management system. It is a system designed to manage business performance, which according to Eckerson (2011), provides three applications composed of three layers of information classified into three types.

These three applications are monitoring, analysis, and management. They are not distinct programs but capabilities provided over an information infrastructure built to fulfill the business user requirements to control and act, analyze, and review performance.

The performance dashboard’s monitoring application, or operational performance dashboard, enables users to monitor performance against metrics aligned with corporate strategy. Users monitor core processes daily at an operational level while monitoring progress towards achieving short- and long-term goals at a strategic level.

Even though companies monitor core operational processes through dashboards and strategic goals using scorecards, both are mechanisms used in a performance management system to display critical performance information. It is crucial to keep in mind that they are not the entire system themselves. While dashboards display detailed data daily or intraday frequency, scorecards convey weekly, monthly, quarterly, or annual snapshots of summary data.

The search for the root cause of an exception highlighted in the monitoring layer of a core business process, or operational performance dashboard, is analyzed using the analysis application of a tactical performance dashboard. It can leverage many technologies to enable such an analysis, including online analytical processing (OLAP), parameterized reporting, ad hoc reporting, visual analysis, and predictive analytics. This research requires a data management infrastructure to provide clean and consistent data, which often follows a dimensional data structure.

Finally, the last type is the performance dashboard management application, or strategic performance dashboard, which provides features enabling collaboration and decision making, supporting navigation to the desired page, and printing its content, for instance, to tailor the dashboard to help in meetings.

These three applications, or types of performance dashboards, enable the business users to handle information in a layered approach, monitor critical metrics for exceptions, analyze data to shed light on those exceptions, and drill to the report details. For this reason, Eckerson (2011) refers to this approach as MAD, which stands for monitor, analyze, and drill to detail.

A critical characteristic of the MAD approach proposed by Eckerson (2011) is that the top layer, or strategic dashboard, display around ten metrics, which drill into ten additional metrics in the middle layer, or tactical dashboard. These middle layer metrics explode into more than ten metrics in the bottom layer or operational dashboard. In other words, a dashboard with around ten metrics in the top layer provides more than a thousand contextual views of these metrics at different levels of granularity.

This MAD approach provides users a tool to monitor the top layer's summary information through visual exception alerts. In the middle layer, users can analyze the dimensional data using analytical tools to enable slice and dicing, drill up and down, or pivot data to have different perspectives of those exceptions. The bottom layer provides detailed data to perform the root cause analyses, usually as reports or lists.

In other words, the MAD approach enables the use of these three types of performance dashboards to emphasize to different degrees the three layers of information and the three applications described previously. An operational dashboard is action-oriented and focuses on monitoring core business processes through detailed data refreshed frequently. A tactical dashboard emphasizes dimensional data to optimize departmental procedures.

A strategic dashboard prioritizes the management by monitoring the strategy's execution to review progress towards strategic goals and objectives, starting with a strategy map and usually implemented using a balanced scorecard methodology. However, dashboards can partially apply the balanced scorecard methodology by, for instance, showing the inter-relationship between metrics instead of goals, which is quicker to build because it does not need the development of a strategy map and is known as a management scorecard.

For Eckerson (2011), a DW and BI infrastructure should be the base for implementing a performance dashboard. However, strategic dashboards usually do not have enough source data to load from and often are populated using manual data entered in a spreadsheet.

5.3.3. A brief discussion of the dashboards subsection

The convergence of business performance management and business intelligence disciplines gave rise to the performance dashboards supported by the MAD approach developed by Eckerson (2011), which helps organizations monitor their strategic goals.

The MAD approach is a framework enabling the integration of strategic, tactical, and operational dashboards. Such dashboards use different types of data to address the various stakeholders' needs. The kind of data used at each level of this integration classifies dashboards by role and leverages Few's (2006) design techniques to build each of them to address a specific audience type. In other words, the sort of data necessary to construct these dashboards determines their visual design and functionality.

5.4. A BRIEF DISCUSSION OF SECTION FIVE

Kimball and Ross' (2013) framework provides a complete DW and BI tool kit, which comprises technical guidelines for building a data warehouse and a technical architecture reference. On the one hand, Kimball and Ross' technical guidelines for developing a data warehouse can improve data consistency and metrics. These guidelines can provide a common vocabulary to support vital business process information by designing a star schema dimensional data model driven by crucial business processes. It can increase the chances of aligning critical business process information with business performance management strategic goals.

On the other hand, Kimball and Ross' (2013) technical reference architecture can directly support Eckerson's (2011) MAD approach for designing performance dashboards by providing a framework based on various integrated tools. Such technical architecture can support the development of operational, tactical, and strategic performance dashboards that can totally or partially apply Kaplan and Norton's balanced scorecard methodology to measure the smart city's environmental, social, and economic aspects.

6. DATA AND RESEARCH METHODOLOGY

This master project conducts an exploratory literature review to identify relevant studies by searching for articles in google scholar, b-on, and science direct with the following keywords: "performance measurement system," "smart cities," "corporate performance system," "performance dashboards," "sustainability," "business intelligence," "sustainable development," "balanced scorecard," "corporate sustainability," followed by cross-references to identify further relevant research.

During the literature review of the smart city concept, this master project found concerns in the material reviewed about the assessment tools created to measure cities' performance. Disciplines to monitor this performance at a strategic level through strategic management for smart cities, used methods, processes, and tools to collect, store, and analyze data to produce the dashboard, complement the study.

This study does not intend to build a strategy formulation process because there are already excellent frameworks to accomplish this task. Instead, it creates a strategic performance dashboard for decision-makers to monitor, under the light of the triple bottom line concept, the EU2020 sustainable development strategy's performance.

The conceptual model presented later aims to provide an overview of the bodies of knowledge necessary to support the dashboard's creation using business intelligence discipline under the light of the triple bottom line concept. It is an extension of the business performance management framework proposed by Eckerson (2011), which considers the smart city, corporate sustainability, and balanced scorecard concepts in the broader strategic management process.

6.1. DATA

The european commission makes available at the eurostat portal data related to its EU2020 sustainable development strategy. The proposed strategic performance dashboard uses such data, comprising thirty headline and contextual indicators observed for twenty-seven european union (EU) countries covering 2012 to 2016. The data depicted by the dashboard and its analysis, both presented later, regards the year 2014 (European Commission, Eurostat Portal, n.d.-a; European Commission, Eurostat Portal, n.d.-b).

According to Akande et al. (2019), Eurostat ensures that its information data quality and integrity processes follow an encompassing and rigorous quality management approach that makes its data suitable for research purposes.

Table 6.1 describes the EU2020 strategy made available by the European Commission and its associated measures, revealing three main priorities and eight goals (European Union, 2018):

Priorities	Measures	Type	Targets
Smart growth	t2020_20	Headline	Increasing combined public and private investment in R&D to 3% of GDP
	t2020_40	Headline	Reducing school drop-out rates to less than 10%
	t2020_41	Headline	Increasing the share of the population aged 30-34 having completed tertiary education to at least 40%
Sustainable growth	t2020_30	Headline	Reducing greenhouse gas emission by at least 20% compared to 1990 levels
	t2020_31	Headline	Increasing the share of renewable energy in final energy consumption to 20%
	t2020_34	Headline	Moving towards a 20% increase in energy efficiency
Inclusive growth	t2020_10	Headline	Increasing the employment rate of the population aged 20-64 to at least 75%
	t2020_50	Headline	Lifting at least 20 million people out of the risk of poverty and social exclusion

Table 6.1 – EU2020 sustainable development strategy targets – Adapted from "*Smarter, greener, more inclusive? Indicators to support Europe 2020 strategy,*" by European Union, 2018, (https://doi.org/doi:10.2785/80156). Copyright 2018 by European Union.

A brief review of table 6.2 reveals that the EU2020 strategy has the five different thematic areas of employment, education, poverty and social exclusion, climate change and energy, and R&D and innovation.

It organizes the thirty headline and contextual indicators of the EU2020 strategy for sustainable development according to these five thematic areas alongside its triple bottom line (TBL) perspective. The lack of data for the five years between 2012 and 2016 led to exclude the measures tps00188 and sdg_04_40 (European Union, 2018).

TBL Perspective	EU2020 Thematic Area	Measure	Type	Description
Economic	Employment	t2020_10	Headline	Employment rate
Economic	Employment	lfsa_enewasn	Contextual	Newly employed persons
Economic	Employment	lfsa_epgar	Contextual	Involuntary part-time employment
Economic	Employment	lfsa_etgar	Contextual	Involuntary temporary employees
Economic	Employment	lfsa_urgaed	Contextual	Unemployment rate
Economic	Employment	tipslm90	Contextual	Not in employment, education, or training
Economic	R&D and innovation	t2020_20	Headline	R&D expenditure
Economic	R&D and innovation	htec_kia_emp2	Contextual	Employment in knowledge-intensive activities
Economic	R&D and innovation	htec_trd_group4	Contextual	High-tech exports outside the EU
Economic	R&D and innovation	rd_p_persocc	Contextual	Total R&D personnel and researchers
Social	Education	t2020_40	Headline	Early leavers from education and training
Social	Education	t2020_41	Headline	Tertiary education attainment
Social	Education	sdg_04_30	Contextual	Participation in early childhood education
Social	Education	sdg_04_50	Contextual	Employed recent graduates
Social	Education	sdg_04_60	Contextual	Participation in adult learning
Social	Poverty and social exclusion	t2020_50	Headline	People at risk of poverty or social exclusion
Social	Poverty and social exclusion	ilc_peps01_age	Contextual	People at risk of poverty or social exclusion by age group
Social	Poverty and social exclusion	ilc_peps01_sex	Contextual	People at risk of poverty or social exclusion by sex
Social	Poverty and social exclusion	ilc_peps03	Contextual	People at risk of poverty or social exclusion by household type
Social	Poverty and social exclusion	ilc_peps06	Contextual	People at risk of poverty or social exclusion by a broad group of the country of birth
Social	Poverty and social exclusion	ilc_peps13	Contextual	People at risk of poverty or social exclusion by the degree of urbanization
Social	Poverty and social exclusion	ilc_peps60	Contextual	Children at risk of poverty by educational attainment level of their parents
Social	Poverty and social exclusion	t2020_51	Contextual	People living in households with very low work intensity
Social	Poverty and social exclusion	t2020_52	Contextual	People at risk of poverty after social transfers
Social	Poverty and social exclusion	t2020_53	Contextual	Severely materially deprived people
Environment	Climate change and energy	t2020_30	Headline	Greenhouse gas emissions
Environment	Climate change and energy	t2020_31	Headline	Share of renewable energy in gross final energy consumption
Environment	Climate change and energy	t2020_33	Headline	Primary energy consumption
Environment	Climate change and energy	t2020_34	Headline	Final energy consumption
Environment	Climate change and energy	sdg_07_50	Contextual	Energy dependence

Table 6.2 – EU2020 sustainable development indicators – Source: European Union (2018)

6.2. RESEARCH METHODOLOGY

According to Cooper and Schindler (2014), a research design is a plan to collect, measure, analyze, and report the analysis to answer questions about a specific phenomenon, classified into the four types of reporting, descriptive, explanatory, and predictive studies.

Descriptive research involves searching for who, what, when, where, and how questions related to a topic. It primarily helps with planning, evaluating, and monitoring activities because of its versatility, and is also prevalent between administrators and policy-makers.

A correlational study is a subset of descriptive research that analyses the relationship between two or more variables. This research type may present a correlational hypothesis, which states that the variables relate to each other without implying that one causes the other.

This master project adopts such a design and uses secondary cross-sectional data downloaded from European Commission, Eurostat Portal (n.d.-a), and European Commission, Eurostat Portal (n.d.-b) to perform a correlational study. It supports decision-makers in measuring the smart city's sustainable development performance using a dashboard. This data comprises the measures described in table 6.2 for twenty-seven EU countries from 2012 to 2016, having each observed metric in one spreadsheet containing all the twenty-seven EU countries for several years.

To analyze this data through correlational analysis and to use its results to complement the dashboard creation, it is necessary to organize it into a star schema dimensional data model. Microsoft power query tool's functionalities help to transpose the spreadsheets' data before loading it into a Microsoft SQL server database.

After loading the data into the star schema dimensional data model, SQL scripts helped prepare and extract a spreadsheet for each year from 2012 to 2016, containing all the measures listed earlier in table 6.2 observed for all the twenty-seven EU countries.

Running descriptive statistics was the first step taken on each of these five spreadsheets after loading them into the sas enterprise guide software. Primarily to check the data's behavior, find missing values to correct, and analyze the distribution of each of these measures to understand whether they follow a normal distribution or not.

Following this pre-analysis, the next step was to run the correlation analysis using the same software to generate a correlation matrix containing relationship information between the measures observed for all the EU countries for each of these years. The star schema dimensional data model received this information back to support the dashboard creation.

This section explains the design choices for creating the star schema dimensional data model and the design features provided by the literature review utilized in the dashboard. Such a dashboard displays relationship information supplied by the correlational study to support the monitoring of a smart city's strategic performance, which has its analysis also presented later.

Besides, this master project provides a conceptual model that is an extension of the business performance management closed-loop process presented by Eckerson (2011). It aims to give business intelligence practitioners a high-level overview of the concepts involved in developing a strategic performance dashboard and when to use them to create this tool to support the strategic management process using the business intelligence discipline.

6.2.1. Conceptual model

This master project does not intend to provide a detailed step-by-step process. Still, it supplies business intelligence practitioners with an overview of when to use the smart city, corporate sustainability, and balanced scorecard concepts to support the proposed dashboard production. Its creation uses the business intelligence discipline’s concepts to monitor a strategic management process by extending Eckerson’s (2011) business performance management framework.

The goal is to create a strategic performance dashboard that partially applies the balanced scorecard framework, which should consider the smart city’s vision, mission, and values to help decision-makers monitor the smart city strategy’s execution to measure its performance.

For this reason, it utilizes a diagram to represent a high-level overview of this four-step closed-loop process to communicate the intended portion of the real-world. To this end, it requires a purpose, already described above, and to address someone’s one or more concerns. The next couple of paragraphs review the sustainable development definition and the following problems presented in section two of this study to support these requirements.

According to Strange and Bayley (2008), sustainable development is a multidimensional challenge founded on the environmental, social, and economic aspects measured through indicators considered altogether to some extent. Ahvenniemi et al. (2017) and Kummitha and Crutzen (2017) declare that the sustainable city concept embraces the sustainable development definition provided by Strange and Bayley (2008). Besides, they state that the smart city framework uses the ideas and values provided by both supported by technology.

On the one hand, Ahvenniemi et al. (2017) and Kummitha and Crutzen (2017) primary concerns are that smart city assessment tools do not consider environmental, social, and economic aspects altogether nor manage these aspects simultaneously. On the other hand, Kourtit and Nijkamp (2018) point out the importance of considering the inter-relationships between environmental, social, and economic measures when creating a dashboard based on balanced scorecard concepts.

The square in the center of figure 6.1, titled “smart city environment,” represents the smart city’s internal environment, in which decision-makers monitor its strategy and measure its performance. This monitoring is essential to verify if the city achieves its environmental, social, and economic strategic targets.

Inside the “smart city environment” is laid the traditional business performance management’s four-step closed-loop process, proposed by Eckerson (2011). It comprises “strategize, plan, monitor and analyze, and act and adjust,” with the addition of the “data warehouse” created using the dimensional data model technical guidelines proposed by Kimball and Ross (2013) in the center of this process.

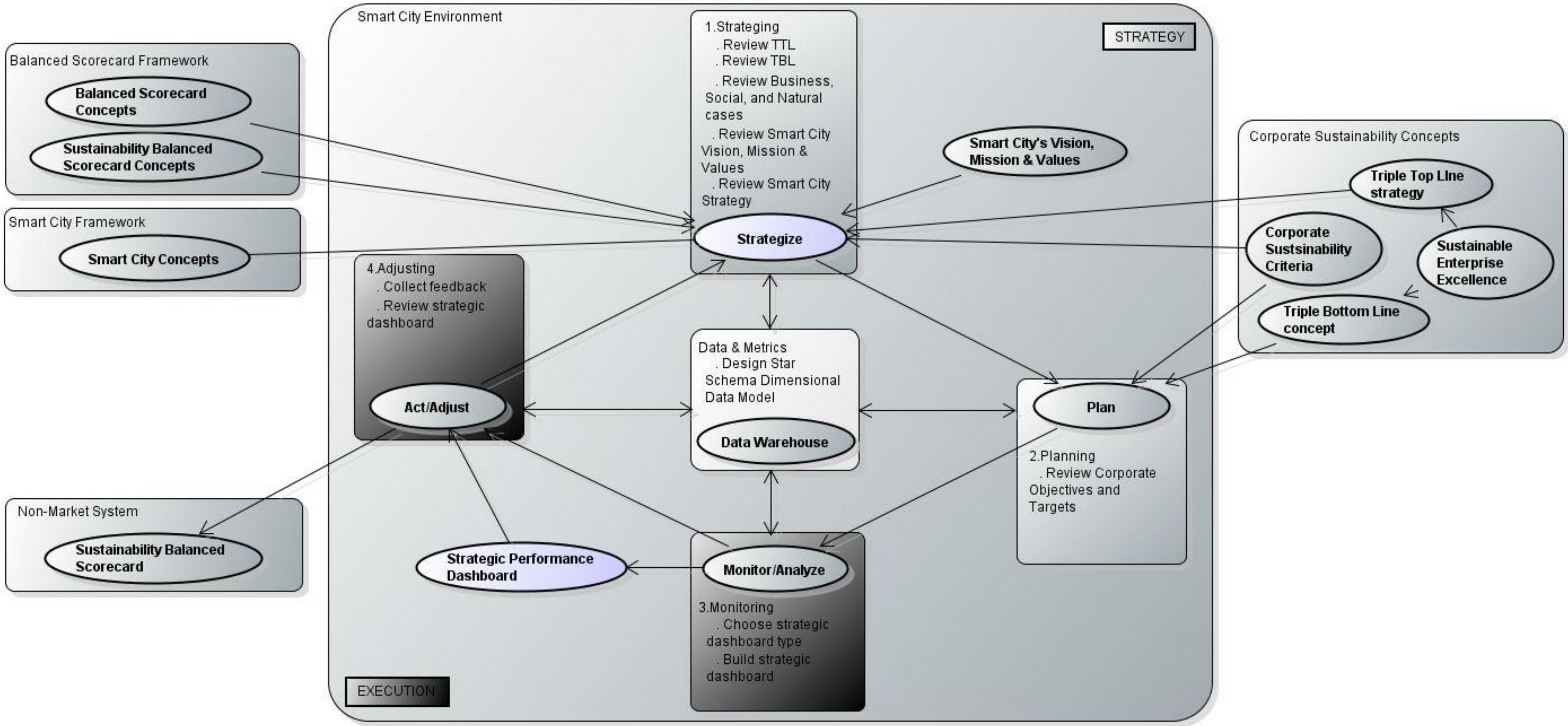

Figure 6.1 – Conceptual Model – Adapted from "*Performance dashboards: Measuring, monitoring and managing your business*," by Eckerson, W., 2011. Copyright 2011 by John Wiley & Sons, Inc.

The closed-loop process steps have one-sided arrows, which indicate the direction of the process's flow between each of the four stages. The "data warehouse" in the center has two-sided arrows leading to each of the process's four-steps to indicate that any of them can reach the "data warehouse" at any point in the process to access consistent data and metrics to manage it.

A smaller square encloses each of these four steps, which contains specific actions to follow at each of them, in which "1.Strategizing" and "2.Planning" have a light shade to represent the "strategy" side of the process. In contrast, "3.Monitoring" and "4.Adjusting" have a darker shade to show the "execution" part of it as in the original process presented by Eckerson (2011).

The values and ideas presented by the "corporate sustainability" concept bring additional information to support the integration of the environmental, social, and economic aspects proposed by the "smart city framework." These values and ideas can help understand how decision-makers arrived at the metrics selected to measure smart city strategic performance.

Besides, the "balanced scorecard" concepts help structure the data from different perspectives on a dashboard. The "sustainability balanced scorecard" concept adapts these ideas to integrate the business's ecological and social dimensions on the dashboard. In other words, such concepts bring the ideas used by decision-makers to associate the objectives of environmental, social, and economic dimensions with their respective metrics in the context of "smart city's vision, mission, and values."

Steps one and two represent the "strategy" part of the process developed by decision-makers. Its comprehension can add considerable value to business intelligence practitioners to build a strategic performance dashboard that can describe a smart city's strategy coherently to measure its performance.

The "execution" part of the process comprises steps three and four. Stage three aims to produce a dashboard to monitor the smart city's progress towards sustainable development's environmental, social, and economic targets established by the strategy under the triple bottom line's light. It leverages business intelligence tools and technologies proposed by Kimball and Ross' (2013) technical reference architecture.

In step four, decision-makers can determine if the "sustainability balanced scorecard" requires reformulation to address the external environment's needs. The "sustainability balanced scorecard" concept in smart cities calls such an environment a "non-market system." Primarily because Figge et al. (2002) believe that a municipality should treat environmental and social aspects as externalities outside the market exchange process, meaning that such elements and their related scarcities are not an integral part of the market system.

6.2.2. Star schema multidimensional data model

Business processes represent an organization's activities, which generate performance metrics that turn into business process events in a fact table when designing a data warehouse. For Kimball and Ross (2013), choosing a business process is the first step to enable the declaration of the grain, dimensions, and facts, which are critical components to define a design target. This design target comprises a star schema dimensional data model containing at least a single fact table surrounded by dimension tables representing a unique business process.

This master project follows the dimensional data modeling guidelines proposed by Kimball and Ross (2103). It assumes that distinct processes generate each measure's data in table 6.2 to design the star schema dimensional data model in figure 6.2. The outcome is a data warehouse having one transaction fact table for each of the thirty headline and contextual metrics obtained from the European Commission, Eurostat Portal (n.d.-a), and European Commission, Eurostat Portal (n.d.-b). These fact and dimension tables form the data infrastructure to create a strategic performance dashboard.

This sort of fact table design represents a business process event enabling better slice and dice of transactional data related to an observable physical activity. For clarity purposes, figure 6.2 depicts the star schema only for the t2020_10 EU2020 metric, having in the center the fact table Fact_ECO_EMPO_t2020_10.

The tables surrounding the transaction fact table in figure 6.2 are known as dimension tables. The Dimdate and DimGeography, respectively, help answer "when" and "where" questions. The other dimension tables of DimPriorities, DimTheme, DimIndicator, and the dimension table called DimDimension provide answers to the question "what," and together, they give context to the measure t2020_10's fact table content.

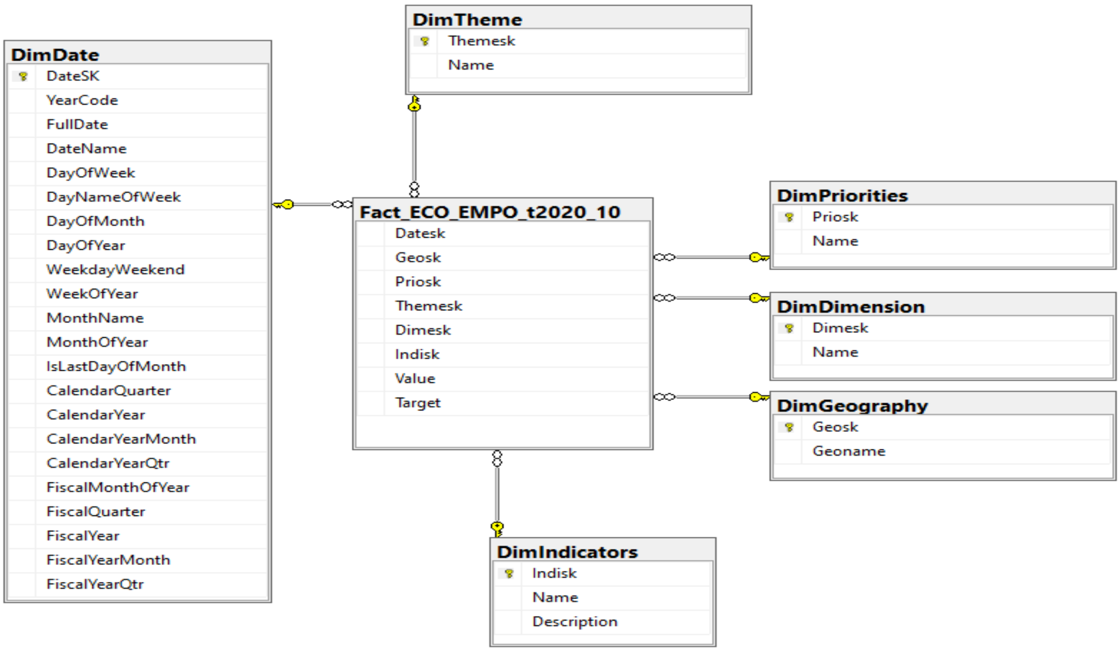

Figure 6.2 – t2020_10's star schema dimensional model

6.2.3. Correlational study

According to Cooper and Schindler (2014), when correlational studies involve interval or ratio data, they utilize Pearson's product-moment correlation coefficient to produce an index to measure the magnitude of the relationship between two or more variables. It determines the direction, strength, and shape features of such relation. The R^2 index, obtained by squaring the Pearson's product-moment correlation coefficient, measures the shared variance between the two variables.

This association measure varies between -1 and 1, meaning that values closer to these extremes represent stronger relationships because of their magnitude, while correlation coefficients closer to zero represent weaker relationships. The two variables' value can move in the same or opposite directions, in which case the former represents a direct relationship and the latter an inverse relationship.

Pearson correlation coefficient is a parametric statistical procedure that measures the linear association between a pair of two variables. For this reason, it requires the assumptions of linearity and normal distribution to be valid and for its results to be considered correct. When the variables involved in the analysis fail to comply with one of these assumptions, researchers must use a nonparametric method to measure the variables' association.

The Spearman association measure is a nonparametric and distribution-free statistic. It uses ranked data and approximates Pearson's product-moment correlation coefficient described in previous paragraphs when continuous variables present abnormalities to correct. Such a nonparametric measure of association is unaffected by outliers or by data transformed by logs or squaring.

Independently of the association measure used to perform the analysis, a hypothesis test can verify whether the coefficient representing the relationship between two variables is real or occur by chance, according to Meyres et al. (2009) and Cooper & Schindler (2014):

- Null hypothesis;
  - H_0: There is no relationship between the two indicators
  - H_1: There is a relationship between the two indicators
- Significance test: Fisher's Z transformation;
- Significance level: $\alpha = 0.05$;
- p-values: The spreadsheet in section 11.3.3 contains all the calculated p-values and confidence intervals for the year 2014;
- Results: p-values lower than 0.05 lead to the rejection of the null hypothesis and the consequent conclusion that the correlation coefficient is statistically significant.

This master project analysis starts with table 6.3, presenting the descriptive statistics of the EU2020 indicators in 2014 generated by the sas enterprise guide software. Figure 6.3 displays two histograms generated by r software to visually explore and compare the metrics t2020_31 and sdg_07_50 as an illustration.

Variable	Mean	Std Dev	Std Error	Minimum	Maximum	N	N Miss	Skewness	Kurtosis
lfsa_enewasn	14.455556	3.7634204	0.7242706	5.7	23.2	27	0	0.1084109	0.4095797
lfsa_epgar	11.777778	9.3999318	1.8090177	1.2	41.8	27	0	1.548913	2.8133055
lfsa_etgar	11.82963	6.8820175	1.3244449	1.5	28.3	27	0	0.6120179	-0.138812
lfsa_urgaed	10.237037	5.2588495	1.0120661	5	26.5	27	0	1.9355056	3.9681684
tipslm90	12.003704	4.5113942	0.8682182	5.5	22.1	27	0	0.5408934	-0.339044
t2020_10	69.381482	5.9343224	1.1420609	53.3	80	27	0	-0.622987	0.8543836
htec_kia_emp2	36.255556	7.3444554	1.4134411	19.5	60.4	27	0	0.9855649	3.9510953
htec_trd_group4	9854.07	17646.83	3396.13	47	76622	27	0	2.7389175	7.8917495
rd_p_persocc	102726.67	149000.36	28675.13	1284	605252	27	0	2.2378659	4.715257
t2020_20	1.6307407	0.8674007	0.1669314	0.38	3.17	27	0	0.5117675	-0.966088
sdg_07_50	55.1	25.60646	4.9279654	9.2	97.7	27	0	-0.051284	-0.932363
t2020_30	81.746667	26.3946	5.0796431	41.52	143.35	27	0	0.646597	0.3563065
t2020_31	18.918519	11.884348	2.2871438	4.5	52.5	27	0	1.0900989	1.0383965
t2020_33	55.596296	75.014073	14.436465	0.9	291.1	27	0	2.0074269	3.5076156
t2020_34	39.137037	51.923095	9.9926043	0.5	208.9	27	0	1.994593	3.6627095
sdg_04_30	92.2	6.7110701	1.291546	76.3	100	27	0	-0.953304	0.0720776
sdg_04_50	75.585185	11.62086	2.2364356	44.3	93.6	27	0	-1.283998	2.1222725
sdg_04_60	10.888889	8.017257	1.5429218	1.5	31.9	27	0	1.2555173	1.1328193
t2020_40	10.162963	4.7630911	0.9166573	4.4	21.9	27	0	1.1998547	0.6662989
t2020_41	39.881482	9.0395302	1.7396584	23.9	53.3	27	0	-0.242169	-1.056803
ilc_peps01_age	31.225926	8.5735099	1.6499727	17.3	51	27	0	0.6563072	0.0199916
ilc_peps01_sex	25.592593	7.0619743	1.3590776	16.3	41.3	27	0	0.7315639	-0.175025
ilc_peps03	49.692593	9.4459974	1.817883	35.8	69.3	27	0	0.3428758	-0.864944
ilc_peps06	22.585185	7.3412797	1.4128299	11.8	38.8	27	0	0.5770855	-0.232244
ilc_peps13	27.548148	11.246961	2.1644786	14.1	51.9	27	0	0.6864262	-0.436886
ilc_peps60	65.488889	14.123911	2.718148	42.8	93.5	27	0	0.6015871	-0.316316
t2020_51	1542.74	2005.01	385.8647	25	6036	27	0	1.5505604	0.882422
t2020_52	3153.48	4067.78	782.84443	66	13337	27	0	1.4727442	0.785513
t2020_53	1624.93	1934.18	372.2324	7	7031	27	0	1.280885	0.8630048
t2020_50	174.55556	856.24652	164.78472	-2155	2616	27	0	0.5075631	3.9855632

Table 6.3 – Descriptive statistics of EU2020 indicators for 2014

The indicator t2020_31 shows a skewness value of 1.09, representing a substantial departure from normality with the distribution “tail” pointing towards the right. Its kurtosis value of 1.03 indicates a departure from normality with a more peaked curve than a normal distribution curve. The histogram on the left-hand side of figure 6.3 shows such characteristics when comparing the blue line representing the t2020_31 indicator distribution in the 2014 dataset against the normal distribution curve’s red line.

On the other hand, the indicator sdg_07_50 shows -0.5 and -0.9 for skewness and kurtosis, respectively. Although the kurtosis value shows a small departure from symmetry, overall, this indicator seems to have a good approximation to a normal distribution as displayed by the histogram on the right-hand side of figure 6.3 when comparing the blue and red lines against each other. Appendix 11 contains the spreadsheets with the descriptive statistics for the remaining years.

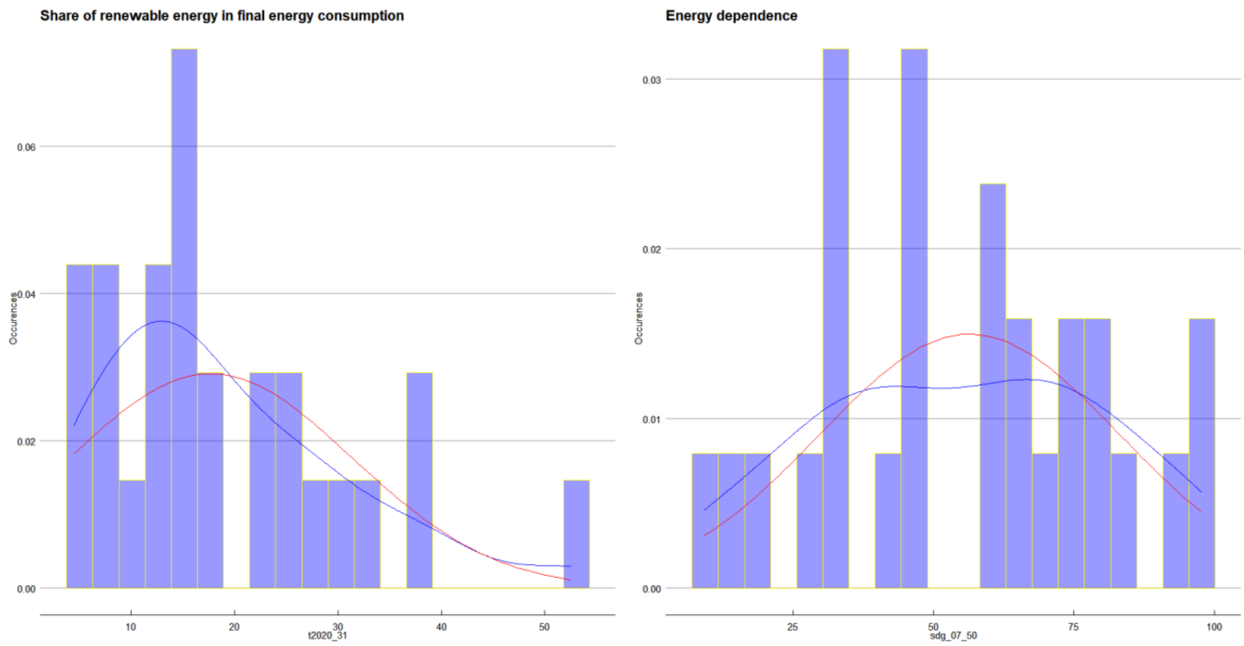

Figure 6.3 – Histograms of t2020_31 and sdg_07_50 indicators in 2014

Running a distribution analysis using the Shapiro-Wilk test to check the null hypothesis if a variable has a normal distribution confirms the histograms' exploratory visual analysis in figure 6.3. In other words, the sdg_07_50 indicator follows a normal distribution, while the t2020_31 indicator does not, according to the following information:

- Null hypothesis;
  - H_0: The indicator follows a normal distribution
  - H_1: The indicator does not follow a normal distribution
- Significance test: Shapiro-Wilk test;
- Significance level: $\alpha = 0.05$;
- p-values: t2020_31 = 0.0257, and sdg_07_50 = 0.5414;
- Results: p-values lower than 0.05 lead to the rejection of the null hypothesis and the consequent conclusion that the metric does not follow a normal distribution. In contrast, p-values greater or equal to 0.05 indicate that the metric follows a normal distribution by failing to reject the null hypothesis.

All the thirty measures in the dataset for 2014 and the remaining years used this same data analysis approach, which found that more than 60% of these metrics do not follow a normal distribution for all the five years analyzed. This outcome led to the usage of the Spearman statistic to conduct the correlation analysis.

According to Cooper & Schindler (2014), as Spearman statistic approximates the Pearson's product-moment correlation coefficient, the scatter plots in figure 6.4 show a red line representing the linear association between the pair enable a visual exploration of the correlation between them for illustration.

The left-hand side scatter plot's measures have a correlation coefficient of -0.45, which shows points plotted apart from each other, characterizing the shape of weaker relationships. The inclination of the red line indicates that both pairs of measures move in the opposite direction.

On the other hand, the other scatter plot's measures have a correlation coefficient of -0.85 and have the points plotted in a tidier fashion, characterizing the shape of stronger relations. The red line's steeper inclination also evidences the relationship's strength compared to the scatter plot on the left-hand side of figure 6.4. The p-values lower than 0.05 obtained from Fisher's z transformation confirms that both correlation coefficients are statistically significant.

This section presented a few visualizations to illustrate the exploratory data analysis used to understand the data before conducting the correlation analysis and loading the results to the star schema multidimensional data model. The first subsection of section seven uses the dashboard presented in figure 6.7 to analyze the relationship between all the eight measures representing the targets and the most influential indicator associated with them. Nevertheless, figure 6.5 depicts a panel of scatter plots of all those measures displayed in the dashboard for visual reference.

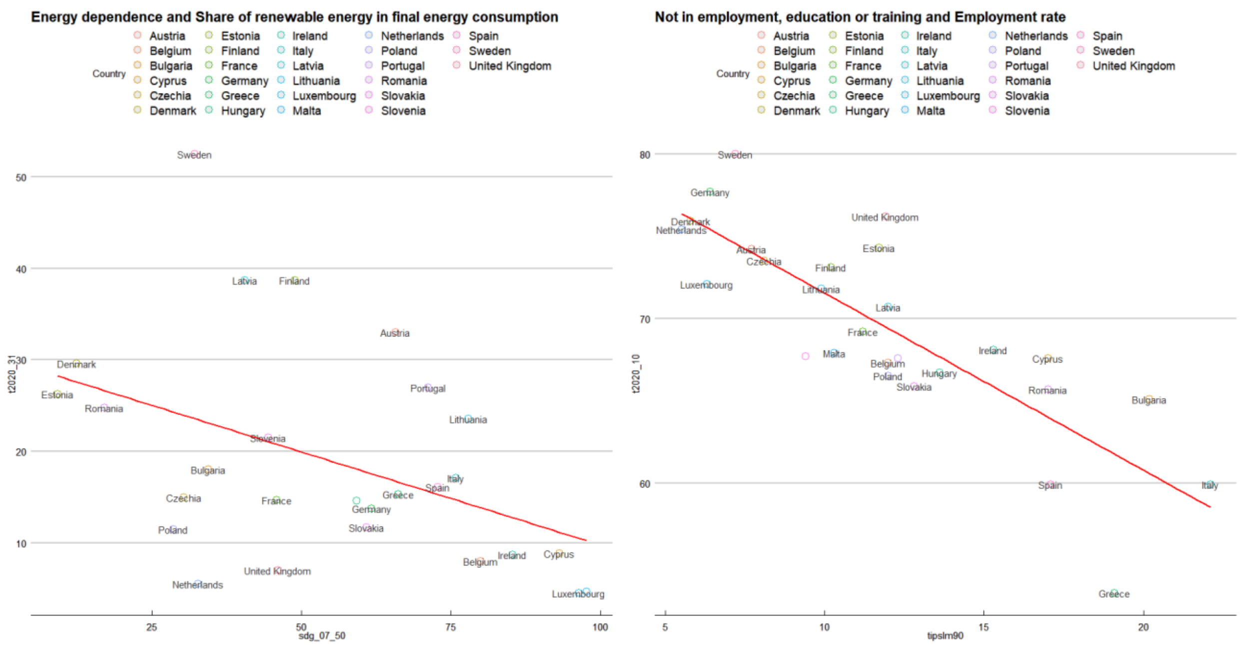

Figure 6.4 – Scatter plots of indicators t2020_31 x sdg_07_50 and t2020_10 x tipslm90

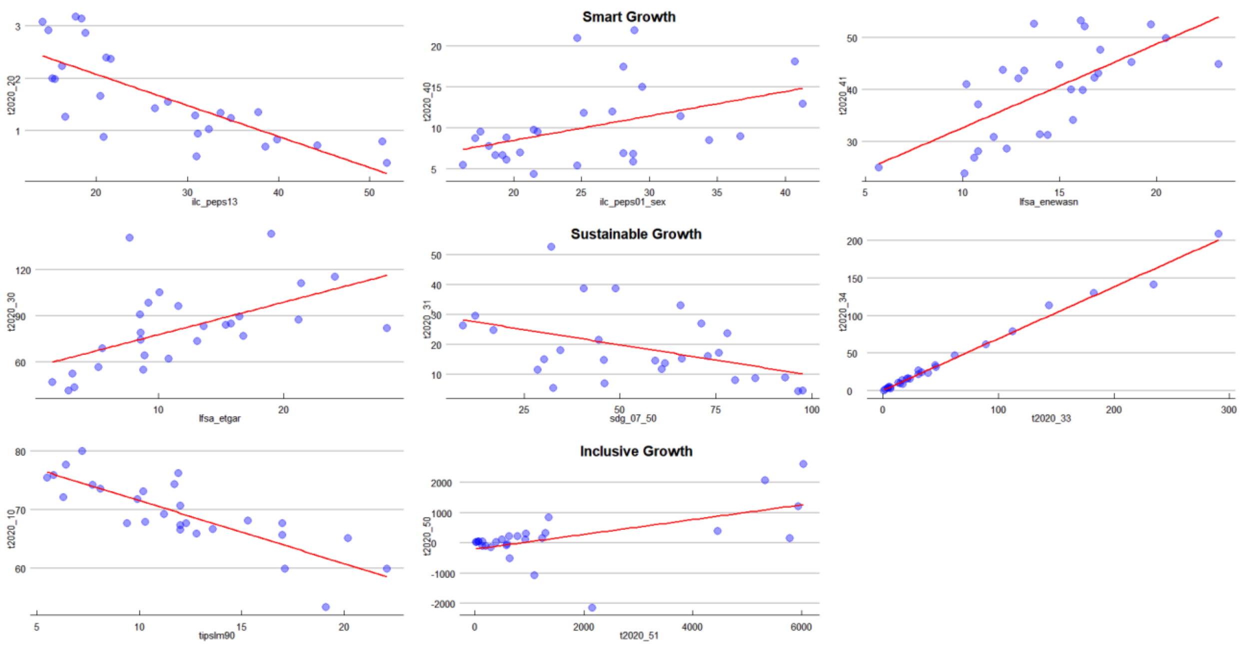

Figure 6.5 – Paneled scatter plots of driver indicators against outcome priorities targets

The star schema dimensional data model receives the resulting Spearman coefficient and the p-value obtained from Fisher's z transformation. The results include thirty measures having the twenty-seven EU countries as cases for each of the five years between 2012 and 2016 to support creating the strategic performance dashboard presented in figure 6.7 independently of their statistical significance. The Fact_Correlations table stores only the highest Spearman correlation coefficient between two indicators.

The star schema dimensional data model includes a reporting table to prepare the data to achieve this reporting goal by displaying the dashboard in figure 6.7 with the highest correlated measure for each indicator. For clarity purposes, figure 6.6 shows only the Fact_Dashboard table that contains the summary information to display in the dashboard and the Fact_Correlations table that stores the highest correlation information per indicator.

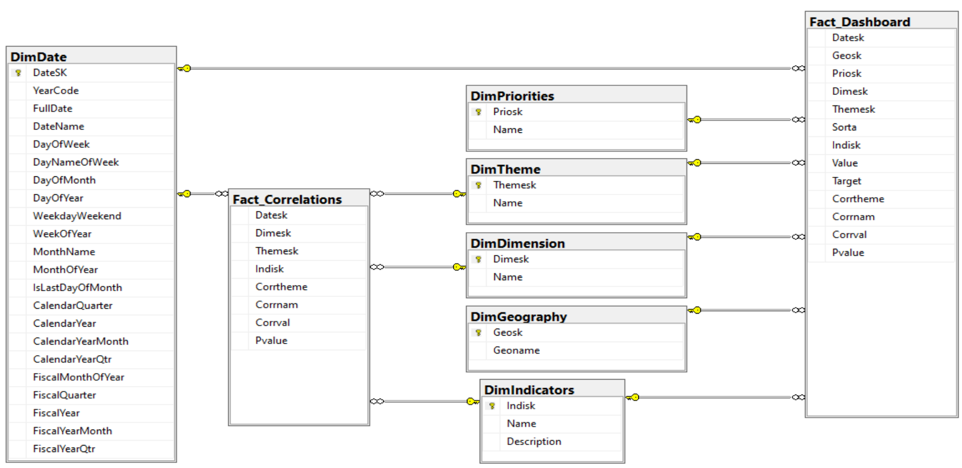

Figure 6.6 – Data model for the reporting table

6.2.4. Strategic performance dashboard

This project's primary goal is to build a strategic dashboard to measure the smart city's strategic performance. Besides, it plans to fill the research gap of equaling the number of strategic themes and performance metrics depicted in a performance monitoring tool proposed by Hu et al. (2017). It accomplishes it by displaying the most influential metric and its related thematic area per priority target, using the design features proposed by Few (2006).

Even though Few (2006) design techniques advise using unidirectional displays in the strategic dashboards to communicate business status, the dashboard shown in figure 6.7 has filters for the year and country-level contexts. These features provide a more granular analysis for a specific country between years, enabling in this fashion the well-being analysis between current and future generations.

The dashboard in figure 6.7 is what Eckerson (2011) calls a management scorecard dashboard, which follows many balanced scorecard framework guidelines. However, for instance, it discards the adoption of the strategy map philosophy.

However, this dashboard displays the correlation coefficient and its statistical significance through the field "p-value" between the observed indicator measuring a goal and the most influential metric associated with it to provide decision-makers a way to analyze the relationship between these metrics.

The observation unit is country and year, and the filters on these features enable the well-being analysis for a specific state within a given year, as mentioned previously. However, as the correlational study analyzes the relationship between the thirty measures across all countries within a particular year, this project's unit of analysis comprises the year of 2014 across all twenty-seven EU countries for each of the eight targets in table 6.1 presented previously and described by the dashboard in figure 6.7.

Smart City Strategic Dashboard

Key Permormance Indicators

EU Priority	TBL	Theme	Metric	Actual	Correlated Metric	Correlated Metric Theme	Corralation Value	Pvalue
Smart growth	Economic	R&D and inovation	t2020_20	1.29	ilc_peps13	Poverty and social exclusion	-0.79	0.00
Smart growth	Social	Education	t2020_40	17.40	ilc_peps01_sex	Poverty and social exclusion	0.47	0.01
Smart growth	Social	Education	t2020_41	31.30	lfsa_enewasn	Employment	0.71	0.00
Sustainable growth	Environment	Climate change and energy	t2020_30	111.05	lfsa_etgar	Employment	0.62	0.00
Sustainable growth	Environment	Climate change and energy	t2020_31	27.00	sdg_07_50	Climate change and energy	-0.45	0.02
Sustainable growth	Environment	Climate change and energy	t2020_34	15.80	t2020_33	Climate change and energy	0.98	0.00
Inclusive growth	Economic	Employment	t2020_10	67.60	tipslm90	Employment	-0.85	0.00
Inclusive growth	Social	Poverty and social exclusion	t2020_50	106.00	t2020_51	Poverty and social exclusion	0.55	0.00

Country Filter

Country ●Austria ●Belgium ●Bulgaria ●Cyprus ●Czechia ●Denmark ●Estonia ●Finland ●France ●Germany ●Greece ●Hungary ●Ireland ●Italy ●Latvia ●Lithuania

Year Filter

2000	2008
2001	2009
2002	2010
2003	2011
2004	2012
2005	2013
2006	2014
2007	2015

Figure 6.7 – Strategic performance dashboard displaying 2014 data

7. RESULTS AND DISCUSSION

7.1. RESULTS

This section analyzes the relationship between the metrics representing the eight targets distributed over three priorities in the early table 6.1 and the most influential indicators associated with each of them, shown by the dashboard in the previous figure 6.7.

The indicators related to the inclusive growth targets in 2014 are t2020_10 and t2020_50, which are respectively associated with the driver indicators tipslm90 and t2020_51, having the following characteristics:

- the correlation coefficient between t2020_10 and tipslm90 is -0.85;
- the correlation coefficient between t2020_50 and t2020_51 is 0.55;
- the first pair has its measures moving in opposite directions, while the second pair has its measures moving in the same direction;
- both pairs are statistically significant with p-values lower than 0.05;
- both pairs have correlation coefficients with moderate to a large magnitude, indicating significance in a practical or business sense.

Reviewing the smart growth priority targets related to the indicators t2020_20, t2020_40, t2020_41, the dashboard shows that in 2014 they have an association with the driver indicators ilc_peps_13, ilc_peps01_sex, and lfsa_enewasn, respectively, with the following features:

- the correlation coefficient between t2020_20 and ilc_peps_13 is -0.79;
- the correlation coefficient between t2020_40 and ilc_peps01_sex is 0.47;
- the correlation coefficient between t2020_41 and lfsa_enewasn is 0.71;
- the first pair has its measures moving in opposite directions, while the other two pairs have their measures moving in the same direction;
- the three pairs are statistically significant with p-values lower than 0.05;
- the three pairs have correlation coefficients with moderate to a large magnitude, indicating significance in a practical or business sense.

Finally, looking at the sustainable growth priority targets described by the indicators t2020_30, t2020_31, t2020_34, in 2014, they have a relationship with the driver indicators lfsa_etgar, sdg_07_50, and outcome indicator t2020_33, respectively, with the following characteristics:

- the correlation coefficient between t2020_30 and lfsa_etgar is 0.62;
- the correlation coefficient between t2020_31 and sdg_07_50 is -0.45;
- the correlation coefficient between t2020_34 and t2020_33 is 0.98;
- the first and third pairs have their measures moving in the same direction, while the second pair has its measures moving in opposite directions;
- the three pairs are statistically significant with p-values lower than 0.05;
- the three pairs have correlation coefficients with moderate to a large magnitude, indicating significance in a practical or business sense.

7.2. DISCUSSION OF FINDINGS

The dashboard in figure 6.7 gives decision-makers an objective way to evaluate the data, enabling them to monitor the smart city's strategic performance and understand the most influential drivers for each strategy's eight targets.

The dashboard's filters on year and country enable comparing the results between years focusing on specific countries at a strategic level. These features allow the sort of analysis shown in the first subsection of section seven for cross-sectional data allowing the well-being analysis between current and future generations.

The sustainable development concept proposed by Strange and Bayley (2008) states that environmental, social, and economic aspects should all be managed simultaneously to some extent, which is the primary concern of Ahvenniemi et al. (2017) and Kummitha and Crutzen (2017).

The primary reason for it is the embracement of sustainable city ideas by the smart city concept, leading to assessment tools based on each of these frameworks that do not cover environmental, social, and economic indicators altogether. Besides, Kourtit and Nijkamp (2018) believe that it is essential to consider such assessment tools, in the form of dashboards, the inter-relationship between environmental, social, and economic aspects' metrics.

The dashboard in figure 6.7 addresses these concerns by displaying the triple bottom line perspective for each of the EU2020 strategy's eight goals and targets, alongside correlation coefficients, statistical significance, and the thematic area of the most influential metric associated with each of them.

A careful analysis of the dashboard in figure 6.7 reveals the decision-makers' detailed thinking process in selecting the eight targets for the strategy, covering the environmental, social, and economic aspects proposed by the smart city concept altogether. The thematic areas of the most influential metric associated with each of the eight targets are in their majority driver indicators, providing the best short-term action to manage the long-term strategy.

In other words, the dashboards' design provides relevant information for decision-makers to understand the inter-relationships between smart cities' environmental, social, and economic metrics to strike a management balance. It considers all three aspects together under the light of the triple bottom line concept, addressing in this fashion the concerns exposed previously.

Independent of its statistical significance, a correlation coefficient between two measures does not mean that one causes the other, primarily because they influence each other reciprocally, is one of several alternative explanations. Despite it, the results in 2014 show that short-term actions related to the most influential driver metrics in the thematic areas of employment, poverty and social exclusion, and climate change and energy, associated with each of the targets might influence their performance.

This project's recommendation is to understand further if all the eight most influential metrics can jointly influence each strategic target. Such understanding may explain if, together, these metrics can lead to smart city strategic performance improvement.

8. CONCLUSIONS

The smart city framework aims to improve the quality of life of cities' inhabitants by developing an economy able to advance its social communities while preserving the city's surrounding environment. Such values are the pillars of sustainable development concepts, which states that city building must meet our society's needs today without putting at risk the needs of its future generations.

Such a framework embraces these concepts' values to consider the impact of decisions on the economy, environment, and society based on cities' growth data collected with information and communication technologies' support.

Sustainable city initiatives also have sustainable development concepts in their roots. The smart city framework embracement of sustainable city concept's values and ideas led to a lack of universal definition and the creation of assessment tools focusing on distinct sets of metrics for both concepts. These assessment tools do not cover environmental, social, and economic aspects altogether. Most importantly, they do not show the inter-relations between these aspects' measures, nor these frameworks give a clear direction on what indicator set to use.

Such concerns indicate that these frameworks may not provide methodologies to build assessment tools to address the fears presented in section two. Failing to evaluate performance properly prevents cities that chose to adopt the smart city concept from realizing the benefits proposed by it and, consequently, prevents them from providing a better quality of life to their citizens while preserving the environment.

This study intends to address such concerns by providing a strategic performance dashboard to enable decision-makers to monitor the smart city's strategy performance. Besides, it aims to fill the research gap of equaling the number of strategic themes per performance metric depicted in a performance monitoring tool or scorecard proposed by Hu et al. (2017). The goal is to display the most influential metric and its related thematic area per priority target alongside the performance measures to answer the following research and hypothesis questions, respectively:

- How can smart cities' sustainability strategic performance be measured?
- Do the measures of environmental, social, and economic dimensions influence each other?

To address the research question is essential to remember that sustainable development assessment, as stated in the introduction, uses indicators to measure cities' contribution to society's needs through the simultaneous management of environmental, social, and economic aspects. Such assessment tools help decision-makers verify the smart cities' contribution to their current and future generations' needs.

The evaluation of sustainable development by using indicators needs data, as declared in section two. For this reason, the smart city concept builds upon these ideas based on ICT to collect cities' data to perform such management to enable decision-makers to evaluate smart city's performance.

Section three explains that simply grouping financial and non-financial measures in a dashboard does not make it a balanced scorecard. In other words, for a dashboard bounded to the balanced scorecard methodology to truly represent a strategy, it must incorporate to it the cause-and-effect relationship between objectives through its different perspectives.

Furthermore, section three presents the idea that measuring the strength of the correlations amongst the lagging and leading measures associated with these objectives is another way to test and validate the business theory. Such business theory can be portrayed through strategy maps or balanced scorecards type II to visually display inter-relationships between the financial and non-financial objectives in the balanced scorecard perspectives and their associated metrics.

The triple bottom line concept, or “people, planet, and profit,” as mentioned in section four, supports businesses to integrate environmental and social aspects through policies, people, and partnerships based on the triple top line strategy having equity, ecology, and the economy as core values. The sustainable enterprise excellence concept establishes a process to drive this integration based on these concepts to achieve corporate sustainability.

Such a process is an evolution of the corporate sustainability criteria used to build “business, social, and natural cases.” Nonetheless, understanding these corporate sustainability criteria and the concepts supporting these cases can help with this integration process to address “people, planet, and profit” to select a set of sustainability, or sustainable development, indicators.

Besides, section four declares that a balanced scorecard aligns non-financial actions with causal chains to long-term business strategy goals. Its reformulation to reflect the inter-relations between environmental, social, and economic aspects aligned with corporate strategic goals produces a sustainability balanced scorecard. Such a tool is also suitable to incorporate ecological and social aspects into the business management system outside the market systems, making it relevant in the smart city context.

The first subsection of section five presents Kimball and Ross’ (2013) framework comprising technical guidelines to build data warehouses through its dimensional data model design technique driven by vital business processes. Also, it provides a technical reference architecture to support the development of business intelligence solutions, enabling the creation of dashboards fully or partially bonded to a balanced scorecard framework.

These features enable Kimball and Ross’ (2013) framework comprising methodologies, tools, and technologies to provide consistent data and essential business information to the business performance management framework presented in the second subsection of section five. The BPM framework aims to bridge the gap between developing strategies by identifying critical business activities contributing to the organization’s long-term health achievement and its execution by monitoring and analyzing performance information presented by dashboards.

As stated in the third subsection of section five, the MAD framework can help build and integrate strategic, tactical, and operational dashboards using the different data types involved in constructing each of them. Such a framework uses business performance management and business intelligence disciplines as the basis for building these sorts of data visualizations.

Furthermore, it reveals that strategic dashboards can strictly follow the balanced scorecard framework depicting measures based on a strategy map that links strategic objectives through its perspectives to produce a BSC type II. However, dashboards can also partially adhere to these framework guidelines creating what Eckerson (2011) calls a management scorecard. It can display the metrics' inter-relationships presented in the dashboard and not use a strategy map as a foundation.

On the one hand, the smart city's ideas and values presented in section two, alongside the corporate sustainability concepts described in section four, can influence what measures to model in the star schema dimensional data model. The first subsection of section five describes Kimball and Ross' (2013) star schema dimensional data model design techniques utilized to design the data model to store the Eurostat data and the correlation information produced from it.

On the other hand, the ideas in sections three and the second subsection of section five provide guidelines for structuring the data and design techniques, respectively, to present it in a strategic management scorecard that partially adheres to a balanced scorecard framework showing correlation information between the metrics. Kimball and Ross' (2013) technical reference architecture presented in the first subsection of section five also provides the tools and technologies to create such a dashboard. This dashboard monitors smart city's strategy execution through the business performance management process described in the second subsection of section five, considering its vision, mission, and values.

The information and concepts summarized in the previous paragraphs laid the foundation for the research methodology presented in section six to build the dashboard in figure 6.7. Such ideas and information led to the conclusion that a strategic management scorecard that partially adheres to the balanced scorecard framework can measure smart city sustainability strategic performance, answering the research question.

A closer look at section seven's findings based on the dashboard's analysis shows each most influential metric correlated to each of the eight targets representing the EU2020 strategy are statistically significant by having a p-value lower than 0.05 with 95% confidence, covering environmental, social, and economic aspects. The p-values and confidence intervals for the 2014 eight targets and their correlated metrics are in the appendix 11.3.3 spreadsheet.

This outcome leads to the rejection of Fisher z transformation's null hypothesis, testing that there is no relationship between the measures analyzed, leading to the conclusion with 95% confidence that environmental, social, and economic dimensions' metrics influence each other. Addressing in this way, the hypothesis question.

Hopefully, this study has contributed to business intelligence practitioners by showing how to create a strategic management scorecard dashboard to measure the smart city's strategic performance and filled the research gap. Such design brings the most influential driver and its related thematic area, associated with an outcome target to help decision-makers manage smart city sustainable development performance. It addresses the concerns presented in section two under the light of the triple bottom line concept.

Besides, it hopes to have contributed theoretically through the conceptual model presented in figure 6.1 by shedding some light on the bodies of knowledge necessary to accomplish this task and when to use them in a business performance management process to produce such a dashboard.

9. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORKS

This project uses secondary cross-sectional data to produce a dashboard to monitor smart cities' strategic performance. It analyzes the relationship between the metrics representing the strategic targets and the most influential indicators associated with them through a correlational study. Its major limitation is that all data is related to European countries, making the results not applicable to other regions.

As already mentioned in the second subsection of section seven, a suggestion for future research is to extend this work to understand if all the eight most influential metrics can jointly influence each strategic target and contribute to smart city strategic performance improvement.

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11.APPENDIX

11.1. ANALYSIS FOR THE YEAR 2012

11.1.1. Descriptive statistics

Summary_Statistics_2
012.xlsx

11.1.2. Correlation analysis

Correlation_Matrix_20
12.xlsx

11.1.3. Fisher's z transformation

Fisher_Z_Transformati
on_2012.xlsx

11.2. ANALYSIS FOR THE YEAR 2013

11.2.1. Descriptive statistics

Summary_Statistics_2
013.xlsx

11.2.2. Correlation analysis

Correlation_Matrix_20
13.xlsx

11.2.3. Fisher's z transformation

Fisher_Z_Transformati
on__2013.xlsx

11.3. ANALYSIS FOR THE YEAR 2014

11.3.1. Descriptive statistics

Summary_Statistics_2
014.xlsx

11.3.2. Correlation analysis

Correlation_Matrix_20
14.xlsx

11.3.3. Fisher's z transformation

Fisher_Z_Transformati
on__2014.xlsx

11.4. ANALYSIS FOR THE YEAR 2015

11.4.1. Descriptive statistics

Summary_Statistics_2
015.xlsx

11.4.2. Correlation analysis

Correlation_Matrix_20
15.xlsx

11.4.3. Fisher's z transformation

Fisher_Z_Transformati
on__2015.xlsx

11.5. ANALYSIS FOR THE YEAR 2016

11.5.1. Descriptive statistics

Summary_Statistics_2016.xlsx

11.5.2. Correlation analysis

Correlation_Matrix_2016.xlsx

11.5.3. Fisher's z transformation

Fisher_Z_Transformation__2016.xlsx

12.ANNEXES (OPTIONAL)