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MLPESTEL: THE NEW ERA OF FORECASTING CHANGE IN THE OPERATIONAL ENVIRONMENT OF BUSINESSES USING LLMS

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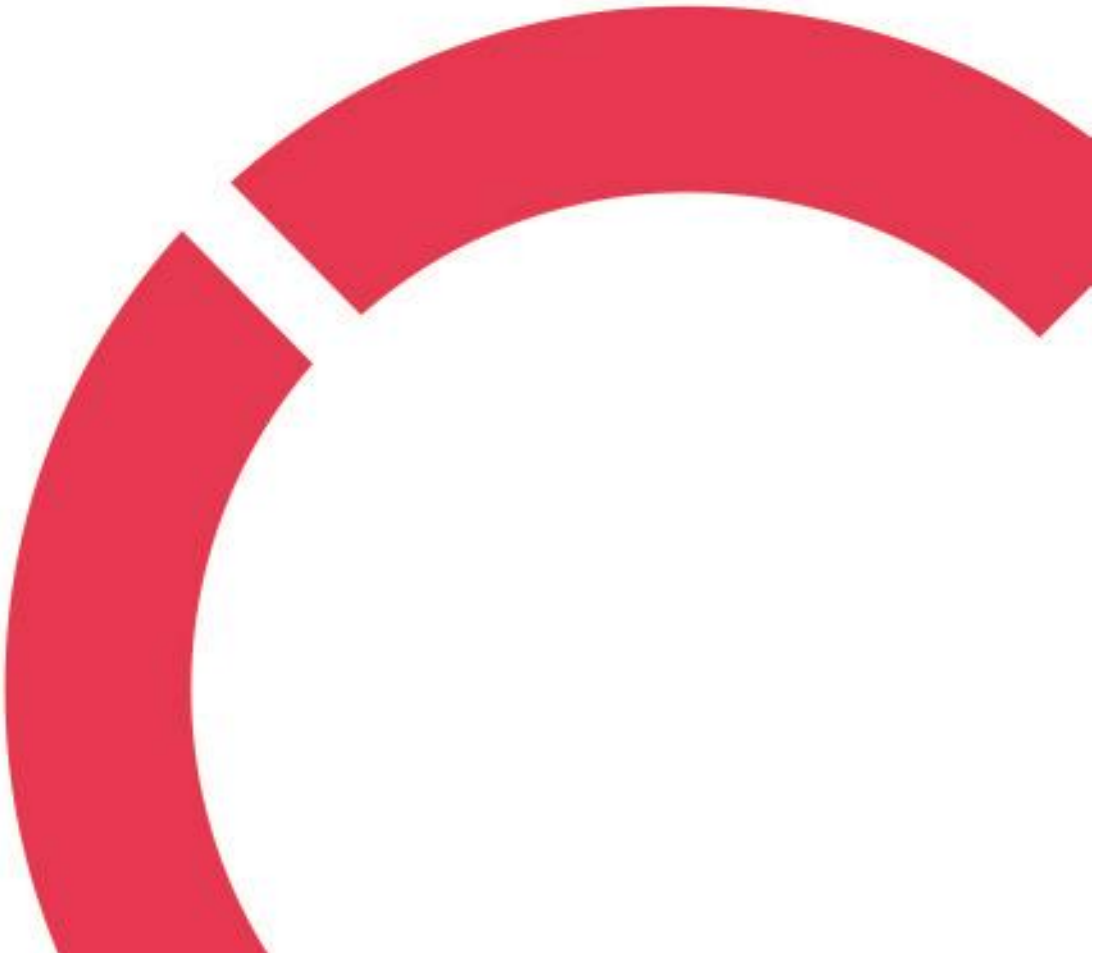

ABSTRACT

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This study explored the integration of futures studies into business strategy, focusing on the development of a novel theoretical framework and computational methods for forecasting future operational environments. Recognizing the critical role of anticipating technological paradigm shifts, as evidenced by the downfall of companies such as Blockbuster, Palm and Nokia, we proposed a new framework called MLPESTEL or Multilayer PESTEL. The framework combines PESTEL analysis with Bronfenbrenner's Ecological Systems Theory. This amalgamation aims to provide a more holistic understanding of a company's operational environment, extending from macro to micro levels. However, adapting Bronfenbrenner's model, originally focused on children's social development, to a business context presents a unique challenge.

Our methodology involved employing advanced AI tools, specifically large language models (LLMs), to analyze and predict changes in various business environments. This approach marks a significant shift from traditional AI applications, which predominantly rely on numerical data, to leveraging LLMs for textual data analysis. Our goal was not to focus on specific companies but to develop and validate generic models applicable across different organizational contexts. By analyzing forecasts for several existing companies, we aimed to validate our model's reliability.

Key words
AI, business strategy, Futures studies, large language models, LLM, MLPESTEL, multilayer PESTEL, natural language processing, NLP, PESTEL

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1 INTRODUCTION

Futures studies is a field of science that is dedicated to predicting what might happen in the future. As part of running a successful business, educated guesses about the future through analysis are important. Not only to detect potential opportunities based on weak signals but also to anticipate paradigm shifts in the operational environment. In technology, paradigm shifts have been disastrous for several companies such as streaming services for Makuuni, smartphones for Palm and their PDAs, Android for Nokia and so on. These technological innovations have changed the landscape so much that a company that fails to adapt to the new technology fast enough simply perishes.

Inspired by PESTEL and its interconnectedness with Bronfenbrenner's Ecological Systems Theory on social development, we aim to combine these two theoretical frameworks into a more comprehensive way to analyze and understand the operational environment of a company. PESTEL focuses mainly on the macro environment of a company, whereas Brofenbrenner's model can be used to understand micro-, meso-, exo- and macrosystems. This provides us with an intriguing extension to how the operational environment is to be understood. However, Brofenbrenner's model focuses solely on social development of children, which means that it needs to be duly adapted to the business context.

We call our combined framework MLPESTEL or Multilayer PESTEL framework. This framework can be used to better analyze the operational environment of a company and forecast the future of the company and the world surrounding it. The term multilayer comes from the layered structure of organizing the environment on several different subsystems with different degrees of abstraction and closeness to the company itself.

Once we have established the comprehensive MLPESTEL framework, we will use the latest AI tools, namely large language models (LLMs) to forecast changes in the operational environment. We do not focus on one company in particular, because our goal is to develop generic models that can be used in forecasting changes in the operational environment of any company. We will, however, validate our model by analyzing its forecasts for several existing companies.

Our thesis thus aims to establish a new theoretical framework (MLPESTEL) and develop new computational LLM-based methods for forecasting the future. Traditionally, AI models have been used to forecast the future solely on numerical data (e.g. weather forecasts, stock markets). With the dawn of

LLMs, we can conduct forecasting on textual data as well. This is something we will demonstrate in this thesis.

1.1 Background

The current business landscape is evolving constantly, with organizations facing unprecedented difficulties and challenges caused by external factors like the COVID pandemic. Such challenges, that shape the organization's operational environment, make it hard to anticipate and adapt to them. Because of this, the need for comprehensive frameworks to analyze these factors has never been more critical. An example of a commonly used and well-established framework is no other than PESTEL analysis (see Çitilci & Akbalık 2020). This framework, used by many researchers, takes into account the Political, Economic, Social, Technological, Environmental and Legal factors affecting an organization under study. PESTEL has been shaped by several researchers as an extension of the original PEST analysis as proposed by Aguilar (1967). The framework makes it possible for organizations to identify and interpret long-term trends in the environment external to them. PESTEL is commonly used for strategic business planning. For instance, a company can effectively use PESTEL analysis to navigate challenges such as changing consumer preferences and economic recessions. This makes it easier for them to maintain their market position.

The Ecological Systems Theory hypothesizes that individuals, in particular during their upbringing, are influenced by multiple interconnected environment systems (Bronfenbrenner 1979). This model has seen adaptations to a variety of contexts such as educational practices and family policies (Olivier-Pijpers et al. 2018; Panopoulos & Drossinou-Korea 2020). In the world of business, this theory can be applied to understand how different levels of organizational ecosystems impact company culture. For instance, big companies such as Google have successfully created a positive microsystem for their employees, resulting in an increase in innovation and productivity (Steiber & Alänge 2013).

Since last year, artificial intelligence (AI), most notably owing to the dawn of LLMs, has opened new possibilities that were previously imaginable only in science fiction movies. For LLMs seem to be having general knowledge and understanding of seemingly an unlimited number of topics coupled with the ability to reason and converse. LLMs have been trained on vast amounts of text-based data and they have demonstrated extraordinary flexibility in the capabilities they showcase in processing and

generating human level text. Unlimited to this, they can exhibit creative skills such as music composition (Alaeddine & Tannoury 2021), coding (Bubeck et al. 2023) and poem generation (Hämäläinen et al. 2022). LLMs present an opportunity to revolutionize business operations, including enhancing traditional forecasting methods with more sophisticated, data-driven approaches. Companies such as Amazon and Walmart have already started to leverage AI-powered forecasting to improve their supply chain management and financial planning (Sanson 2024).

Integrating AI in business forecasting does not, however, come without challenges. Yann LeCunn, Chief Scientist at Meta, tweeted "a house cat has way more common sense and understanding of the world than any LLM[1]". This clearly highlights the need for a balanced approach that combines the computational power of AI with human expertise and intuition, which we aim to achieve in this thesis.

In our current work, we aim to combine PESTEL analysis and Bronfenbrenner's Ecological Systems Theory with the capabilities of LLMs to develop a more comprehensive and nuanced framework for analyzing and forecasting changes in business environments. The new, combined, framework will be called MLPESTEL. Our theoretically motivated AI-enhanced approach has a great potential to provide organizations with deeper insights into external factors, rendering them more informed about their strategic decision possibilities.

Furthermore, our approach not only enhances the accuracy of future forecasts but also provides organizations with a more holistic understanding of the intricacies of different environmental factors and how they might be affecting businesses. If we think about Tesla's success, we can see that it can be attributed to Tesla's ability to anticipate and capitalize on the convergence of technological advancements and changing consumer preferences (Stringham et al. 2015). Failing to adapt to such changes might result in severe negative implications. As an example of this, Kodak failed to adapt to the digital photography revolution, which turned once a big company into a memory of what once was (Lucas & Goh 2009).

We chose to integrate LLMs into the framework as they offer remarkable benefits for processing unstructured data at scale. They excel at identifying subtle patterns and generating insights that might lead human analysts to new revelations. For example, Watson, which is developed by IBM, has been

[1] https://x.com/ylecun/status/1622300311573651458

used to go through medical literature and analyze patient data to assist doctors in cancer treatment decisions (Chen et al. 2016). This is just a simple example demonstrating the potential of AI in complex decision-making processes; however, LLMs and AI solutions are not flawless technologies and it is important to acknowledge them, such as potential biases in training data and the need for human oversight in interpreting results.

In addition to that, adapting Bronfenbrenner's Ecological Systems Theory to business contexts enriches our understanding of how different levels of the environment interact and influence organizational behavior. The recent increase in remote work, especially after COVID, is an example where this approach could be particularly valuable as it would allow analyzing the impact of remote work on company culture and employee productivity. A recent research done by Microsoft demonstrates the effects of hybrid work models (Yang et al. 2021), which highlights the importance of understanding the interactions between the different levels of the environment along with their effect on each other.

1.2 Motivation

In this thesis, we aim to develop more robust strategies that can be used by businesses to explore complex and interconnected global marketplaces. We will achieve this by leveraging AI capabilities and combining the two frameworks. We hope the approach we are proposing would improve strategic planning, risk management and decision-making processes across various industries.

Setting clear goals and communications are crucial for aligning all organizational efforts across different departments, as it would ensure that they would be working towards common objectives for the success of the organization. Machine learning systems could enhance planning and achieve target service levels by forecasting future demands. For instance, Artificial Neural Networks (ANN) can be used to model complex non-linear relationships in demand data and when combined with statistical models (e.g. autoregressive integrated moving average –ARIMA– integrated with ANNs) they can yield superior forecast accuracy by accounting for different types of uncertainty (Tan 2007). These approaches aid in managing fluctuating consumer demands effectively, hence, setting clearer goals. Based on Kumar (2024), enhancing cross-departmental collaboration fosters a culture of trust and transparency, leading to increased productivity and better decision-making. Staying flexible and responsive to market trends is of high importance as it could minimize any technological disruptions impacting busi-

nesses negatively. Other gains of employing forecasting models in setting clear goals and communications include, but not limited to, improving promotional planning (to make informed decisions about promotions, leading to increased profits), market expansion strategies (to navigate new markets effectively) and scenario planning allows businesses to explore various future scenarios and develop robust strategies, as demonstrated by companies investing in AI tools for better forecasting.

The main purpose of performance improvement and optimization is to turn business operations into more efficient and cost-effective ones. This involves processes such as reducing supply chain costs, improving financial planning, enhancing profit margins, optimizing pricing strategies and marketing spend, managing supplier lead times, product lifecycle management and improving cash flow and supply chain sustainability. With AI-powered solutions, these processes could be done more efficiently and with higher accuracies. As an example, AI-powered demand forecasting can help in minimizing excess inventory and reduce waste (Porter 2023), yielding a cheaper supply chain operation. Another example for optimizing pricing strategies which allows businesses to adjust prices based on demand forecasts and market conditions.

No business is immune to uncertainties and potential threats and, to mitigate potential threats, businesses perform risk management where they identify potential threats and develop strategies to address them. AI could assist here to predict and manage such risks (Yazdi et al. 2024). AI, for instance, could process a vast amount of historical data to identify patterns to predict risks (e.g., forecasting financial risks by examining market trends, economic indicators and industry-specific data). A recent example of a risk that could have been mitigated by forecasting risks is addressing supply chain disruptions that were caused by the COVID-19 pandemic (Accenture 2023), as by predicting them businesses would have been able to develop resilient supply chain strategies. Other use cases with respect to risk management are avoiding missed market opportunities, preventing revenue loss, improving crisis management and addressing geopolitical risks and technological convergence.

Maintaining customer satisfaction and staying competitive can be achieved through various essential approaches such as keeping a strong focus on the customer and market to understand their needs and deliver products that meet them. Also, ensuring that the brand has a positive image through consistent quality and customer engagement is important, not to mention adapting to changing consumer behaviors as seen with companies leveraging social media and other digital platforms (see Siddiqui et al. 2023). Forecasting techniques with AI can aid in maintaining customer satisfaction. For instance, they

can be used to predict and manage seasonal demand variations or analyze customer data to develop effective targeted marketing strategies, leading to more effective customer engagement (Pecan 2024). Moreover, they can be utilized to analyze the market and forecast customer expectations to meet them.

Managing resources and talents is very critical to achieve business goals. A successful utilization of AI to predict future skill needs and inform talent development strategies would support workforce planning. Topics such as resource allocation, capital investment decisions and talent management can all benefit from AI too, when incorporated aptly in future forecasting to inform investment strategies, meet strategic objectives and develop concrete plans to attract, retain and develop top talents.

The above are just examples of business areas that would greatly prosper with the correct use of AI and planning. Other areas such as maintaining competitive advantage and strategic positioning (e.g., maintaining market leadership and achieving long-term success by staying ahead of market trends and making informed strategic decisions) and enhancing organizational culture and employee engagement (e.g., fostering a positive work environment and driving business success by improving stakeholder communication and addressing labor market and demographic shifts) can also be positively impacted by AI. All of these potential implications motivate defining the topic of this thesis.

1.3 Problem Statement

The main problem we are addressing here are the current limitations of forecasting and strategic planning that suffer from taking multiple levels of environmental factors into account and making slow and narrow forecasts. Our proposed approach that integrates PESTEL analysis, Bronfenbrenner's Ecological Systems Theory and LLMs is a novel one and we expect it to be applicable to a wide range of use cases. In this thesis, however, we focus it on forecasting and strategic planning in business environments. Although such frameworks and LLMs have been employed in existing research separately, most of their potential remains largely unexplored when combined together. We will research how to harness what each one excels at to bolster and support business decision-making and adaptability, especially in an increasingly complex global marketplace.

PESTEL analysis can barely capture the complex interplay between various environmental factors that affect businesses. While it is comprehensive in its coverage of macro-environmental factors, it does

not capture interactions across different systemic levels and their influence on the business. Bronfenbrenner's Ecological Systems Theory is not intended for business management since it is originally developed for human development. However, it offers a multi-layered perspective which could potentially address the limitation of PESTEL analysis when adapted in a business context.

LLMs are quite recent as they started getting a lot of attention in December 2022[2], immediately after the release of ChatGPT. Given that, their application in business forecasting and strategic planning is still in its infancy, which puts a high demand to develop methodologies that can effectively harness their power while addressing their limitations, such as potential biases and the lack of real-world understanding.

The work herein seeks to bridge the gap between traditional strategic analysis frameworks and cutting-edge AI technologies by combining PESTEL analysis, an adapted version of Bronfenbrenner's Ecological Systems Theory and LLMs. Our approach has the potential to give deeper insights into the complex interactions between various environmental factors across different systemic levels by providing businesses with a more comprehensive, dynamic and actionable understanding of their operational environment. Businesses can leverage this knowledge to navigate uncertainty and capitalize on emerging opportunities more effectively.

1.4 Research Objectives and Questions

In this study, we define three main objectives, each is broken down into multiple research questions, that will guide the study. By answering these questions, we aim to advance the field of business forecasting and provide concrete use-cases on how organizations can benefit from the power of AI for strategic decision-making. The objectives of the research are as follows:

1.4.1 Objective 1 - Developing an Integrated Forecasting Framework

The first objective is to develop a comprehensive forecasting framework that incorporates PESTEL analysis and Bronfenbrenner's theory with the processing capabilities of LLMs. To achieve it, we de-

[2] https://web.archive.org/web/20240804184028/https://en.wikipedia.org/wiki/ChatGPT

fine two research questions. The first RQ1.1 is *How can PESTEL analysis and Bronfenbrenner's Ecological Systems Theory be adapted and integrated to create a comprehensive framework for understanding the business environment?* Our approach to solving it is to conduct a thorough literature review to identify the key elements of each framework and their potential synergies. Based on that, we will develop a framework that integrates all three components. The second research question, RQ1.2 is *What are the technical challenges and considerations in incorporating LLMs into the integrated framework?* Exploring the architecture and capabilities of state-of-the-art LLMs, such as GPT-4, to identify their potential applications in business forecasting will be our methodology to address this research question.

1.4.2 Objective 2 - Utilizing and Validating LLMs for Forecasting

The second objective of this thesis focuses on implementing a prototype system that showcases the practical application of our framework to generate comprehensive forecasts and strategic recommendations. The prototype would ingest various data sources such as news articles, social media trends, economic indicators and regulatory changes to make forecasts. We raise three research questions here, which are: RQ2.1 *How can LLMs be leveraged to process and analyze unstructured data sources for generating business insights and forecasts?,* RQ2.2 *What are the limitations of LLMs in understanding real-world contexts and how can these limitations be addressed?* and RQ2.3 *How effective is the integrated forecasting model in predicting business outcomes across different industries and geographical contexts?*

To answer the first one, we will utilize AI solutions that are capable of searching the web to retrieve relevant sources, regardless of the platform. We will research their capability of finding adequate indicators together with insightful information that aid in making successful predictions. We will extend our experiments, in effort to address the second research question on assessing the LLM's ability to generate actionable recommendations. Biases in the output are also of the utmost importance for us when conducting our research.

Building on that, we will validate the performance of our MLPESTEL framework based on empirical experiments. We will test the framework across two different industries from two geographical con-

texts (Tesla and Nokia) to measure its generalizability and effectiveness in different business environments. In addition, we will compare the forecasts generated by the LLM with actual historical outcomes, which will give us an idea of how reliable our approach is.

1.4.3 Objective 3 - Contributing to Best Practices for Responsible AI Use

Our last objective aims to contribute to the ongoing dialogue about the role of AI in strategic decision making. By developing a model that combines AI capabilities with our newly established theoretical frameworks, we seek to demonstrate how AI can complement rather than entirely replace human judgment in complex business contexts. Here, we ask the research question RQ3.1 *What are the ethical considerations and potential risks associated with using AI-powered forecasting models in business decision-making?*. Our plan to address this question is to examine the implications of AI-generated predictions on issues such as transparency.

2 RELATED WORK

In this section, we conduct a literature review of the most relevant concepts for our research such as futures studies in business, forecasting methods, PESTEL analysis, Bronfenbrenner's theory and LLMs. The growing importance of futures studies in business has also been reflected in the academic literature. For instance, Molyboga et al. (2021) note that previous research has suggested substantial improvements of active strategic risk-adjusted returns by combining a multitude of trading signals. Khan (2022), who highlighted a similar observation, points out the increasing attention given to human resource management strategies in the context of the COVID-19 pandemic, since organizations try to motivate and develop their employees in the face of changing external conditions.

2.1 Review of Futures Studies in Business

Futures studies is the discipline the practitioners of which dedicate themselves to exploring possible, probable and preferable futures. The field has become more relevant to businesses as an increasing number of corporations and institutions look for ways to study what is yet to come, namely, the future. Business leaders are facing an increasingly volatile technological and social global environment, which calls for predictive insight into future trends. Such insight offers a huge competitive advantage for coming up with innovative ideas. For instance, a recent study by Molyboga et al. (2021) indicates that ensembling multiple trading signals such as time-series momentum and carry trades has the potential of improving the risk-adjusted returns of active strategies in future markets.

The business practice of futures studies has evolved from utopianism to the making of empirical predictions, as Inayatullah (2003) commented that currently, strategic planning, technology impact assessment and risk analysis remain the dominant practices of the field in both the government and business sectors. However, increasing complexity and uncertainty of the business environment paved the way for a paradigmatic shift towards more critical and emancipatory approaches to the studies of futures. This shift also brings out the need to take into view multiple visions in the envisioning and shaping of the future, in particular, that of the marginalized stakeholders.

COVID-19 has brought out this fact even more strongly in case of business futures. The pandemic has been a tough time for organizations, pushing them to evolve their organizational and HR operations based on changing external scenarios (Khan 2022). Businesses have shifted towards understanding and

designing resilience into their operations to continue performing even in the face of these disruptive events which is now a key concern for them, enabling them to plan ahead as they prepare themselves for an uncertain future.

Futures studies have also played a crucial role in guiding businesses through crises. Anderson et al. (2022) explore how futures studies can assist retailers in serving their customers during and after times of crisis. This underlines the importance of systems development, relationship building practices, consumer safety and adaptability in navigating uncertain times. Through the development of a model on the current crisis state, businesses can pave a road towards a more resilient and customer centric future.

Futures studies have, as of late, been integrated with other disciplines. It has opened up new avenues for business innovation and sustainability. The researchers Heiskanen, Jalas & Kärnä (2000) explore the potential of services and information technology in contributing to the reduction of material consumption in the economy. The authors note a lack of empirical work on the actual impact of such a shift, but they do emphasize the importance of considering the social consequences and conditions for the aforementioned changes.

The field of future studies has quickly become more closely integrated with strategic decision making processes. This can be attributed to the fact that businesses are increasingly recognizing the value of the discipline. Moody (2021) examines how memories of Liverpool city’s involvement in the transatlantic slave trade have shaped the community's identity and influenced its present day understanding of its own history. The study highlights historical context and societal impact of business activities when making plans for the future.

However, it is not without any challenges that futures studies are integrated in the process of business decision making. For example, Inayatullah (2003) argues that, historically, the discipline has been a preserve of business and scientific interests with only a few considerations to marginalized stakeholders. This shift, however, calls for businesses to hold discussions with a wider representation of the members in the society. This is to better take into account the social implications and moral dimensions connected with their business operations.

Futures studies face significant difficulties as a result of its ever increasing complexity as well as uncertainty in today’s business environment. Anderson et al. (2022) state that COVID-19 pandemic has

shown that companies must be able to adapt and showcase resilience when facing unexpected disruptions. Foreseeing such future event requires understanding how complex interactions between different aspects of the operational environment will shape the world of tomorrow

The potential benefits that could result from the integration of futures studies with business decision-making are immense. Businesses can develop a holistic and more long-term perspective to grasp emerging opportunities, or even mitigate risks better. Heiskanen, Jalas & Kärnä (2000) indicate that such an integration of futures studies with another sector, like information technology, is needed to open up new avenues for business innovation and sustainability.

2.2 Evolution of Forecasting Methods

Forecasting methods have evolved a lot over the past decades. This has been driven by leaps in technological advancements that have been made possible by an increasing data availability and computational power. Traditional forecasting methods such as time series analysis and regression models have been replaced by new ones following the emergence of deep learning (DL) techniques. Such techniques offer new possibilities for accurate and efficient forecasting in various business domains (see Gilliland et al. 2021; Hämäläinen et al. 2024).

Time series analysis has been one of the traditional ways for generating forecasts. Models such as the Auto-Regressive Integrated Moving Average (ARIMA) and its variations are widely applied because of their capability in capturing temporal patterns and dependencies in data. These models have been found to be quite effective in predicting future values based on past observations (see Stevenson, 2007). They are very useful in tasks such as demand forecasting and sales projection for inventory management (see Spedding & Chan, 2000).

Business environments have become very unpredictable and the available vast amounts of data have led the way for adopting more and more advanced techniques of forecasting. In the real of machine learning algorithms, Support Vector Machines (see Sun et al. 2021), Random Forests (see Orte et al. 2023) and Gradient Boosting (see Gu et al. 2021), have gained a good amount of popularity due to their capability of handling high-dimensional data and capturing nonlinear relationships (Siddiqui et al. 2023). These models typically include a very large number of features, including external ones such as economic indicators and sentiment expressed on social media (see Demir et al., 2019).

Deep learning methodologies, especially the Long Short-Term Memory (LSTM) networks and Convolutional Neural Networks (CNN), have been embraced as useful tools in conducting forecasting (Ji et al., 2019; Vidal & Kristjanpoller 2020). These deep learning models can efficiently capture the long-term dependencies and complex patterns prevailing in time series data, and they are therefore suitable for tasks like demand forecasting (Abbasimehr et al. 2020). The ability of deep learning models to automatically learn relevant features from raw data has further enhanced their appeal in business forecasting applications (see Makridakis et al. 2023).

The increasing availability of big data coupled with the need for making real-time predictions have acted as a catalyst in the evolution of methods for forecasting (see Zhao 2021). New data sources have made it possible for businesses to be in a position where they can obtain an overall understanding of markets and customers with ease. This leads to wiser decision making and gaining more competitive advantages (Molyboga et al. 2021). The latest developments have led to the development of hybrid approaches that can combine traditional statistical methods with modern machine learning techniques (see Ghosh et al. 2022).

The evolution of forecasting methods has had a great impact on various business domains such as the retail and financial sectors. Machine learning and deep learning models can enable more informed decision making and risk management strategies in applications such as prediction of the stock exchange market, risk assessment and fraud detection. Although clear progress in forecasting methods is evident, still, three major challenges persist: data quality, model interpretability and requirements for domain expertise (see Thakkar & Chaudhari 2021; Makridakis et al. 2023). Within some business scenarios, it is not easy to obtain relevant and accurate data, not to mention the complexity introduced by machine and deep learning models is hard to understand for decision makers (see Nielsen 2022). Therefore, trusting the predictions becomes very difficult for decision-makers, which highlights the need for explainable AI (where we can interpret and explain the model behavior).

2.3 PESTEL Analysis

PESTEL analysis has become an important tool in the process of strategy planning and decision-making due to its utilization in studying macro-environmental factors that affect an organization or industry. PESTEL refers to Political, Economic, Social, Technological, Environmental and Legal elements

that may have an impact on the business environment separately or together (Sammut-Bonnici & Galea, 2015).

PESTEL analysis has been used as a tool in many business contexts, including the tourism industry. Gregoric (2014) employed a comparative PESTEL analysis between Croatia and Qatar as tourist destinations to order to study the potential for business tourism (Meetings, Incentives, Conferences and Exhibitions --MIC-- industry). The research showed that the assessment and knowledge of global behavior of tourism demand should be performed through the PESTEL factors. This can allow researchers to conduct an overall assessment of the SWOT[3] of each destination.

PESTEL has also been applied in studying new technologies that have enormous potential and that are sustainable within different industries. For example, Sugiyono et al. (2022) used the PESTEL framework to analyze the prospects for biomass and coal co-firing power plants within Indonesia. The political, economic, social, technological, environmental and legal factors that would act upon the implementation and long-term viability of this technology were identified in the study. The researchers particularly mentioned that a well-developed supply chain for the biomass and positive policy support remain necessary.

PESTEL analysis has been used to compare and contrast the business environments in different countries. According to Lang (2022), a PESTEL analysis between Georgia and the United States reviewed current trends, priorities and the establishment of objectives on various dimensions between the two countries. The research found that bilateral relations and strategic links are important in developing the business environment and economic development of nations.

PESTEL is clearly one of the most widely used analysis frameworks in the realm of business studies, it does have its own shortcomings. One of the critical issues is the dynamic nature of the macro environment, which can impact some factors and their value rapidly over time (see Sammut-Bonnici & Galea, 2015). The framework's effectiveness also relies heavily on the quality and accuracy of the data available for analysis. The effectiveness also depends on the researcher's ability to interpret and prioritize the identified factors in the context of specific business objectives.

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[3] Strengths, Weaknesses, Opportunities and Threats

PESTEL analysis, however, provides only a high-level description of the macro-environment that might not explain all the complexities of individual companies or organizations. For this reason, PESTEL is oftentimes complemented by other strategic tools such as SWOT analysis or Porter's Five Forces (Porter 1989) to create a more comprehensive view on the business environment (Gregoric 2014).

2.4 Bronfenbrenner's Ecological Systems Theory

Bronfenbrenner (1979) established the Ecological Systems Theory. The theory was originally developed with the goal of understanding the process of becoming a social being by explaining the steps of the sociocognitive development of a child. The theory builds upon the notion that an individual's development is influenced by multiple, nested systems, ranging from the immediate environment (microsystem) to the broader cultural context (macrosystem).

One adaptation of Bronfenbrenner's theory can be found in its use in examining how different forms of violence can cumulatively affect development. Flynn & Mathias (2023) harnessed the model to study how young adults in the city of Philadelphia understood violence across different neighborhood contexts. The analyses revealed that multiple forms of violence ranging interpersonal and structural all the way to symbolic were found across micro-, meso- and macrosystems. This was found to impact young adults' development and well-being. This adaptation shows why it is important to acknowledge that violence permeates throughout ecological systems, and it may affect individuals in ways yet to be considered.

When looking at the research conducted in the field of pedagogy, Bronfenbrenner's theory has been applied to research the role of school climate in moderating relations between neighborhood, violence and academic achievement. Ruiz et al. (2018) found that a lower socio-economic background was related to lower levels of academic achievement. Violent crime was found to partially mediate this relationship. School climate was found to be positively related to academic achievement, it did not have a moderation effect significant enough to the relationship between socio-economic status and level of achievement.

Bronfenbrenner's model has been embraced most recently by researchers conducting studies in psychedelic-assisted therapy. DellaCrosse et al. (2024) report that the model helps build an analytical

structure through which contextual factors could become even more explicit and researchable components in psychotherapy research. By considering multifaceted components of psychotherapy through the model, researchers are able to conceptualize the role of therapeutic support and contextual factors within clinical trials.

The theory of Bronfenbrenner has also been applied to understanding territorial resilience management, business and tourism within the context of urbanization and socio-economic processes. Prysiazhniuk & Plotnikova (2023) conducted iterative interviews on the study of the evolution over time of open innovation initiatives in the context of social innovation ecosystems. The research findings revealed that the management initiatives of social innovation ecosystems take the form of being dynamic, evolutionary and incorporating a values focus over time. This adaptation from Bronfenbrenner's theory allows for an emphasis on the dynamic and complex characteristics of socio-economic processes within an ecological framework.

Even the very popularized use of Bronfenbrenner's Ecological Systems Theory is not immune to criticism in the post-humanist age. Elliott & Davis (2020) contest taken-for-granted early childhood education ideas, suggesting that a focus on human development via the theory might miss the significance of non-human actors and their more complex entanglements with humans and their environments.

2.5 Role of AI and LLMs in Business Forecasting

AI and LLMs have emerged as powerful tools for enhancing forecasting capabilities (c.f. Ceperic & Markovic 2024). These technologies have the potential to revolutionize the way organizations predict future trends. By leveraging vast amounts of data and advanced computational techniques, AI and LLMs can provide more accurate insights compared to traditional forecasting methods.

Of the major business forecasting applications of AI, one is inventory management. Dhaliwal and Tomar (2022), very effectively analyzed this application area for the use of AI in improving efficiency and reducing costs for inventory management. An AI-driven inventory management system will look through all historical data, identify trends and patterns within it and accurately forecast future demand. This makes it possible for business enterprises to finetune their inventory levels to avoid items getting out of stock. This helps the business provide a higher level of customer satisfaction that leads to an increased profitability.

LLMs have shown potential for sales forecasting in digital marketing. Biswas and Sanyal (2021) proposed an AI based sales forecasting model that uses machine learning techniques to predict future sales based on historic data and various market factors. This model considers several aspects such as customer behavior, marketing trends and competitor activities in order to come up with accurate and timely sales forecasts. AI powered sales forecasting can provide information related to potential sales opportunities and challenges making it possible for the business to efficiently allocate resources and adjust its marketing efforts.

The power of LLMs is in their potential to overhaul startup evaluation and future success rate prediction. Wang and Ihlamur (2024) showcased an automated pipeline for evaluating startups and rating their probability of success. This came to be called the Startup Success Forecasting Framework. It looks at several factors such as team composition, market potential, financial health of the startup to estimate the overall prospects of succeeding.

There are challenges and limitations in AI and LLMs, albeit they can be quite useful if used correctly. The biggest concerns are related to data availability and its quality (see Chui et al. 2018). LLMs require heaps of accurate and reliable data in order for them to extract meaningful insights. Therefore this calls for businesses to invest in reliable data collection and management practices (see Roh et al. 2019) in order to fully capitalize on the gospel of LLMs.

A challenge lies in the lack of interpretability and explainability of the current LLM based forecasting models. The more complex the model is, the more difficult it becomes for the end user to understand how the predictions came to be to begin with (see Greco, 2019). It can provoke a lack of confidence and hesitation to use AI generated insights in critical areas of business (c.f. Hämäläinen 2024).

Integrating AI and LLMs into existing business processes and systems is a complex and resource-intensive undertaking (see Cleland Silva & Hämäläinen 2024). Organizations are in a need for investing the necessary infrastructure and human resources to efficiently utilize AI powered forecasting solutions. This requires a rather strategic approach that aligns the adoption of AI and LLMs with the organization's existing business goals.

3 MULTILAYER PESTEL FRAMEWORK

There is no denying that PESTEL is a useful tool when analyzing the operational environment of a company. However, we find that it is not granular enough to make a nuanced inspection of the overall context of a business possible. Political, economic, social, technological, legal and environmental aspects are all important but the shortcoming of this theoretical framework becomes evident when we start inspecting each component individually.

Politics, for example, can affect a company on many different levels of abstraction. On one hand, a country might have a stable political system that relies on democracy and that does not go from one extreme to another after each round of elections. On the other hand, actions of a local mayor or councilman also have a huge impact on a company on a macro level. Therefore, each aspect of the PESTEL framework is quite more complex than what the framework can capture. We need an extension to this framework and we shall call our extended framework **Multilayer PESTEL or MLPESTEL** for short.

Rather than coming up with a completely new way of establishing granularity on the approach on our own, we opt for combining PESTEL with the Ecological Systems Theory (Bronfenbrenner 1977) or EST for short. EST is primarily used to understand the socialization of a child from the point of view of developmental psychology. EST divides the influence of the social environment on a child in micro-, meso-, exo-, macro- and chronosystems. This is the division we shall adopt in MLPESTEL as well. In this section, we will establish what each system means for every aspect of PESTE.

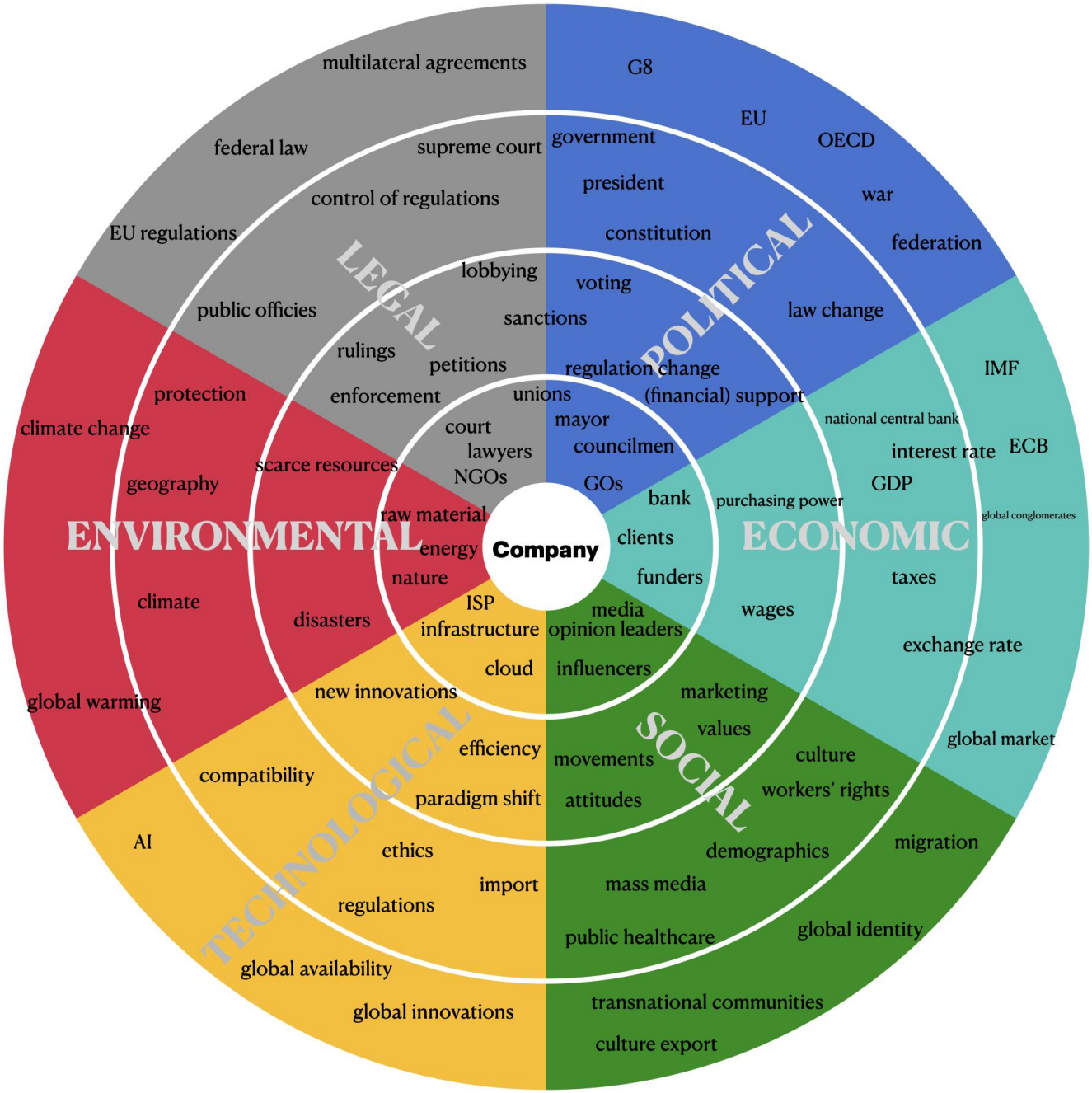

FIGURE 1. MLPESTEL framework

3.1 Subsystems of the MLPESTEL Framework

Much like Bronfenbrenner's theory, our framework also consists of four systems: micro-, meso-, exo- and macrosystems. Each system is divided into overarching sectors for legal, political, economic, social, technological and environmental aspects following the PESTEL framework.

3.1.1 Microsystem

The microsystem is the closest layer to the company and encompasses the immediate environment in which the company operates. This includes direct interactions with various stakeholders such as employees, customers, suppliers and local communities. The microsystem is characterized by the most immediate and direct influences on the company's operations and strategic decisions.

From the legal perspective, the company might face actors in its immediate vicinity such as the local court, lawyers and Non-governmental organizationsin the long run. Also the actions these legal actors take may directly or indirectly affect the operations of the company.

In the realm of the political, local legislators such as mayors, councilmen or governmental organizations can have effect on the company. For instance, direct ties with Macron[4] were of a great importance when Uber wanted to retain a light regulation in France for ride hailing services. When inspected on a microlevel, the closeness of the company to the political actors is important - if Macron had been an exo-level actor for Uber, they wouldn't have had the opportunity to make a political change in the microlevel.

Directly involved money handling actors such as banks, clients and funders belong to the economic section of the microsystem. These actors are directly influencing the finances of the company by giving or taking money from the company. There can be plenty of regional variation in terms of financial opportunities - some funders might be interested in a specific region while some banks only operate physically in certain cities.

Controlling the social is controlling the opinion of the many. Knowing media representatives, opinion leaders or influencers can help a company build a better social image of themselves. Influencer marketing in particular has been proven to be beneficial for companies (Gambhir & Ashfaq 2021).

A company does not exist in a technological vacuum. When inspected on a microlevel, companies operating in different regions have access to a set of very different technologies that depend on the ISP[5],

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[4] https://www.theguardian.com/news/2022/jul/10/emmanuel-macron- secretly-aided-uber-lobbying-drive-france-leak-reveals

[5] Internet Service Provider

infrastructure and cloud services. Internet speed varies in different regions and it may directly affect the company.

From an environmental perspective, companies exist in different surroundings. Some might find themselves in a desert while others might be close to a forest. How electricity is produced in the locality also has an impact on the microlevel environmental aspect. If the company works in an industry that utilizes raw material, its availability also depends on the geographical location of the company.

3.1.2 Mesosystem

The mesosystem represents the second layer in our MLPESTEL framework. This level is a step towards a higher level of abstraction in the relations of the company to its surrounding reality. Microsystem level highlighted concrete, immediate interactions, whereas mesosystem is about higher level emerging factors in each PESTEL category.

When inspecting the mesosystem from a legal perspective, we can identify several factors that may influence the company such as how the law is actually enforced and enacted in the society. Perhaps there are laws that nobody follows, maybe there are legal petitions set forward for or against the company and so on.

The political section of the mesosystem consists of factors such as voting, regulation change and political support. A company can receive direct financial support from the government in dire times. For example, Finnair received financial support from the government during the pandemic[6]. How people vote can also have an effect on the operational environment of a company, which is a likely reason for several Silicon Valley CEOs siding with Trump in 2024 elections[7].

From the economic perspective, we can identify mesosystem components such as purchasing power and wages. In a country where salaries are high, the company also needs to pay their staff high salaries or else they will risk losing their staff in the long run. If there is a lot of purchasing power, companies can thrive easier than at times of recession.

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[6] https://www.ts.fi/uutiset/5167859
[7] https://www.ft.com/content/e2ffd807-1c18-436c-9f70-2fa7181ace2a

Looking into the social, we can identify that people have certain values, attitudes and beliefs. These can even turn into movements. Harnessing these as part of a marketing strategy can be beneficial for a company. People need to be communicated with in their own language and from the perspective of their own value system.

Technology develops rapidly in giant leaps from black and white TV all the way to modern AI. New innovations introduce paradigm shifts that companies can turn into their advantage in the competitive business landscape. New technology also makes it possible to do things more efficiently and typically, with less human resources.

Mother nature is unpredictable and, at times, she is ready to unleash her wrath upon humanity. Natural disasters such as earthquakes and landslides can put company operations at an unexpected halt. There is always a degree of scarcity related to natural resources, especially when talking about non-renewable resources. This scarcity tends to cause fluctuation in prices.

3.1.3 Exosystem

The exosystem represents the third layer in our MLPESTEL framework, encompassing a broader national context that indirectly influences the company through their overarching impact on the micro- and mesosystems. While the company may have little possibility to directly interact with these elements, they play a significant role in shaping the overall business environment.

Law is ultimately governed in a country by its legal system. Oftentimes, there are several levels of courts of justice all the way to the supreme court. How fairly and truthfully these actors enact the power bestowed on them has an impact on any company operating in the country.

The current government and president have an indirect effect on the company. They can change the laws and even alter the constitution. It is to be noted that a company might be able to lobby these actors already at the level of the microsystem. However, in the exosystem these actors act in their national duty of exerting power.

Many national economic factors influence the company. Gross domestic product (GDP) is an indication of how well the economy fares. During times of plenty, companies find it easier to get their products and services sold. Taxes and decisions by the national central bank in regard to altering the external value of the currency have a great impact on the company.

What emerges from the values and beliefs of groups is culture. This along with demographics, mass media, the availability of healthcare and workers rights set the frames within which the company can operate in the realm of the social.

With the rise of AI, ethics and regulations have come into play when talking about technology at the exosystem level. Import and export of certain technologies and their compatibility across regions may also be limited and impact the company.

When inspecting the environmental aspects on a more national level, geography and climate are the clearest limiting and enabling factors for the company. The level in which nature is to be protected als varies from one country to another.

3.1.4 Macrosystem

The macrosystem represents the outermost layer of our MLPESTEL framework. At this level, we already move away from the national level and we take a global or supranational perspective at inspecting the operational environment of a company.

Countries set their internal laws, but there are several regulatory bodies that set laws that are above the local government. For example, in the US, there are federal laws imposed on all states and in the EU, there are regulations that each member state must implement in their own legislation. Additionally, countries have several multilateral agreements such as agreements between the OECD and UN countries.

There are several supranational political actors as well such as the European Commission, G8 countries, OECD countries, federations and so on. War and peace are also purely political decisions and their ripple effects can be felt in companies globally.

Just as a national central bank can alter the external value of a currency, for currencies used in several countries, the central bank is on the level of the macrosystem such as the European Central Bank. In the economic sector, we can also identify other global actors such as the IMF and global conglomerates.

Diving into the social, migration has a big role in transnational identities and communities. These can form a sense of a global identity of individuals and companies alike. Big countries also engage in culture export – K-pop, anime and Ikea meatballs are but examples of the global world we live in.

Technology requires raw materials and thus comes in limited quantities. The global availability of certain technology may be limited and favor companies from certain countries. For instance, there has been a shortage of GPUs globally[8] ever since the early pandemic and it has further been accentuated by the increase in demand due to the AI boom.

Currently, there are two severe things affecting the environmental aspects globally. The climate change and the global warming resulting from it will change the operational landscape for many companies for good.

3.1.5 Chronosystem

The last system is more of a reminder of the dynamic nature of the world. No system is stable but volatile and retaining a status quo is difficult for long periods of time. Chronosystem takes time into consideration. As time goes on, there will be changes on all levels of the MLPESTEL framework. Sometimes the changes might be gradual such as global warming, which progresses steadily. Sometimes changes can occur all of a sudden such as in the case of a big war.

Each system also interacts with each other and it is not to be seen that the systems would have clear cut boundaries. There is overlap in different levels just as there is overlap in the different PESTEL categories.

[8] https://www.run.ai/guides/multi-gpu/gpu-shortage

3.2 Implications of MLPESTEL

In today's complex and interconnected global economy, businesses operate in environments characterized by multifaceted and dynamic influences. Analyzing these influences effectively requires a framework that can capture the nuances of various external factors, while also considering their interactions at different levels. As opposed to the regular PESTEL framework, MLPESTEL makes it possible to conduct analysis on a more granular level through different levels of abstraction of each subsystem.

By using our framework, companies can gain a comprehensive and concrete understanding of the external operational environment in which they ubicate, enabling them to make well-informed strategic decisions and adapt to changing conditions. Identifying the key actors already in the microsystem, makes it possible to provoke positive change across different systems.

We further study the usefulness of our framework by elaborating a computational approach to forecasting. Our MLPESTEL framework is deeply interwoven into the very fabric of the computational model. This enables us to test-drive our model with data from real world companies.

4 COMPUTATIONAL APPROACH

Building upon the MLPESTEL framework introduced in the previous section, this chapter outlines the computational approach designed to leverage LLMs in analyzing and forecasting the complex business environment across multiple systemic levels.

4.1 Overview of Computational Methods

The computational approach in this thesis leverages the power of LLMs and Natural Language Processing (NLP) techniques to operationalize the MLPESTEL framework. This approach aims to provide a systematic and scalable method for analyzing the complex business environment across multiple systemic levels.

At its core, our computational method utilizes a state-of-the-art LLM, namely GPT-4o (OpenAI 2023), as the primary tool for processing and analyzing textual data. We use the model through Perplexity AI platform[9], due to its ability to conduct thorough web searches to obtain relevant content (e.g., news articles and company press releases) to include in the LLM context and the ability to manually control its access to the internet. The choice of using an LLM is motivated by the remarkable capabilities of LLMs in understanding context and performing various NLP tasks simultaneously with high accuracy (Brown et al. 2020). The use of LLMs in business analysis and forecasting has gained significant interest in recent years, with applications ranging from market trend analysis to risk assessment (Biswas & Sanyal 2021).

Our approach consists of two main components: data collection and iterative prompt engineering. The data collection step consists of automated retrieval of relevant news articles, industry reports and company-specific information. The prompt engineering involves development of carefully crafted prompts that guide the LLM to extract and analyze information relevant to each layer of the MLPESTEL framework. Iterative prompting is used to generate insights, identify trends and synthesize information across different systemic levels.

[9] https://www.perplexity.ai/

This computational approach is based on some of the recent work in the field of AI assisted business analysis. An example of such recent work comes from Garg et al. (2023) who demonstrated the effectiveness of using LLMs for startup evaluation and success prediction. Another worthy example is by Siddiqui et al. (2023) who showcased the potential of integrating machine learning techniques with traditional forecasting methods in the sector of fast moving consumer goods.

By putting focus on prompt engineering and iterative analysis, our approach aims to find a balance between the sophisticated capabilities of LLMs and the need for human oversight and interpretation. This aligns with the growing recognition in the field that effective AI-assisted analysis requires a symbiotic relationship between human expertise and machine intelligence (DellaCrosse et al. 2024). In the following sections, we will delve deeper into each component of our computational approach, discussing the specific techniques, challenges and considerations involved in implementing this method within the context of the MLPESTEL framework.

4.2 Role of LLMs in Textual Data Analysis

LLMs have a wide range of textual analyses that they are able to perform instantly on the text. Some of the critical textual analysis abilities for our approach are, information extraction, sentiment analysis, trend identification, crosslingual analysis and summarization and synthesis. Through *information extraction*, key information would be retrieved from several volumes of text in quick time, from news articles to industry reports to social media posts, which will help us in quickly gathering the relevant data for each of the layers in the MLPESTEL framework.

Sentiment analysis provides us with the general feeling and emotional tone of textual data, including the prevailing opinion, the market atmosphere and the attitude of stakeholders across the different levels. This is essential in our MLPESTEL framework as we would be able to understand positive and negative influences impacting the company, for example. Moreover, LLMs can help in the *identification of emerging trends* and shifts in most PESTEL categories.

Many LLMs are multilingual; the *crosslingual analysis* feature would allow for trend analysis on a global scale and comparison tools cross-culturally, useful at the macro and exosystem levels and when the company is not based in an English speaking country, such as Nokia. A well-known ability of LLMs is *text summarization*, reducing huge volumes of text into succinct summaries that make the

process for extracting insights across different systemic levels and PESTEL categories much easier to manage.

However, it's important to acknowledge the limitations and challenges associated with using LLMs for textual analysis. A recent survey study by Kalyan (2023) found that issues such as bias, hallucination and lack of true understanding of the world can negatively affect the reliability of LLM outputs. In order for us to address these challenges, we incorporate human oversight and validation in our approach. This is done to ensure that the insights generated by LLMs are critically evaluated and contextualized within the broader context of theMLPESTEL framework. For a comprehensive limitation analysis conducted by the authors of GPT-4, see Achiam et al. (2023).

4.3 Model Development and Implementation

The development and implementation of our computational model for the MLPESTEL framework involves a systematic approach. This approach uses the capabilities of LLMs while addressing the specific requirements of each system level and PESTEL category. Our model is designed to be both comprehensive and adaptable. It is capable of processing diverse inputs and generating nuanced insights across the complex business environment.

Prompt engineering is the most important part in getting the best results out of an LLM. There is no single correct way of doing prompt engineering that would work in all contexts. Prompt engineering should be seen as an iterative process of continuous artesanal prompt refinement. For this task, we use Prompterator (Sučik et al. 2023), which is a tool that lets us iteratively refine our prompts in order to reach the optimal prompt for our task.

Fine-tuning ML models is proven to yield the best results (see Alyafeai et al. 2020). The process of fine-tuning involves adjusting the weights of the neural network to be able to handle a specific task better (e.g., adjusting its knowledge to a specific domain). However, this is not desired in all situations as it requires data collection to fine-tune the model on, and technical knowledge about training the model, along with the extra costs associated with it and that the model’s performance might degrade on other tasks. For these reasons, we decided to focus on prompt engineering in this study and left fine-tuning for future research.

In our approach, we perform multiple passes over the data, each of them focusing on one systemic level or PESTEL category at a time. The outputs from earlier iterations are fed back into the model to inform subsequent analyses, hence better identification of cross-level interactions and emergent patterns.

We have been conscious of the ethical considerations and potential biases throughout the development process. We implement safeguards to ensure that the model's outputs are transparent, traceable and subject to human oversight (e.g., providing all the online resources used to back up the analysis and statements produced by the LLM). This approach aligns with recent recommendations for responsible AI development in business applications (see Tamburri 2020).

Figure 2 illustrates an overview of our approach for forecasting using MLPESTEL and LLMs. The process begins by querying an LLM to obtain historical data about the company. Alternatively, a database consisting of relevant data about the company can be built by the forecasting researcher or the company itself, which might yield better results.

The next step is to perform the analysis. During the analysis, we recommend limiting the scope to the past few years (~ 5). In this analysis, all the layers of our MLPESTEL framework must be analyzed, from all the six segments. Once the analysis is done, the results are fed to the LLM along with a prompt instructing it to forecast future trends.

In our research, we perform the data collection and analysis for 2015-2020 and forecast trends for the next 2-3 years. This would allow us to validate our approach by checking the predictions against real world events that took place recently.

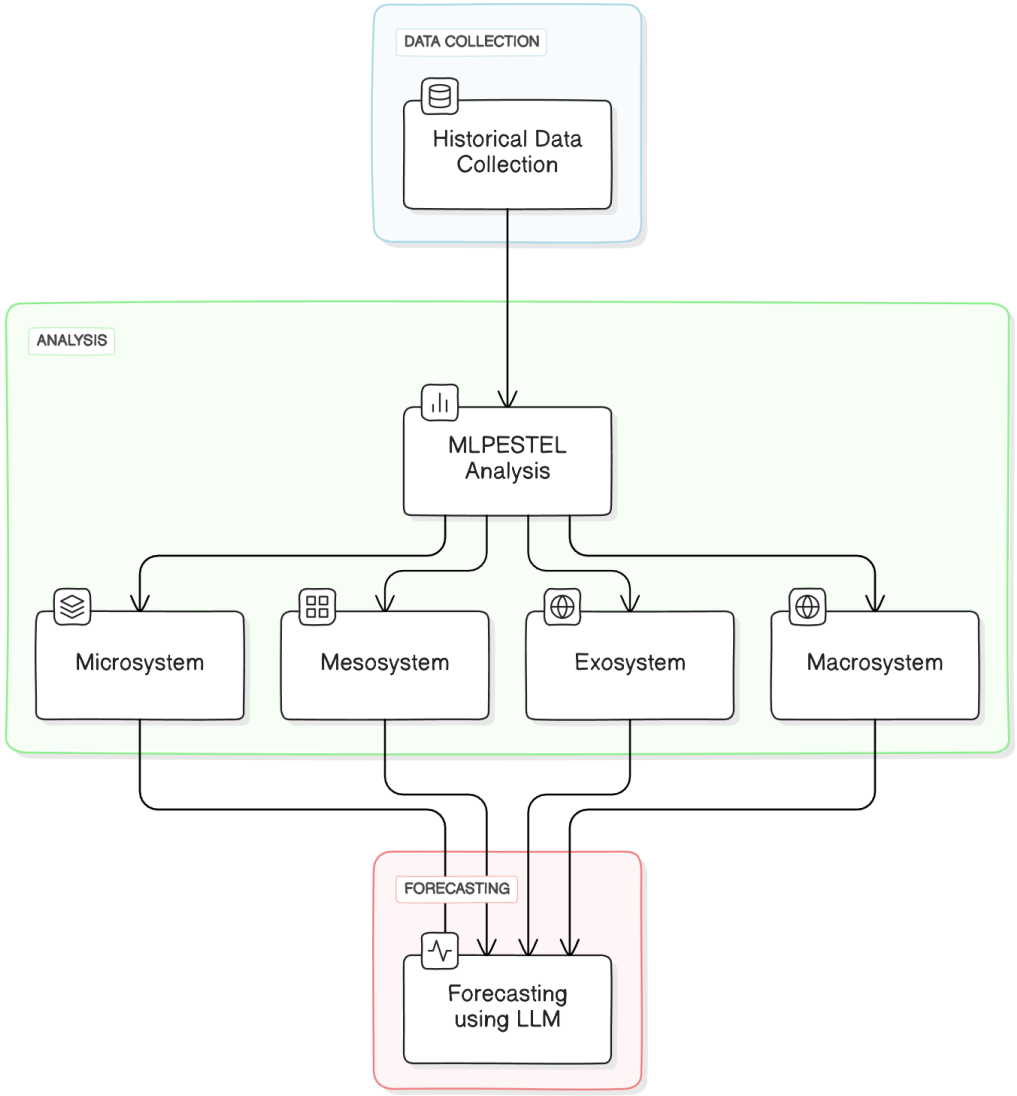

FIGURE 2. An overview of MLPESTEL in the LLM pipeline

4.4 Prompts

In this section, we describe the 26 prompt templates we used to prompt the LLM with company data and MLPESTEL. These templates are later on, applied for each individual company. Because these are prompt templates, they include placeholders such as [Company] and [start year] which are replaced by actual values when the actual prompting is done. Furthermore, the template can be tuned to be more specific to a given area within the company, such as supply chain.

4.4.1 Historical Data Collection

Our first prompt deals with historical data collection and it is used to gather data from the internet that is relevant for understanding the company in question. This can give the LLM a better grasp on the company and past events that explain its current and future standing.

> Prompt Template 1: *Collect and summarize key events from the web, market data and industry trends related to [Company] and the [Company's industry] industry from [start year] to [end year]. Focus on technological advancements, supply chain developments, regulatory changes and market dynamics.*

Prompt Template 1 is the initial seed prompt that tells the LLM to seek information about a company within the specified year range. This data is then utilized in the later stages of the process.

4.4.2 MLPESTEL Analysis

In this section, we describe the various prompt templates that we use to have the LLM analyze the company based on the four subsystems of our MLPESTEL framework and the 6 segments of the model. We present the prompts for each subsystem in this section.

Microsystem

The following prompt templates are tailored strictly with the microsystem in mind. Each PESTEL segment is prompted separately.

> Prompt Template 2 Political**:** *Provide a detailed analysis of the specific political relationships and direct influences that local government officials and immediate government bodies have exerted on [Company] from [start year] to [end year]. Include examples of regulatory interactions and policy impacts.*

> Prompt Template 3 Economic**:** *Identify and evaluate the direct economic relationships between [Company] and its key financial stakeholders such as banks, investors and financial services from [start year] to [end year]. Assess how these relationships have influenced the company's financial stability and growth.*

Prompt Template 4 Social**:** *Examine the direct social influences on [Company], focusing on interactions with local media, community leaders and influencers from [start year] to [end year]. How have these relationships shaped the company's public image and community engagement?*

Prompt Template 5 Technological**:** *Detail the technology providers and the technological environment that have directly impacted [Company] from [start year] to [end year]. Evaluate how regional technological disparities have influenced operational efficiencies.*

Prompt Template 6 Environmental**:** *Assess the direct environmental factors such as local regulations and geographical conditions impacting [Company] from [start year] to [end year]. How have these factors influenced company operations and sustainability initiatives?*

Prompt Template 7 Legal**:** *Review the legal environment and immediate legal challenges faced by [Company] in its locality from [start year] to [end year], focusing on cases, regulations and compliance issues. How have these influenced strategic decisions?*

Prompt Templates 2-7 make the LLM analyze the company at the level of the microsystem. The analyses are restricted to the year span provided in the prompt template

Mesosystem

The following prompt templates are meant to analyze the company at a mesosystem level. Again, there is a separate prompt for each PESTEL segment.

Prompt Template 8 Political**:** *Evaluate how local government policies and community political actions have directly affected [Company] from [start year] to [end year]. Discuss specific policies and their impacts on business operations.*

Prompt Template 9 Economic**:** *Analyze the local economic conditions like market demand and employment trends in the regions where [Company] operates from [start year] to [end year]. Assess their impact on staffing and sales figures.*

Prompt Template 10 Social**:** *Identify broader local cultural trends and social attitudes impacting [Company] from [start year] to [end year]. How have these trends influenced marketing strategies and customer engagement?*

Prompt Template 11 Technological**:** *Assess how local technological availability and infrastructure have influenced [Company]'s product development and operational capabilities from [start year] to [end year]. What technological gaps or advantages has the company experienced?*

Prompt Template 12 Environmental**:** *Examine local environmental policies and sustainability initiatives affecting [Company] from [start year] to [end year]. How have these policies shaped the company's environmental strategy and compliance?*

Prompt Template 13 Legal**:** *Review broader legal issues and compliance demands locally where [Company] operates from [start year] to [end year]. How have these influenced operational practices and risk management?*

Prompt Templates 8-13 serve for having the LLM conduct a thorough analysis from the point of view of the mesosystem. These prompt templates are time sensitive as they encompass a certain timeframe.

Exosystem

This section showcases the prompt templates that were used to elicit analyses for the exosystem. PESTEL segments are represented as separate prompt templates.

Prompt Template 14 Political**:** *Analyze the broader state or national political landscape's impact on [Company] from [start year] to [end year], with emphasis on legislative changes and government relationships. How have these factors affected market entry and regulatory compliance?*

Prompt Template 15 Economic**:** *Evaluate macroeconomic factors like GDP trends, fiscal policies and economic cycles impacting [Company] from [start year] to [end year]. Assess their influence on investment decisions and pricing strategies.*

Prompt Template 16 Social**:** *Identify national cultural shifts and demographic changes influencing [Company] from [start year] to [end year]. How have these trends affected consumer behavior and product acceptance?*

Prompt Template 17 Technological**:** *Review the impact of national technology policies and innovation trends on [Company] from [start year] to [end year]. What opportunities or challenges have arisen from these trends?*

Prompt Template 18 Environmental**:** *Assess national environmental initiatives and their effects on [Company]'s operations from [start year] to [end year]. How has this altered the company's sustainability goals and practices?*

Prompt Template 19 Legal**:** *Analyze national legal reforms and their implications for [Company] from [start year] to [end year], focusing on compliance and legal risks. How have these reforms shaped the company's legal strategy?*

Prompt Templates 14-19 invite the LLM to analyze a given company from the perspective of the exosystem. The company name and year span are populated when the templates are used.

Macrosystem

The last system we craft prompt templates for is unsurprisingly the macrosystem. These prompt templates can be seen in this section.

Prompt Template 20 Political**:** *Examine global political trends and international relations affecting the industry and [Company] from [start year] to [end year]. How have these trends influenced international trade and diplomatic relationships?*

Prompt Template 21 Economic**:** *Analyze long-term global economic paradigms and their influence on sustainable transportation from [start year] to [end year]. Evaluate how these paradigms have affected [Company]'s market expansion and global positioning.*

Prompt Template 22 Social**:** *Identify overarching cultural values and global movements related to sustainability and technology from [start year] to [end year]. How have these influenced [Company]'s branding and consumer engagement globally?*

Prompt Template 23 Technological**:** *Assess fundamental technological paradigm shifts in energy, transportation and AI from [start year] to [end year]. How have these shifts presented opportunities or challenges for [Company]?*

Prompt Template 24 Environmental**:** *Evaluate global environmental ideologies and long-term climate patterns from [start year] to [end year]. How have these ideologies and patterns influenced [Company]'s operations and strategic planning?*

Prompt Template 25 Legal**:** *Review evolving global legal philosophies on technology regulation and environmental protection from [start year] to [end year]. How have these philosophies impacted [Company]'s compliance strategies and international operations?*

Prompt Templates 20-25 are essential for extracting a macrosystem level analysis from the LLM. Not unlike the other templates, these too are time sensitive.

4.4.3 Forecasting

The prompt used for the actual forecasting is described in this section. It is important to note that the internet access was toggled off when the forecasting prompt was passed to the model. This way we could ensure that the results are based on a forecast rather than prior knowledge accessible to the model.

Prompt Template 26: *Based on the Multilayer PESTEL analysis of [Company] from [start year] to [end year], predict concrete future key trends for each layer, which are Micro (individual actors level), Meso (local-level), Exo (national-level), Macro (global and international level), and each PESTEL category. Forecast potential future disturbances and opportunities that would impact [Company]'s business model and success for the next 2-3 years.*

Prompt Template 26 will conduct the final forecasting task. This structured approach allows us to systematically analyze a company's environment across multiple levels, leverage the LLM to identify trends and make predictions and then validate those predictions against the company's actual trajectory. This process will help demonstrate the potential of our MLPESTEL framework and LLM-based analysis in forecasting significant business challenges and opportunities for a company undergoing major transformation in a rapidly evolving industry.

4.5 Analysis on Companies

We have chosen two companies from different industries that would be suitable for validating the MLPESTEL framework and computational approach, namely Tesla (automotive and energy industry) and Nokia (mobile and network industry). These two companies were picked because they are international and well-known, making obtaining online information about them easier and faster. Nonetheless, our framework is applicable to local and smaller companies, as long as the relevant information can be harnessed (manually or automatically) and provided to the LLMs.

Tesla[10] is a leading electric vehicle and clean energy company, known for its innovative approach to sustainable transportation and energy solutions. We chose Tesla because it operates at the intersection of multiple PESTEL factors, particularly in the technological, environmental and economic domains. Its business model is highly sensitive to changes in government policies, environmental regulations and technological advancements.

> Validation Case 1: *The global chip shortage of 2021-2022. Using the MLPESTEL framework and LLM analysis, Tesla could have potentially predicted the supply chain disruptions caused by the semiconductor shortage, allowing them to better prepare and mitigate its impact on production.*

We use Validation Case 1 to check whether the forecast predicted by the LLM has any truth value to it. A truthful forecast should include this validation case for Tesla.

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[10] https://www.tesla.com/

Nokia[11], a well-known Finnish multinational telecommunications, information technology and consumer electronics company. Nokia's history of transformation and its position in the global tech industry make it an excellent candidate for our MLPESTEL analysis. Validation case 2 is used to validate the LLM's forecasting performance for Nokia.

> Validation case 2: *Nokia exits the Russian market in 2022 following the sanctions on Russia due to the ongoing war*.

For each of these cases, we apply our MLPESTEL framework and computational approach retrospectively, using historical data up to a certain point before the significant event. We would then compare the model's predictions and insights with the actual outcomes, evaluating the framework's effectiveness in identifying key trends and potential disruptions across different systemic levels.

This approach allows us to validate the framework's predictive capabilities without the need for new data collection, instead relying on publicly available historical information and demonstrating how AI/LLM analysis could have provided valuable foresight in each scenario.

[11] https://www.nokia.com/fi_fi/

5 RESULTS AND EVALUATION

This section is dedicated to describing our main findings when applying our MLPESTEL framework on forecasting changes in the operational environment of Tesla and Nokia using an LLM. We showcase the full final analysis of the LLM for both companies, after which we proceed to validating the results of the automated analysis.

5.1 Case Study Findings

This section is divided into two subsections: one for Tesla, one for Nokia. In this section, we will describe and analyze the output produced by the LLM.

5.1.1 Tesla

The results produced by the LLM for Tesla can be seen in Table 1. The table is an LLM prompted summary of the analysis produced by the LLM.

TABLE 1. LLM predicted trends for Tesla in 2021-2023 based on MLPESTEL

	Microsystem	**Mesosystem**	**Exosystem**	**Macrosystem**
Political	Regulatory Compliance: Individual actors, such as Tesla's leadership team, will need to focus on navigating complex regulatory landscapes, especially in regions with stringent emissions and safety standards.	Local Incentives: Tesla will benefit from local government incentives for clean energy and EV adoption, which will influence production and sales strategies	National Policies: National policies promoting EV adoption and clean energy will drive Tesla's strategic planning and market expansion efforts	Global Trade Relations: Navigating global trade relations and geopolitical dynamics will be critical for Tesla's supply chain management and international operations
Economic	Cost Management: Decisions on cost management and pricing strategies will be crucial as Tesla aims to produce more affordable models like the "Model 2" to capture a broader market segment	Local Market Dynamics: Economic conditions in key local markets, such as purchasing power and consumer confidence, will impact Tesla's sales and marketing strategies	National Economic Trends: National economic stability and consumer spending power will influence Tesla's pricing strategies and market penetration	Global Economic Conditions: Global economic conditions, including currency fluctuations and raw material prices, will affect Tesla's production costs and pricing strategies

Social	Consumer Engagement: Tesla's direct-to-consumer sales model and strong brand loyalty will be leveraged to maintain consumer engagement and adapt to changing consumer preferences for sustainable products	Community Engagement: Tesla's engagement with local communities, including educational initiatives and job creation, will enhance its brand image and support local economies	Cultural Shifts: National cultural shifts towards sustainability and technological adoption will support Tesla's brand positioning and consumer engagement	Global Consumer Trends: Global consumer trends towards sustainability and innovation will support Tesla's market expansion and brand positioning
Technological	Innovation Leadership: Continued focus on R&D and maintaining technological superiority in battery technology and autonomous driving will be critical to staying ahead of competitors	Infrastructure Development: Expansion of charging infrastructure and local manufacturing capabilities will be essential to support Tesla's growth in specific regions	National Innovation Ecosystems: Collaboration with national innovation ecosystems will enhance Tesla's R&D capabilities and technological advancements	Global Technological Advancements: Leveraging global technological advancements in AI and renewable energy will enhance Tesla's competitive edge and product offerings
Environmental	Sustainability Initiatives: Individual actors within Tesla will prioritize sustainability in operations and product development to align with global environmental goals	Local Environmental Policies: Compliance with local environmental regulations and initiatives will shape Tesla's operations and sustainability practices	National Environmental Goals: Alignment with national environmental goals and emissions reduction targets will guide Tesla's sustainability initiatives	Global Environmental Initiatives: Participation in global environmental initiatives and alignment with international climate goals will reinforce Tesla's commitment to sustainability
Legal	Intellectual Property: Protecting intellectual property and navigating legal disputes will be important for maintaining Tesla's competitive edge	Local Compliance: Navigating local legal frameworks, including labor laws and safety standards, will be crucial for operational efficiency	National Regulatory Frameworks: Compliance with national regulatory frameworks, including emissions standards and safety regulations, will impact Tesla's operations and product offerings	Global Legal Compliance: Ensuring compliance with international legal standards and regulations will be essential for Tesla's global operations and market access

The forecast of Tesla's operational environment, as seen in Table 1, presents a view on the challenges and opportunities across different levels of systems impacting the company. At the microsystem level, Tesla's focus on regulatory compliance is paramount, with individual actors, particularly its leadership team, needing to adeptly navigate complex regulatory landscapes. This includes adhering to stringent emissions and safety standards in various regions. Simultaneously, local incentives play a crucial role, as Tesla can benefit from government policies promoting clean energy and electric vehicle (EV) adoption. Such incentives can be seen to directly influence production and sales strategies. This has a potential in enhancing Tesla's competitive edge in these markets.

The mesosystem and exosystem levels reflect the varying degrees of impact from economic, social, technological and environmental factors. Economic conditions, such as local market dynamics and national economic trends have a great effect on the pricing strategies and market penetration efforts embraced by Tesla. For instance, Tesla's ability to manage production costs and pricing is of paramount importance as the company aims to release more affordable models like the Model 2. When inspecting the social, Tesla's direct to consumer sales model and great brand loyalty are important for keeping consumer engagement up. Cultural shifts towards sustainability are guaranteed to boost Tesla's brand positioning, which will further reinforce its market presence. Technological innovation remains a cornerstone with Tesla's leadership in battery technology and autonomous driving being vital to staying ahead of competitors.

At the macrosystem level it is to be noted that global trade relations and economic conditions heavily influence Tesla's operational strategies. The company's current ability to navigate geopolitical dynamics and economic fluctuations is important for an effective supply chain management practice and any future desire for international market expansion. Tesla's commitment to sustainability is perfectly aligning with global climate goals and environmental initiatives. Legal factors such as intellectual property protection and compliance with international regulations are essential for maintaining Tesla's competitiveness and ensuring hassle free global operations.

Accuracy of Predictions

The LLM accurately predicted the persistence of semiconductor shortages in the short term, impacting Tesla's production capabilities, which was also our validation case for Tesla. This prediction was validated by the global chip shortage that began in 2020 and continued through 2021 and beyond. Tesla, like many other automakers, faced production challenges due to the shortage. In Q2 2021, Tesla CEO Elon Musk stated that the global chip shortage was a "huge problem" and cited it as a reason for production delays[12].

The LLM correctly identified the risk of ongoing supply chain disruptions leading to production delays and increased costs. This prediction was realized as Tesla faced production constraints due to supply chain issues, particularly related to semiconductor chips. Tesla's 2021 Impact Report[13] acknowledged

[12] https://www.cnbc.com/2021/09/24/tesla-ceo-elon-musk-says-the-chip-shortage-is-a-short-term-problem.html
[13] https://www.tesla.com/ns_videos/2021-tesla-impact-report.pdf

the challenges posed by supply chain disruptions, including the semiconductor shortage, but also highlighted the company's efforts to mitigate these issues through vertical integration and supply chain innovations.

The LLM highlighted the potential challenges in securing raw materials for batteries. While Tesla has made efforts to secure long-term contracts for critical materials, the industry has indeed faced challenges related to raw material supply, particularly for lithium and nickel. Despite the challenges, Tesla managed to increase its vehicle deliveries by 87% in 2021 compared to 2020, demonstrating the effectiveness of its supply chain management strategies[14].

The LLM's prediction that Tesla's investments in vertical integration could enhance its resilience to supply chain disruptions proved accurate. Tesla's efforts to develop its own battery technology and secure raw material supplies have helped mitigate some of the impacts of the global chip shortage. Tesla's development of its own chip designs and efforts to secure long-term supply agreements have helped the company navigate the chip shortage more effectively than some competitors[15].

The predictions were not all spot on, either. For example, the LLM was overly optimistic in its production and delivery forecasts. The predictions assumed Tesla would significantly increase production and deliveries year-over-year. However, Tesla faced production challenges and slower demand, particularly in China[16]. The predictions did not adequately account for the intense competition Tesla would face, especially from Chinese carmakers aggressively cutting prices[17].

On the financial side, some predictions, like ARK Invest's forecast of Tesla stock reaching $2,600 by 2029, appear to be extremely optimistic given the current market conditions and challenges faced by Tesla[18]. The predictions did not fully account for the impact of high interest rates, inflation, and global economic uncertainties on Tesla's performance[19].

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[14] https://digitalassets.tesla.com/tesla-contents/image/upload/IR/TSLA-Q4-2021-Update
[15] https://www.bloomberg.com/news/articles/2022-01-06/tesla-chips-and-china-the-auto-storylines-to-watch-in-2022
[16] https://fxopen.com/blog/en/analytical-tesla-stock-predictions-for-2024-2025-2030-and-beyond/
[17] https://www.litefinance.org/blog/analysts-opinions/tesla-stock-price-prediction/
[18] https://fortune.com/2024/06/12/tesla-stock-price-predictions-cathie-wood-ark-invest-elon-musk/
[19] https://www.blog-trends.com/tesla-pestel-analysis/

The model also ended up underestimating regulatory challenges. The predictions did not fully account for the regulatory hurdles Tesla would face in various markets, particularly regarding autonomous driving technology[20]. These inaccuracies highlight the difficulty in making long-term predictions in a rapidly evolving industry like electric vehicles, where technological advancements, market dynamics, and regulatory environments can change quickly.

Discussion

The MLPESTEL framework proved to be a valuable tool for analyzing the complex factors affecting Tesla's operations and supply chain. By considering multiple systemic levels, the framework provided a comprehensive view of the potential risks and challenges facing the company. The accuracy of the predictions regarding semiconductor shortages and supply chain disruptions highlights the framework's ability to identify key vulnerabilities in Tesla's operations.

The analysis correctly anticipated the impact of global economic and industry trends on Tesla's production capabilities. Nevertheless, the use of the framework could be further improved by incorporating an increasing number of quantitative data and actual timelines for predicted events. The automatic analysis could benefit from a more nuanced examination of technological innovations specific to Tesla and their potential impact on mitigating supply chain risks.

The MLPESTEL analysis of Tesla demonstrated the usefulness of the framework in identifying potential risks and providing valuable insights for decision makers. The accuracy of the predictions leaves more to be desired, but it is important to consider multiple system levels when analyzing complex business environments.

5.1.2 Nokia

Table 2 showcases the results produced by the LLM for Nokia. The table showcases a summary prompted from the LLM on the analysis conducted by the LLM.

TABLE 2. LLM predicted trends for Nokia in 2021-2023 based on MLPESTEL

[20] https://www.linkedin.com/pulse/tesla-external-environment-analysis-pestle-approach-isaiah-musolio

	Microsystem	Mesosystem	Exosystem	Macrosystem
Political	Increased scrutiny on corporate governance and ethical practices. Nokia may need to enhance transparency and accountability in its operations to meet stakeholder expectations.	Local governments pushing for digital infrastructure development. Opportunities for Nokia to partner with local authorities on smart city projects.	National policies supporting 5G and digital transformation. Nokia could benefit from government contracts and partnerships.	Global geopolitical tensions affecting supply chains. Nokia might diversify its supply chain to mitigate risks.
Economic	Individual investors and stakeholders demand sustainable financial practices. Nokia might focus on sustainable investments and transparent financial reporting to attract and retain investors.	Local economic incentives for tech companies. Nokia might leverage these incentives to expand local operations and R&D.	National economic recovery plans post-COVID-19. Opportunities for Nokia in infrastructure projects funded by recovery plans.	Global economic shifts towards digital economies. Nokia could capitalize on the demand for digital infrastructure.
Social	Growing consumer preference for ethical and sustainable brands. Nokia could strengthen its brand by emphasizing sustainability in marketing and product development.	Community-driven demand for digital inclusion. Nokia could engage in local initiatives to bridge the digital divide.	National focus on digital education and skills. Nokia might invest in educational partnerships to support digital literacy.	Global movements for social justice and equality. Nokia might enhance its corporate social responsibility initiatives.
Technological	Rapid adoption of AI and IoT by individual consumers. Nokia may need to innovate continuously to offer cutting-edge, consumer-friendly technologies.	Local tech hubs fostering innovation. Nokia might collaborate with local startups and tech communities for innovation.	National investments in AI and cybersecurity. Nokia could expand its offerings in AI-driven network solutions and cybersecurity.	Global acceleration of 5G and IoT adoption. Nokia could lead in providing comprehensive 5G solutions globally.
Environmental	Increased consumer awareness of environmental impact. Nokia might prioritize eco-friendly product designs and packaging.	Local regulations on waste management and recycling. Nokia could implement local recycling programs and sustainable practices.	National commitments to carbon neutrality. Nokia might align its operations with national sustainability goals.	Global climate change initiatives. Nokia might intensify its efforts in sustainable technology development.

Legal	Heightened individual awareness of data privacy rights. Nokia could enhance data protection measures to ensure compliance and build consumer trust.	Local compliance requirements for tech products. Nokia may need to adapt its products to meet local legal standards.	National data protection laws. Nokia may need to ensure compliance with varying national data regulations.	Harmonization of international tech regulations. Nokia may benefit from streamlined compliance processes across borders.

Nokia's operational environment, as seen in Table 2, is forecasted to be shaped by a complex interplay of factors across various systems. At the microsystem level, increased scrutiny on corporate governance and ethical practices signifies a need for Nokia to enhance transparency and accountability. This shift could demand Nokia to adapt its internal policies to meet higher stakeholder expectations, which may include stricter reporting standards and improved ethical practices. Similarly, individual investors are increasingly focused on sustainable financial practices, pushing Nokia to prioritize sustainability and transparent financial reporting to attract and retain investment.

On a mesosystem level, local and national dynamics present both opportunities and challenges for Nokia. Local governments are advocating for the development of digital infrastructure, creating potential partnerships for Nokia in smart city projects. Additionally, national policies that support 5G and digital transformation open doors for government contracts and collaborative ventures, potentially boosting Nokia's market presence. However, global geopolitical tensions could disrupt supply chains, prompting Nokia to consider diversifying its supply sources to mitigate potential risks. Economic recovery plans post-COVID-19 and global shifts towards digital economies also offer Nokia opportunities to engage in infrastructure projects and capitalize on the growing demand for digital solutions.

At the exosystem level, technological advancements and environmental considerations play crucial roles. The rapid adoption of AI and IoT necessitates continuous innovation from Nokia to stay competitive, while local tech hubs offer avenues for collaboration with startups and tech communities. National investments in AI and cybersecurity further emphasize the need for Nokia to expand its offerings in these areas. Concurrently, increasing consumer awareness of environmental impacts drives Nokia to focus on eco-friendly practices and align with national and global sustainability goals. Finally, the legal landscape is evolving with heightened data privacy concerns and varying national regulations, prompting Nokia to enhance data protection measures and adapt to diverse legal standards.

Accuracy of Predictions

The analysis correctly predicted the rapid growth and importance of 5G technology. Nokia indeed became a key player in the 5G market, with its 5G equipment being deployed globally. By 2023, Nokia

had secured over 300 commercial 5G deals[21], confirming the prediction of 5G's significance for the company's future.

The prediction highlighting the increasing importance of network security was accurate. Nokia expanded its security portfolio and partnerships to address growing cybersecurity concerns in the telecom sector. In 2022, Nokia launched its Advanced Security Testing and Research (ASTaR) lab in Dallas[22] to protect 5G networks, demonstrating the company's focus on this area.

The analysis correctly identified the intensifying competition in the telecom equipment market. Nokia faced strong competition from companies like Huawei and Ericsson, particularly in the 5G space. This competition led to pressure on profit margins and the need for continuous innovation, as predicted[23].

The prediction regarding the impact of geopolitical factors on Nokia's operations proved accurate. The US-China trade tensions and security concerns surrounding Huawei created opportunities for Nokia in markets like the United States[24] and Europe[25].

Unfortunately, our model was unable to predict our validation case of Nokia exiting the Russian market. This is but an event in the trajectory of Nokia, but the lack of the model's predictive capabilities in covering the validation case highlight that the model may not have a high recall on all possible events.

Based on the search results obtained from the LLM, there are several issues with the predictions for Nokia. The predictions did not accurately forecast the significant market challenges Nokia would face, particularly in its Mobile Networks division. Nokia reported a 19% year-on-year decline in net sales in Q1 2024, with Mobile Networks experiencing a 37% decline in constant currency[26]. Nokia revised its

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[21] https://www.nokia.com/system/files/2024-03/nokia-annual-report-2023.pdf
[22] https://www.nokia.com/system/files/2023-03/nokia-annual-report-2022.pdf
[23] https://www.lightreading.com/5g/huawei-amid-sanctions-beats-ericsson-and-nokia-on-every-measure
[24] https://www.theregister.com/2024/01/17/nokia_us_sales_list/
[25] https://www.lightreading.com/open-ran/nokia-is-replacing-huawei-at-deutsche-telekom-sites-in-germany
[26] https://www.telecomreview.com/articles/telecom-vendors/8030-resilience-amidst-market-volatility-nokia-s-q1-2024-performance

2026 comparable operating margin target downward from at least 14% to at least 13%[27]. This indicates that the company's profitability outlook was not as strong as initially predicted.

The predictions did not anticipate the extent of difficulties in the Mobile Networks division. For 2024, Nokia expects revenues for this division to decline by 10-15% following the loss of the AT&T radio access network (RAN) contract to Ericsson, which is impacting Nokia's 2024 outlook[28].

The predictions were overly optimistic about the timing of market recovery. Nokia now expects Q1 2024 to mark the low point in demand, with activity progressively picking up through the remainder of 2024. The predictions did not accurately forecast the significant slowdown in spending in key markets like North America and India, which has particularly impacted the Mobile Networks business[29].

Discussion

The MLPESTEL analysis of Nokia demonstrates the framework's effectiveness in providing a comprehensive understanding of a company's operational environment. The accuracy of key predictions, particularly regarding 5G adoption, network security and market competition, validates the framework's utility for strategic planning in the telecommunications industry.

The framework's multi-layered approach allowed for the identification of interconnected factors across different systemic levels. This holistic view enabled a nuanced understanding of how global trends, industry dynamics and company-specific factors would interact to shape Nokia's future.

The Nokia case study underscores the value of the MLPESTEL framework in navigating the complex and rapidly evolving telecommunications industry. By accurately identifying key trends and risks, the framework provided Nokia with actionable insights that aligned with the company's actual trajectory from 2021 to 2024.

5.2 Comparative Analysis

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[27] https://www.nokia.com/about-us/news/releases/2023/12/12/inside-information-nokia-provides-an-update-on-group-strategy-2026-comparable-operating-margin-target-and-preliminary-assumptions-for-2024/

[28] https://www.telecomtv.com/content/5g/nokia-set-to-shrink-again-in-2024-49482/

[29] https://www.telecomreview.com/articles/telecom-vendors/8030-resilience-amidst-market-volatility-nokia-s-q1-2024-performance

When we look at the results produced by the LLM for the two companies side by side, we can perceive significant differences in the output. In this section, we will show a comparative analysis on the LLM output.

TABLE 3. Number of sentences in the LLM outputs for the 25 analysis prompts for each company

Company	**Mean**	**Std Dev**	**Min**	**P_{25}**	**P_{50}**	**P_{75}**	**Max**
Nokia	18.64	1.955	14.0	17.0	19.0	20.0	23.0
Tesla	24.00	2.160	20.0	23.0	24.0	25.0	30.0

Table 3 shows the number of sentences the LLM generated for each company. As we can see, it generated fewer sentences for Nokia than what it did for Tesla. This might be due to the fact that many LLMs are biased towards the English speaking world, most notably the US. Based on our own prior experience, many LLMs showcase a wider understanding of American companies than Finnish companies. On the average, the responses for the prompts about Nokia were 18.64 sentences long whereas, the responses for Tesla were 24 sentences long.

Furthermore, we look into the number of words in the generated text by the LLM for each of the 25 analysis prompts per company, as shown in Table 4. The results confirm that the model indeed provided more content to the US company, Tesla, in comparison to the Finnish company Nokia, which highlights the bias and limitations of LLMs when asked about non-US-based companies.

TABLE 4. Number of words in the LLM outputs for the 25 analysis prompts for each company

Company	**Mean**	**Std Dev**	**Min**	**P_{25}**	**P_{50}**	**P_{75}**	**Max**
Nokia	401.24	36.839	339	375	404	426	474
Tesla	481.24	41.322	402	455	475	512	556

Next, we analyze the content of the text by clustering paragraphs returned by the LLM for both companies. Paragraphs are obtained by splitting the returned output by a new line. To clean the text, we removed numbers, headings and citations. In total, Tesla had 105 paragraphs while Nokia had 191. It is interesting to note that the number of paragraphs for Nokia is higher despite the fact that the paragraphs themselves were shorter than those of Tesla.

We utilized BERTopic (Grootendorst 2022) with SentenceEmbeddings (Reimers 2019) using "all-MiniLM-L6-v2"[30] model (Reimers, & Gurevych 2020) to represent each paragraph in an embeddings space which allows us to compare their semantic similarities. The process of clustering them begins with reducing the embeddings dimensionality to 5 components, using UMAP (McInnes et al. 2018), based on the closest 3 neighbors on the cosine similarity metric. To confirm that the reduced dimensionality represents the original space and retains its structure, we calculate the trustworthiness score (Van Der Maaten, 2009)[31]. For Tesla's dimensionality reduction case, the trustworthiness score is 0.90 suggesting that the structure is maintained to a high degree and it is even higher for Nokia's embeddings, 0.93.

Following that, we apply HDBSCAN (McInnes et al., 2017) to cluster the embeddings and count the frequent tokens in each cluster to act as its representation.

[30] https://huggingface.co/sentence-transformers/all-MiniLM-L6-v2

[31] Implemented in https://scikit-learn.org/stable/modules/generated/sklearn.manifold.trustworthiness.html

FIGURE 3 A plot showing the semantic clusters of LLM responses for Tesla's use case in a two-dimensional embedded space

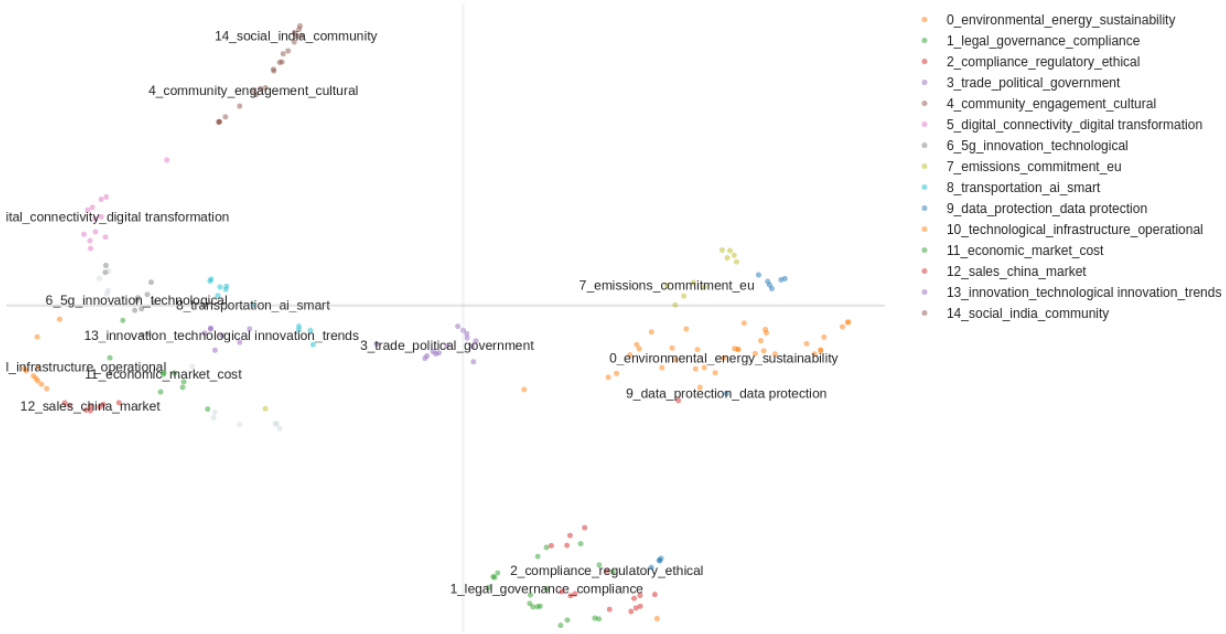

FIGURE 4. A plot showing the semantic clusters of LLM responses for Nokia's use case in a two-dimensional embedded space

As shown in Figure 3 and 4, semantic cluster plots for Tesla and Nokia, respectively, reveal specific patterns of the strategic focus area for each company, which provide some very interesting insights into what strategic focus areas the two companies are concerned about. By observing the main clusters that emerge from data, comparing and contrasting them we can see that Tesla’s clusters are more evenly distributed in comparison to Nokia’s. The figures show the focus of both companies on technology, sustainability, regulatory compliance, and market engagements. They point out peculiar challenges that each company faces in their respective industries and, therefore, the insight into their strategic priorities and areas of operational focus. Such differences in approach reflect not only the distinct positions each occupies within different industries but also their corporate philosophies and long-term vision as separate entities.

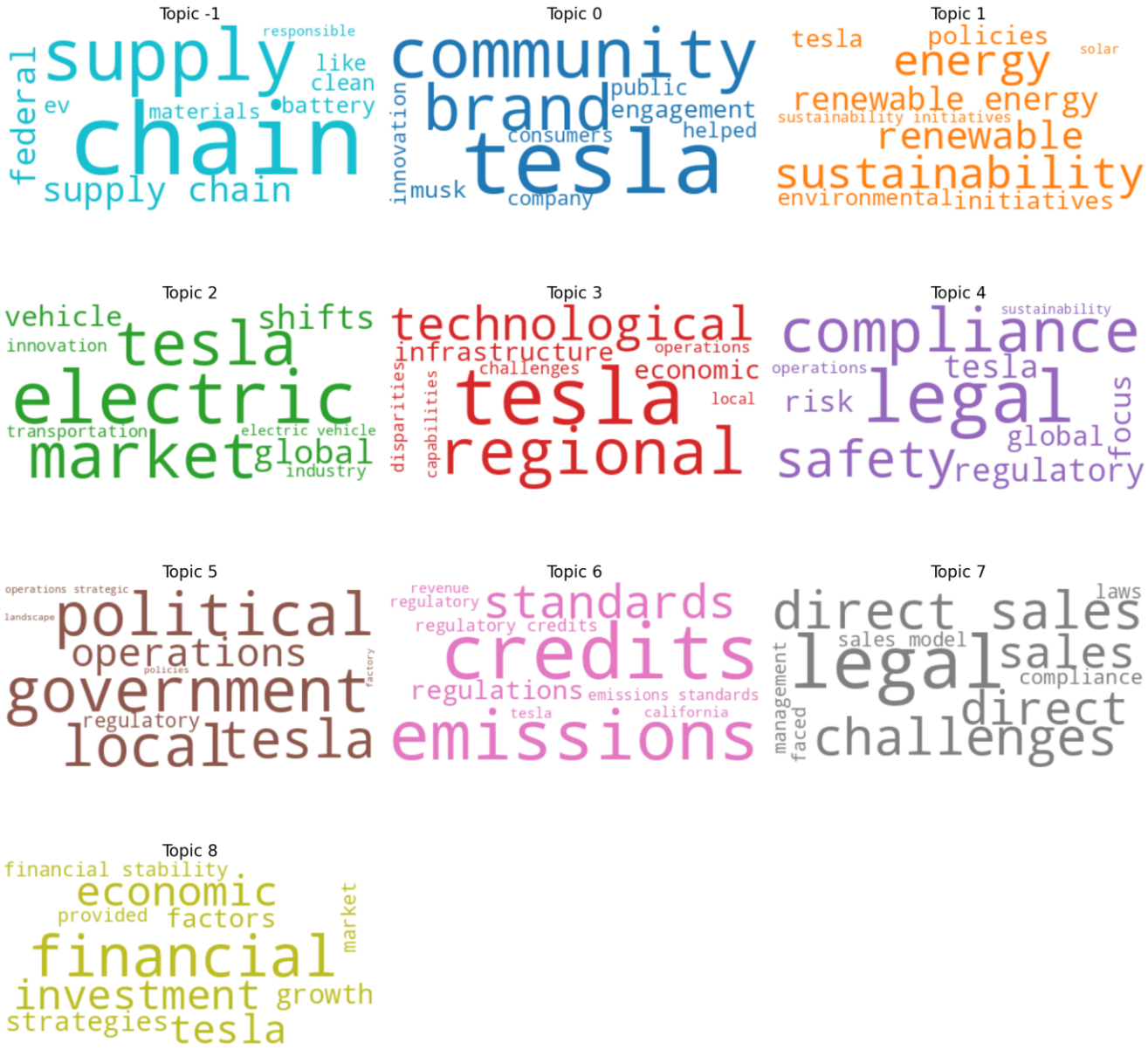

FIGURE 5. Word clouds showing the most prominent words in each semantic cluster (topic) for Tesla

Tesla's semantic clusters are mainly about sustainability, electric vehicles, and brand community. The fact that the three most prominent topics are "sustainability_energy_renewable", "electric_market_tesla", and "tesla_community_brand" reflects upon Tesla's public image and strategic priorities in the electric vehicle and renewable energy sectors. This is further supported by word cloud visualizations, shown in Figure 5, where emphasis is given to such terms as "supply chain", "battery", and "renewable energy". Tesla's approach seems to be highly integrated, with sustainability and technological innovation very much interwoven with the brand and community building efforts.

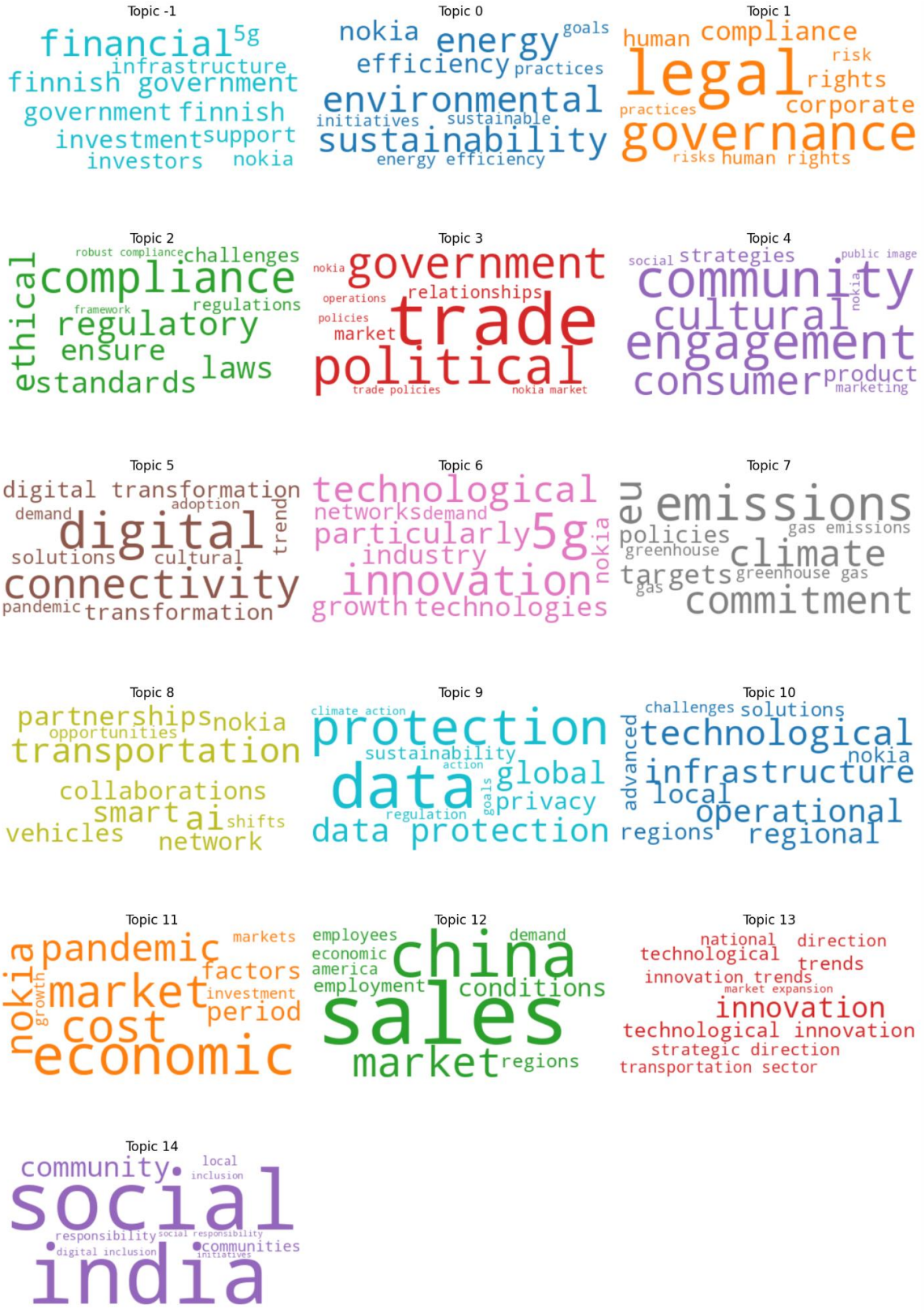

FIGURE 6. Word clouds showing the most prominent words in each semantic cluster (topic) for Nokia

In direct contrast, Nokia's clusters are highly focused on the theme of telecommunications technology, with "5g_innovation_technological", "digital_connectivity_digital_transformation", and "data_protection_data_protection" being some of the most outstanding themes. This is due to the fact that Nokia is one of the leading companies within the telecommunications industry and has set itself out as a leader in the use of new technology. The word clouds for Nokia, see Figure 6, emphasize words such as "5G", "innovation", and "digital connectivity", underlining the company's commitment to fostering advanced technological infrastructure.

Attention to legal and regulatory matters in both companies is high but different in emphasis. Clusters such as "legal_compliance_safety" and "legal_direct_sales_challenges" are indicative that Tesla is still evolving its way up the steep regulatory landscape typical of the automotive industry-a fact underlined in word cloud topic combinations such as "compliance," "safety," and "direct sales challenges." On the other hand, Nokia aims at more corporate governance and compliance with ethics in the technology industry, as evidenced from clusters such as "legal_governance_compliance" and "compliance_regulatory_ethical.".

The economic considerations for both companies are notable but approached differently. In Tesla, the cluster "financial_economic_investment" suggests a strong underlying focus on economic considerations and investment strategies, most likely due to the fact that electric vehicle and energy storage markets represent capital-intensive industries. Nokia's economic considerations appear more integrated with its technological focus, as seen in clusters like "economic_market_cost" and the prominence of terms related to market dynamics and cost factors in its word clouds.

All in all, the major themes emerging for Tesla are related to environmental sustainability. For example, "sustainability_energy_renewable" is a dominant cluster and the word clouds are full of words related to sustainability. For Nokia, there are indeed environmental concerns, but not as core to its overall strategy. Equally interesting are the differences that emerge from this analysis on how companies approach community and social engagement. Tesla strongly focuses on "tesla_community_brand", revealing that customer and brand loyalty are cornerstones in the development of its business model. Nokia follows a more B2B approach, as "community_engagement_cultural" is a cluster apart and not central, hence showing another way of considering stakeholder engagement in strategy.

By looking at the clusters and clouds, it is clear that the LLM demonstrated a comprehensive understanding of both companies, their industries, and the complex ecosystems in which they operate. This

shows that the LLM is trained with up-to-date information that exposes the model to recent events concerning both companies and their business models, legal compliance, and strategies on innovation, sustainability.

6 DISCUSSION

In this section, we discuss some of the theoretical and practical implications of our work. Furthermore, we identify some limitations and potential future research directions. We also indicate how we achieved the objectives and answered the research questions of this thesis. Theoretically, our findings contribute to a deeper understanding of how the MLPESTEL framework can be applied to analyze the operational environment of a company for the needs of forecasting. This offers new insights into automating and enhancing environmental scanning processes using LLMs, making them more data-driven and responsive to real-time changes. From a practical standpoint, these results have significant implications for business strategy and decision-making, as organizations can leverage the MLPESTEL framework to more effectively anticipate external challenges and opportunities in areas such as politics, economics and technology.

6.1 Theoretical Implications

The MLPESTEL framework developed in this study represents a significant advancement in futures studies and strategic management. By integrating Bronfenbrenner's Ecological Systems Theory with traditional PESTEL analysis, we have created a more nuanced approach to understanding complex business environments across multiple systemic levels (Objective 1, RQ1.1). Our framework's ability to capture the interplay between different environmental factors is a key contribution. Unlike traditional PESTEL analysis, MLPESTEL explicitly examines interactions between micro-, meso-, exo-, and macrosystems. This multi-layered perspective enables a more holistic view of challenges and opportunities facing organizations in rapidly evolving industries.

The application of MLPESTEL to Tesla and Nokia showcased its versatility in analyzing diverse industries and business models. By providing a structured approach to examining both immediate and distant environmental influences, the framework improved upon the classical methods of anticipating potential disruptions and identifying emerging trends (Objective 2, RQ2.3).

Incorporating LLMs into the MLPESTEL analysis process represents a novel approach to leveraging AI in strategic foresight (Objective 1, RQ1.2). This combination addresses a significant gap in existing

futures studies methodologies, which often struggle to process vast amounts of unstructured data effectively. LLMs enable rapid analysis of diverse information sources, providing a more comprehensive understanding of the business environment.

Our research revealed that LLMs are indeed capable of processing unstructured data, hence, offering deeper insights and more accurate predictions when it comes to futures studies (Objective 2, RQ2.1). Nonetheless, we also identified limitations when it comes to using LLMs. For example, the predictions done for Tesla were more relevant and accurate than the ones generated for Nokia, which is likely due to the little exposure to Nokia related data during the training phase of the LLM. This highlights the importance of involving human experts in interpreting results (Objective 2, RQ2.2).

6.2 Practical Implications

In addition to the benefits of embedding LLMs into MLPESTEL that are detailed earlier, our approach also provides decision-makers with a more comprehensive, nuanced, and forward-looking understanding of factors influencing their operations across multiple systemic levels. One primary advantage is ingesting and analyzing vast amounts of information from diverse sources to predict future events. Looking at the list of sources accesssed by the LLM during the analysis phase, we observe that it used data from news articles, industry reports, and social media. Such resources might be overlooked or require significant resources to uncover manually. The ability to quickly generate and evaluate multiple scenarios based on real-time data inputs enables businesses to be more agile and responsive to changing market conditions. These observations address our Research Question 2.1.

The multi-layered nature of MLPESTEL enables decision-makers to better understand the interconnectedness of various factors affecting their business. For instance, our analysis of Tesla's supply chain vulnerabilities demonstrated how micro-level operational decisions could be influenced by macro-level geopolitical tensions and global economic trends (Objective 2, RQ2.3). MLPESTEL supports more effective risk management strategies by providing a systematic approach to identifying and assessing potential risks across different systemic levels. This proactive approach can help companies build resilience and maintain operational stability in the face of unforeseen challenges.

6.3 Limitations and Future Research Directions

While offering valuable insights, the MLPESTEL framework and its application has limitations. One primary challenge lies in the framework's complexity, which can be difficult to operationalize fully. Future research could focus on developing more precise criteria for delineating systemic levels, perhaps through quantitative metrics or machine learning algorithms.

The reliance on publicly available data by the LLM is another limitation of this research. While the LLM used diverse sources, access to proprietary data could have provided deeper insights. This is clearly visible in the case of Nokia as the LLM made multiple incorrect predictions, in comparison to Tesla. Future studies could benefit from partnerships with industry players to gain access to such information, enhancing the depth and accuracy of the analysis. Also, building models tailored for certain regions (e.g., EU-specific), industries (e.g., cybersecurity-specific) and companies (e.g., Nokia-specific) can produce better predictions.

Our research also highlighted the importance of responsible AI use in business forecasting (Objective 3, RQ3.1). We found that maintaining human oversight and judgment in interpreting and acting upon AI-generated forecasts is crucial for addressing ethical considerations and potential risks associated with AI-powered decision-making. This is mainly because LLMs will always make predictions, even when there is not enough evidence to back them up or they are not confident about them. This LLM hallucination is a serious limitation that requires closer inspection of their output.

The use of LLMs, while innovative, presents certain limitations. The potential for bias in training data could influence the interpretation of environmental factors. Additionally, the "black box" nature of LLMs can make it challenging to fully understand the reasoning behind certain predictions. Future research could explore integrating explainable AI techniques with MLPESTEL, enhancing the transparency and interpretability of the analysis.

Our work focused only on two case studies, Tesla and Nokia. Application of MLPESTEL to other industries may give new insights about its generalizability. Using the framework to analyze the sustainability strategies within, for instance, the agricultural sector may offer interesting views about how different systemic levels interact within more traditional industries.

Another possible line of future research is that of integrating quantitative approaches with the qualitative framework of the MLPESTEL. For example, devising a system of weighted indicators for each PESTEL factor at systemic levels would give the possibility to obtain more realistic comparisons and analyze the trends; this could be pretty interesting in domains like finance or energy.

Our current research did not take into account start-ups or small and medium-sized enterprises for the most part. Further studies may also wish to examine how MLPESTEL can be used in relation to such a category, providing further nuance on the ways in which the various levels of the systemic will impact businesses in different stages of development and size.

The rapid rate of change in technology and world events would suggest even greater dynamism for MLPESTEL applications. Avenues for future research may include how to develop a digital platform or dashboard whereby the analysis is refreshed on an ongoing basis by real-time data feeds to provide businesses with an even more agile tool to inform strategic decisions in rapidly changing environments.

7 CONCLUSIONS

We successfully developed a comprehensive forecasting framework that integrates PESTEL analysis and Bronfenbrenner's Ecological Systems Theory with the processing capabilities of Large Language Models (LLMs), that is the first objective of this research. This framework, which we named MLPESTEL, provides a holistic approach to understanding complex business environments. The integration of these components allowed for a multi-layered analysis that captures both macro and micro-level factors influencing business outcomes.

Moreover, we identified several technical challenges in incorporating LLMs into the framework, including data quality issues, potential biases in LLM outputs, and the need for continuous model updates to reflect changing business landscapes. However, we also found that LLMs significantly enhanced the framework's ability to process vast amounts of unstructured data, providing deeper insights and more accurate predictions.

Our research has shown the significant potential that the MLPESTEL framework, when combined with LLMs, would provide a comprehensive and nuanced understanding of complex business environments. Merging Bronfenbrenner's Ecological Systems Theory with a traditional PESTEL analysis has yielded a very powerful tool for strategic planning and decision-making for an increasingly interconnected global marketplace.

A key contribution of this research is the successful integration of LLMs into the MLPESTEL framework. This integration proves that LLMs significantly enhanced our ability to process and analyze great volumes of unstructured data, which visibility results in deeper insights and more accurate predictions. Identification of subtle trends and weak signals that may escape being noticed during the more classical ways of analysis is made possible by the use of LLMs.

Our analyses of Tesla and Nokia, following MLPESTEL framework and using the computational approach, had demonstrated the full depth of the framework in depicting a multi-systemic level business environment. To be exact, the MLPESTEL analysis conducted on Tesla had provided very accurate predictions regarding its supply chain vulnerabilities, especially about semiconductor shortages. The case study on Nokia has been very good in showcasing the utility of the framework for understanding technological transitions and market repositioning strategies.

Furthermore, our research has highlighted the importance of considering interactions between different systemic levels. This is where, in fact, the power of MLPESTEL comes in: it can capture these interactions for a more holistic view of the business environment, thus offering much robust strategic planning. For instance, our analysis revealed how macrosystem-level factors, such as global climate change initiatives, cascaded down to influence microsystem-level operational decisions in companies like Tesla.

We recommend the adoption of the MLPESTEL framework by all practitioners, even as a stand-alone framework without incorporating it with an LLM, as it acts as a comprehensive tool for environmental scanning and strategic planning. The framework's novel multi-layered approach can provide valuable insights for decision-makers across various industries.

When plugging in an LLM to the MLPESTEL framework, significant abilities are unlocked that facilitate analyzing and forecasting complex business environments rapidly which speed up making informed and robust strategic decisions. As we navigate an increasingly complex and interconnected global business landscape, tools like the MLPESTEL framework become invaluable and essential for making sense of the constantly changing world affecting businesses. They allow us to not only react to changes in the business environment but to anticipate and proactively address potential challenges and opportunities. Of course, it is important to recognize that while the MLPESTEL framework is a powerful tool, it is not a panacea. Its effectiveness ultimately relies on the quality of data input, the expertise of those interpreting its outputs and the willingness of decision-makers to act on its insights.

With the above, we have completed the second objectives of this thesis which are Utilizing and validating LLMs for forecasting. We have considered the limitations and biases of LLMs when used for forecasting. When it comes to best practices for responsible AI, our findings emphasize the importance of maintaining human oversight and judgment in interpreting and acting upon AI-generated forecasts. In addition to that, it is also critical to understand the limitation of LLMs especially when it comes to SMEs or non-US companies as these models would not have sufficient knowledge about them to make very reliable predictions.

Looking ahead, we see great potential for further refinement and application of the MLPESTEL framework across various industries and contexts. As AI and machine learning technologies continue to evolve, we anticipate even more sophisticated integrations that could further enhance the framework's

predictive capabilities. Additionally, we believe that building organization-specific LLMs by fine-tuning LLMs on private and public business data would yield more relevant and up-to-date predictions, which is something we hope to see in future research.

REFERENCES

Abbasimehr, H., Shabani, M., & Yousefi, M. (2020). An optimized model using LSTM network for demand forecasting. Computers & industrial engineering, 143, 106435.

Accenture. (2023). Supply Chain Disruption and How to Respond. https://www.accenture.com/cn-en/insights/consulting/supply-chain-disruption

Achiam, J., Adler, S., Agarwal, S., Ahmad, L., Akkaya, I., Aleman, F. L., & McGrew, B. (2023). Gpt-4 technical report. *arXiv preprint arXiv:2303.08774*.

Aguilar, F. J. (1967). Scanning the business environment. MacMillan Co., New York.

Alaeddine, M., & Tannoury, A. (2021). Artificial intelligence in music composition. In Artificial Intelligence Applications and Innovations: 17th IFIP WG 12.5 International Conference, AIAI 2021, Hersonissos, Crete, Greece, June 25–27 2021, Proceedings 17 (pp. 387-397). Springer International Publishing.

Alyafeai, Z., AlShaibani, M. S., & Ahmad, I. (2020). A survey on transfer learning in natural language processing. arXiv preprint arXiv:2007.04239.

Anderson, S., Rayburn, S. W., Sierra, J. J., Murdock, K., & McGeorge, A. (2022). Consumer buying behavior and retailer strategy through a crisis: A futures studies perspective. *Journal of Marketing Theory and Practice*, 30(4), 457-475.

Biswas, S., & Sanyal, S. (2021). AI-Based Sales Forecasting Model for Digital Marketing. International Journal of Advanced Computer Science and Applications, 12(4), 285-292.

Bronfenbrenner, U. (1979). The ecology of human development: Experiments by nature and design. Harvard University Press.

Brown, T. B., Mann, B., Ryder, N., Subbiah, M., Kaplan, J., Dhariwal, P., & Amodei, D. (2020). Language models are few-shot learners. arXiv preprint arXiv:2005.14165.

Bubeck, S., Chandrasekaran, V., Eldan, R., Gehrke, J., Horvitz, E., Kamar, E., & Zhang, Y. (2023). Sparks of artificial general intelligence: Early experiments with gpt-4. arXiv preprint arXiv:2303.12712.

Ceperic, V., & Markovic, T. (2024). Transforming Time-Series Data for Improved LLM-based Forecasting through Adaptive Encoding. International Journal of Simulation – Systems, Science & Technology, 25(1).

Chen, Y., Elenee Argentinis, J., & Weber, G. (2016). IBM Watson: How Cognitive Computing Can Be Applied to Big Data Challenges in Life Sciences Research. Clinical Therapeutics, 38(4), 688-701.

Chui, M., Manyika, J., & Miremadi, M. (2018). What AI can and can't do (yet) for your business. McKinsey Quarterly, 1(97-108).

Cleland Silva, T. C., & Hämäläinen, M. (2024). Innovating for the Future: AI and HRM Capabilities for Sustainability in Higher Education. In Academy of Management Proceedings (Vol. 2024, No. 1, p. 19249). Valhalla, NY 10595: Academy of Management.

DellaCrosse, M. A., Garcia-Romeu, A., & Davis, A. K. (2024). Seeing the forest for the trees: An ecological systems theory approach to addressing emergent issues in psychedelic-assisted therapy research. *Journal of Psychedelic Studies.*

Demir, S., Mincev, K., Kok, K., & Paterakis, N. G. (2019). Introducing technical indicators to electricity price forecasting: A feature engineering study for linear, ensemble and deep machine learning models. Applied Sciences, 10(1), 255.

Dhaliwal, J., & Tomar, P. (2022). A detailed Analysis of Use of AI in Inventory Management for technically better management. International Journal of Advanced Research in Science, Communication and Technology, 6(1), 1-6.

Elliott, S., & Davis, J. M. (2020). Challenging taken-for-granted ideas in early childhood education: A critique of Bronfenbrenner's ecological systems theory in the age of post-humanism. *Research handbook on childhood nature: Assemblages of childhood and nature research*, 1119-1154.

Flynn, K., & Mathias, B. (2023). "How Am I Supposed to Act?": Adapting Bronfenbrenner's Ecological Systems Theory to Understand the Developmental Impacts of Multiple Forms of Violence. *Journal of Adolescent Research*, 07435584231159674.

Gambhir, M. K., & Ashfaq, R. (2021). The Role of Influencer Marketing in Building Brands on Social Media: An Analysis of Effectiveness and Impact. Journal of Language and Linguistics in Society (JLLS) ISSN, 2815-0961.

Ghosh, I., Chaudhuri, T. D., Alfaro-Cortés, E., Gámez, M., & García, N. (2022). A hybrid approach to forecasting futures prices with simultaneous consideration of optimality in ensemble feature selection and advanced artificial intelligence. Technological Forecasting and Social Change, 181, 121757.

Gilliland, M., Tashman, L., & Sglavo, U. (2021). Business forecasting: the emerging role of artificial intelligence and machine learning. John Wiley & Sons.

Greco, S. (2019). Explaining black-box models in the context of Natural Language Processing (Doctoral dissertation, Politecnico di Torino).

Gregoric, M. (2014). PESTEL analysis of tourism destinations in the perspective of business tourism (MICE). Tourism and Hospitality Industry, 1, 561-573.

Grootendorst, M. (2022). BERTopic: Neural topic modeling with a class-based TF-IDF procedure. *arXiv preprint arXiv:2203.05794*.

Gu, Q., Chang, Y., Xiong, N., & Chen, L. (2021). Forecasting Nickel futures price based on the empirical wavelet transform and gradient boosting decision trees. Applied Soft Computing, 109, 107472.

Heiskanen, E., Jalas, M., & Kärnä, A (2000). Dematerialization: The potential of services and information technology. Futures, 32(3-4), 267-280.

Hämäläinen, M. (2024). Legal and Ethical Considerations that Hinder the Use of LLMs in a Finnish Institution of Higher Education. In Proceedings of the Workshop on Legal and Ethical Issues in Human Language Technologies@ LREC-COLING 2024 (pp. 24-27).

Hämäläinen, M., Alnajjar, K., & Poibeau, T. (2022). Modern French poetry generation with roberta and gpt-2. In The Proceedings of the 13th International Conference on Computational Creativity (ICCC).

Hämäläinen, M., Huhtaniemi, M., & Unkari-Virtanen, L. (2024). Suositus ennakointitiedon johtamiseen. Tulevaisuuden kudelmia. Ennakointikyvykkyyden kehittäminen Metropoliassa, 50-63.

Inayatullah, S. (2003). Futures studies in Asia: Players and institutions. Futures, 35(6), 689-694.

Ji, L., Zou, Y., He, K., & Zhu, B. (2019). Carbon futures price forecasting based with ARIMA-CNN-LSTM model. Procedia Computer Science, 162, 33-38.

Kalyan, K. S. (2023). A survey of GPT-3 family large language models including ChatGPT and GPT-4. Natural Language Processing Journal, 100048.

Khan, R. A. (2022). COVID-19's impact on human resource management strategy: A review study. IUBAT Review — A Multidisciplinary Academic Journal, 5(1), 44-53.

Kumar, A. (2024). 10 Ways to Improve Cross-Departmental Collaboration. https://www.saviom.com/blog/improve-cross-departmental-collaboration/

Lang, I. (2022). PESTEL Analysis of the Business Environment of Georgia and the United States of America. *Economics & Business (1987-5789)*, (3).

Lucas, H. C., & Goh, J. M. (2009). Disruptive technology: How Kodak missed the digital photography revolution. The Journal of Strategic Information Systems, 18(1), 46-55.

Makridakis, S., Spiliotis, E., Assimakopoulos, V., Semenoglou, A. A., Mulder, G., & Nikolopoulos, K. (2023). Statistical, machine learning and deep learning forecasting methods: Comparisons and ways forward. Journal of the Operational Research Society, 74(3), 840-859.

McInnes, L., Healy, J., & Astels, S. (2017). HDBSCAN: Hierarchical density based clustering. Journal of Open Source Software., 2(11), 205.

McInnes, L., Healy, J., & Melville, J. (2018). UMAP: Uniform manifold approximation and projection for dimension reduction. *arXiv preprint arXiv:1802.03426*.

Molyboga, M., Qian, J., & He, C. (2021). Practical applications of carry and time-series momentum: A match made in heaven. The Journal of Alternative Investments, 23(4), 123-138.

Moody, J. (2021). The persistence of memory: Remembering slavery in Liverpool, "slaving capital of the world". Liverpool University Press.

Nielsen, S. (2022). Management accounting and the concepts of exploratory data analysis and unsupervised machine learning: a literature study and future directions. Journal of Accounting & Organizational Change, 18(5), 811-853.

Olivier-Pijpers, V. C., Cramm, J. M., & Nieboer, A. P. (2018). Influence of the organizational environment on challenging behaviour in people with intellectual disabilities: Professionals' views. Journal of Applied Research in Intellectual Disabilities, 32(3), 610-621.

OpenAI. (2023). Gpt-4 technical report. arXiv preprint arXiv:2303.08774.

Orte, F., Mira, J., Sánchez, M. J., & Solana, P. (2023). A random forest-based model for crypto asset forecasts in futures markets with out-of-sample prediction. Research in International Business and Finance, 64, 101829.

Panopoulos, N., & Drossinou-Korea, M. (2020). Bronfenbrenner's theory and teaching intervention: The case of a student with intellectual disability. Journal of Language and Linguistic Studies, 16(2), 537-551.

Pecan. (2024). Revamp Your Marketing Campaigns With AI Customer Segmentation. https://www.pecan.ai/blog/ai-customer-segmentation-marketing/

Porter, J. (2023). 5 Strategies for Reducing Costs in the Supply Chain. https://stockiqtech.com/blog/strategies-cost-reduction-supply-chain/

Porter, M. E. (1989). How competitive forces shape strategy (pp. 133-143). Macmillan Education UK.

Prysiazhniuk, O., & Plotnikova, M. (2023). Managing the Resilience of Territories, Business and Tourism in the Context of Urbanization of Socio-Economic Processes. In Sustainable Socio-Economic Development Journal

Reimers, N. (2019). Sentence-BERT: Sentence Embeddings using Siamese BERT-Networks. *arXiv preprint arXiv:1908.10084.*

Reimers, N., & Gurevych, I. (2020). Making monolingual sentence embeddings multilingual using knowledge distillation. *arXiv preprint arXiv:2004.09813*.

Roh, Y., Heo, G., & Whang, S. E. (2019). A survey on data collection for machine learning: a big data-ai integration perspective. IEEE Transactions on Knowledge and Data Engineering, 33(4), 1328-1347.

Ruiz, L. D., McMahon, S. D., & Jason, L. A. (2018). The Role of Neighborhood Context and School Climate in School-Level Academic Achievement. American Journal of Community Psychology, 61(3-4), 296-309.

Sammut-Bonnici, T., & Galea, D. (2015). PEST analysis. In C. L. Cooper (Ed.), *Wiley Encyclopedia of Management* (pp. 1-8). John Wiley & Sons.

Sanson, M. (2024). The transformative power of AI in logistics and supply chain management. The Virtual Forge. https://www.thevirtualforge.com/company/blog/the-transformative-power-of-ai-in-logistics-and-supply-chain-management

Siddiqui, K. I., Lee, M. M. Y., Koch, T., & Dugundji, E. (2023). Case Fill Rate Prediction. In International Conference on Innovative Intelligent Industrial Production and Logistics (pp. 285-303). Cham: Springer Nature Switzerland.

Spedding, T. A., & Chan, K. K. (2000). Forecasting demand and inventory management using Bayesian time series. Integrated Manufacturing Systems, 11(5), 331-339.

Steiber, A., & Alänge, S. (2013). A corporate system for continuous innovation: the case of Google Inc. *European Journal of Innovation Management*, 16(2), 243-264.

Stevenson, S. (2007). A comparison of the forecasting ability of ARIMA models. Journal of Property Investment & Finance, 25(3), 223-240.

Stringham, E. P., Miller, J. K., & Clark, J. R. (2015). Overcoming barriers to entry in an established industry: Tesla Motors. California Management Review, 57(4), 85-103.

Sugiyono, A., Febijanto, I., & Hilmawan, E. (2022). Potential of biomass and coal co-firing power plants in Indonesia: a PESTEL analysis. In *IOP Conference Series: Earth and Environmental Science* (Vol. 963, No. 1, p. 012007). IOP Publishing.

Sun, M., Zhang, Y., Chen, R., Wen, Y., & Nie, P. (2021). Hedging strategy for commodity futures based on SVM-KNN. International Journal of Reasoning-based Intelligent Systems, 13(3), 139-146.

Sučik, S., Skala, D., Švec, A., Hraška, P., & Šuppa, M. (2023). Prompterator: Iterate efficiently towards more effective prompts. In Proceedings of the 2023 Conference on Empirical Methods in Natural Language Processing: System Demonstrations (pp. 471-478).

Tamburri, D. A. (2020, September). Sustainable MLOps: Trends and challenges. In *2020 22nd international symposium on symbolic and numeric algorithms for scientific computing (SYNASC) (pp. 17-23)*. IEEE.

Tan, T. (2007). Using imperfect advance demand information in forecasting. BETA publicatie: working papers, 199.

Thakkar, A., & Chaudhari, K. (2021). A comprehensive survey on deep neural networks for stock market: The need, challenges and future directions. Expert Systems with Applications, 177, 114800.

Van Der Maaten, L. (2009). Learning a parametric embedding by preserving local structure. In *Artificial intelligence and statistics* (pp. 384-391). PMLR.

Vidal, A., & Kristjanpoller, W. (2020). Gold volatility prediction using a CNN-LSTM approach. Expert Systems with Applications, 157, 113481.

Wang, X., & Ihlamur, Y. (2024). An Automated Startup Evaluation Pipeline: Startup Success Forecasting Framework (SSFF). arXiv preprint arXiv:2405.19456.

Yang, L., Holtz, D., Jaffe, S., Suri, S., Sinha, S., Weston, J., & Teevan, J. (2021). The effects of remote work on collaboration among information workers. *Nature human behaviour*, 6(1), 43-54.

Yazdi, M., Zarei, E., Adumene, S., Beheshti, M., & Li, H. (2024). Navigating the power of artificial intelligence in risk management: A comparative analysis. Safety, 10(2), 42.

Zhao, L. (2021). Event prediction in the big data era: A systematic survey. ACM Computing Surveys (CSUR), 54(5), 1-37.

Çitilci, T., & Akbalık, M. (2020). The importance of PESTEL analysis for environmental scanning process. In Handbook of research on decision-making techniques in financial marketing (pp. 336-357). IGI Global.