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Business Ecosystem Profiling Visualization with Data Analytics: A Review

Minnu Helen Joseph* and Timo Kärri

Department of Industrial Engineering and Management, LUT University,
Yliopistonkatu 36, Lappeenranta, Finland

Minnu.Joseph@lut.fi, timo.karri@lut.fi

Abstract. In business fields, an ecosystem, which is a shared environment consisting of organizations, individuals, resources, and technologies that are dynamically interconnected, is needed to provide and deliver emerging innovations and sustain competitive advantages. This article provides a thorough, systematic, and structured review of several frameworks of business ecosystems and their functioning. It also covers how data analytics can enhance ecosystem profiling by integrating it into these frameworks. Additionally, by considering advanced methodologies, this article highlights how actionable insights can be gained in the different operations and applications, from market analysis to risk management. Also, this review showcases several visualization tools that can be used to view complicated ecosystem structures, which helps employers to explore, analyze, and visualize data effectively. Finally, the article discusses the strengths and weaknesses of these tools and also offers some insights that can enhance decision-making in the emerging trends in the business ecosystem.
Keywords: Business Ecosystem, Profiling, Ecosystem Frameworks, Data Analytics, Visualization.

1 Introduction

As the business landscape evolves, companies and organizations continue to recognize the importance of understanding the broader context in which their systems operate. The business ecosystem concept serves as a framework for companies and industries to illustrate the interconnected nature of various entities and the complex relationships that highlight their dynamic competition. This concept was initially presented by James F. Moore in his article "Predators and Prey: A New Ecology of Competition" in 1993, which was published in Harvard Business Review. This title connects the business environment to a biological ecosystem, which shows how the functionality of the terms "predators" and "prey" works within dynamic and emerging

* Corresponding author

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Additional information. Author ORCID iD: M. H. Joseph – https://orcid.org/0009-0002-1714-7933, T. Kärri – https://orcid.org/0000-0002-6659-1419. PII S225599222500235X. Received: 4 April 2025. Accepted: 4 July 2025. Available online: 31 July 2025.

systems [1], [2]. This work shows the interconnections and dependencies of businesses and showcases that the success of each company or industry often depends not only on internal capabilities but also on external interactions.

Since its initiation, the business ecosystem concept has gained significant power in the industry, and it has become a central point of interest for both researchers and experts in this field. The business ecosystem concept concerns a framework that provides a detailed analysis of various components that impact an organization's success, growth, and long-term survival in the competitive and complex market [2], [3]. This ecosystem framework also shows the interconnected relationship among the diverse groups of stakeholders, including suppliers who deliver essential resources, competitors who monitor and influence the changes in the current market, customers who prefer to generate demands, and regulatory bodies who establish legal and ethical constraints within the business operation.

By understanding the inter-relationships among these groups, organizations can make valuable contributions and insights that help industries shape and enhance their position in the current markets. The use of the ecosystem framework helps businesses to face challenges effectively, identify new collaborations, and adapt to new changes. It helps organizations maintain sustainable growth and remain effective in a rapidly changing economic landscape.

In addition to the framework, the ability to profile and visualize the business ecosystem effectively has a pivotal impact in this context. Profiling helps organizations get a clear view of the competitive environment, identify capable collaborators, and expose new opportunities for innovation [4]. On the other hand, visualization helps to translate complex ecosystem data into more actionable insights and supports decision-making. Combining profiling and visualization allows organizations to understand industry trends, adapt to new challenges, and maintain their position in a competitive and dynamic environment [2], [5].

Even though the business ecosystem is widely adopted among researchers and experts, it faces several challenges. Among those, the first is semantic ambiguities in the terms such as "innovation" and "digital ecosystems", the delay in sharing knowledge, and interdisciplinary collaborations [6]. Secondly, the integration of different data sources, mainly the types of datasets, which can be from structured databases to unstructured text-based data. These challenges force the deployment of strong analytical frameworks and visualization techniques that can simplify the complexity and dynamic changes in the business ecosystems.

This article aims to contribute knowledge on:

- Exploring the basics of business ecosystems, including their frameworks and dynamics.
- Investigating the current data analytics techniques for ecosystem profiling.
- Evaluating the various visualization tools and methodologies that can enhance decision-making.

By addressing these topics, this article aims to provide insights that can be used by both researchers and industry experts on how the business ecosystem can be managed more effectively using data analytics in this competitive marketplace. Section 2 provides a literature review. The literature analysis results are amalgamated in Section 3. Section 4 concludes the article.

2 Literature Review

2.1 Literature Review Methodology

A systematic and structured approach was used to gather and analyze the literature. The review was conducted on different academic websites, including Google Scholar, ScienceDirect, Scopus, and JSTOR. The search process focused primarily on articles published between 2015 and the present, ensuring the inclusion of recent research. To provide a comprehensive view, earlier works were also considered to support the context and background of the study.

As a search and selection strategy, a combination of broad and specific keywords was used to capture the in-depth literature. The following strings were applied: "business ecosystem profiling", "data analytics in business ecosystems", "visualization techniques for business ecosystems", "business ecosystem frameworks", and "data visualization for decision-making". Boolean operators such as AND and OR were used to refine searches with the keywords. Filters were used to narrow down the search results based on peer-reviewed articles, journal articles, and the English language. The search process initially identified 108 articles, and after removal, a total of 87 articles were considered for this study, including the articles that highlighted the tools.

Regarding categorization, a qualitative analysis was done to categorize the key themes and findings. Articles were categorized according to theoretical framework (Section 2.2), data analytics and its application in business ecosystems (Section 2.3), and visualization techniques (Section 2.4). The analysis was focused on common trends, existing literature gaps, and the main focus was on how data analytics can be integrated to find solutions for the challenges faced by business ecosystems. Through this method, the article provides a comprehensive review of the current state of research, highlights the contributions of data analytics and visualization in business ecosystem profiling, and gives ideas for future exploration in this field.

2.2 Business Ecosystem Foundations and Frameworks

The concept of the business ecosystem has made a considerable evolutionary change in the industrial management field since it was first introduced by Moore in 1993 [1]. He used the term to show the relationship between companies' interactions. These kinds of interactions can happen within a single company or within multiple companies, which can create rich collaborations and competition. Somehow, the business ecosystem can be similar to biological ecosystems, where different species co-exist and rely upon each other for their survival and growth. Likewise, business ecosystems also consist of organizations that rely on each other for their interdependencies for their business and co-evolution, which helps them to respond well to the dynamic market and create an adaptive value that benefits all the participants in the ecosystem.

Based on Moore's foundational work, researchers and experts have developed and deployed various theories and frameworks that help to effectively understand and analyze the flow of ecosystems. These frameworks consider factors such as innovation dynamics, competitive strategies, and the impact of technology on collaboration and value creation. The concept of a business ecosystem requires focusing on how organizations are interconnected and help each other overcome the difficulties faced in complex business environments [7].

2.2.1 Biologic Analogies

As mentioned earlier, business ecosystems are framed based on biological frameworks, where the organizations act like species in nature, cohabiting with each other. These kinds of frameworks convey co-evolution, adaptation, and mutual dependency among firms.

The organizations in the ecosystem can be categorized as Predators, Prey, and Keystone species. Dominant organizations are considered predators, which puts extensive pressure on smaller organizations considered as prey. For instance, larger e-commerce companies such as Amazon act as the predator that controls the market dynamics, with smaller retailers facing challenges in the intense competition [8]. Sometimes, some companies act as a keystone in the ecosystem. Consider Microsoft, which acts as a keystone in the whole software ecosystem. It helps in delivering vast networks of hardware and third-party tools. These keystone companies provide an infrastructure that other companies can depend on [9].

Also, organizations in the ecosystem are involved in co-evolution and mutual dependencies. Organizations in the ecosystems must always respond to each other. In an ecosystem, organizations cannot stand independently and must be interdependent on each other. For instance, top companies like Apple and Google must collaborate for innovative ideas in the mobile and technology industries [10]. Similarly, in the automotive industry, car manufacturers, battery companies, and governments must work together and depend on each other to promote electric vehicles [11].

As part of this interdependence, all involved organizations would benefit. For instance, Intel and Microsoft collaboratively work together in the computing ecosystem, with Microsoft providing operating systems and Intel supplying processors [12], [13].

Commensalism (one organization benefits without affecting the other dependent ones) also matters in these interdependencies. For instance, Amazon AWS provides the framework for other companies without affecting their core business. There can also be parasitic relationships between organizations where one organization benefits from the expenses incurred by the other organization.

Ecosystem changes depend on technology and market forces. Sometimes, some new technologies replace old ones. It is called disruptive innovation [14]. We can see that the transition from Kodak's films to digital cameras shows ecosystem changes. Here, companies such as Canon emerged and replaced the older ones such as Kodak [15].

2.2.2 Platform-Centric Ecosystems

The platform-centric ecosystem was first introduced by [9]. In a platform-centric ecosystem, some organizations work as a hub and keep good network effects and interactions between other entities. As an example, digital platforms, such as Apple's App Store and Google's Android, serve as hubs by helping to facilitate interactions between developers, users, and other stakeholders. The platform owners set the technical rules and standards for smooth transactions, while entities, such as developers, always try to maintain their content or services and ensure smooth transactions with the other entities. Other entities, like consumers, use these platforms. As more entities join, the platform's value increases and can create a virtual cycle.

Even though the concept of platform-centric ecosystem is widely accepted, there are some challenges. The rules set by the platform owners must be balanced so that they encourage more participation, and at the same time, maintain quality. The platform owners must also maintain healthy competition among the entities without affecting the market while ensuring fair value for all entities.

2.2.3 Network-Theory-Based Modeling

A business ecosystem is considered a complex system that consists of many hierarchical entities and relationships. The entities include companies, suppliers, customers, the government, and other regulatory bodies. Understanding the relationship of these entities is essential for gaining insights and for further innovation [16]. Network theory helps us to visualize the relationships among entities. All entities are depicted as nodes and their relationships as edges [17], [18]. These relationships can be partnerships, supply chain links, customer relationships, or inter-company interactions. Each node has specific attributes like size, market influences, and role within the ecosystem. In the same way, edges are weighted according to their strength and importance in the relationship [19].

Even though network theory helps us to view the complex relationships between entities, it also helps us to understand the hidden patterns of collaborations and competition. It helps organizations with their strategic planning and operational efficiencies. It also helps provide some insights into the ecosystem's strength by categorizing the entities with various metrics, such as connectivity, clustering [20], classifications [21], and redundancy. It also conveys the resource flow and the impact of individual node failures.

2.2.4 Frameworks for Business Ecosystems

Frameworks have been developed to understand the ecosystem of organizations and how these organizations collaborate, innovate, adapt, and interact with other entities in their environment.

Adner's Value Blueprint [22], [23] proposed a framework that shows the interdependencies of an organization's ecosystem, mainly to identify collaborations and risks. The main aim of this framework is to show participants the effect of shared objectives, especially showing the value of how it helps in their collaborative effort. It allows organizations to identify complexities and to encourage real partnerships [24].

Burmeister et al. [25] proposed a framework called ARBITER, which works well with the digital business ecosystem. Digital business ecosystem frameworks show the necessity of IT infrastructures and platforms to help organizations' self-maintenance, scalability, and co-evolution. The ARBITER framework helps to break the digital ecosystems into clustered components, so it will be easier to find the gaps between technologies and viewpoints and maintain smooth transformations and integrations to adapt to dynamic digital environments.

The combination of business and the digital ecosystem is known as a knowledge ecosystem, which can work well in industries, government, and academia. The Triple Helix model, as outlined by [6], demonstrated these intersections by using a framework and shows how well it can contribute to academia, industries, and governments for their innovation-driven ecosystems. In addition to that, the adaptability of cognitive fit theories, which were discussed in [26], helps to visualize the ecosystem and helps to enhance the decision-making process according to the user's needs. The visualization approach helps the ecosystem participants view the interactions and the dynamic changes in the ecosystems to enhance their organizations' management and further planning.

The key characteristic of an ecosystem is that it helps in co-evolution. As an example, the integration of artificial intelligence and big data analytics helps in the evolution of the digital ecosystem [18]. Also, the interdependent and interconnectivity roles of an ecosystem help to maintain total risk management, which can overcome the difficulty of one failure in one entity affecting the entire network [22]. An ecosystem is dynamic, according to the real-time changes, involving the entry and exit of entities, technological advancements, and adaptation to new market demands. One such example of the involvement of artificial-intelligence-powered visualization analytics in the ecosystem has been explained by Basole et al. [18].

2.3 Data Analytics in Business Ecosystem Profiling

Data analytics has led to a big change in the organization's view of an ecosystem. It has become easy for them to understand and manage the ecosystem using tools to explore, analyze, and visualize diverse datasets. Data analytics helps the participants view the organization's interconnections and interactions, track market fluctuations, and identify potential risks and opportunities. It offers descriptive, predictive, and prescriptive insights that can help in making meaningful decisions in dynamic environments [26].

Graph-based models use network-based models to show the relationships between participants in the ecosystem. Entities such as firms, technologies, and participants are nodes, and their relationships are shown with edges. The graph-based model helps find the key entities and clusters within the ecosystem. Basole et al. [18] have used the graph-based model to showcase the visualization of the ecosystem, which helped to reveal its hidden patterns and interdependencies. This model helps to identify the visual complexity, such as the strong hubs and the weak links. Also, it can analyze potential changes, such as the entry and exit of key players. It also helps to enhance the robustness of the ecosystem by evaluating the vulnerabilities within it.

Data analytics also helps to extract insights from unstructured data sources such as press releases, blogs, reports, and social media. Techniques such as text mining and natural language processing help to transform unstructured data into structured data for various analyses in order to gain insights [27]. For instance, sentiment analysis can be used to monitor public opinion of firms and products, topic modeling to uncover emerging trends within the industries, and entity recognition to identify potential nodes.

Predictive analysis uses historical data to predict future trends and events within an ecosystem. Machine learning algorithms play an important role in identifying insights and predicting future trends [6]. It can be used to identify industry shifts or turns, possible threats such as supply chain disruptions or competitive pressures, and to estimate market growth potential and investment opportunities. Clustering and classification techniques were used to segment the participants into groups according to similar attributes [20], [28]. Multivariate techniques are used to extract high-dimensional data into predictable components. Time series techniques are used to analyze the effects over time and help make real-time adjustments to strategies [26].

Data analytics helps to derive actionable insights using various tools and techniques, especially in business ecosystem profiling. In the remainder of this sub-section, some application domains of these techniques and tools are listed and briefly described.

Market Analysis and Segmentation: Data analytics helps to analyze the market by integrating various data sources, such as customer sales transactions, social media conversations, industrial reports, and government laws. Clustering, classification, and regression techniques help to analyze the market and segment the businesses into more detail and categories [29]. For instance, the clustering technique groups customers according to their purchase behavior, which helps to decide on market strategies. These analytics techniques helped sales growth by 85% and gross margin by 25% [29].

Customer Behavior and Sentimental Analysis: Analyzing customer behavior is essential to understanding market dynamics. A natural language processing (NLP) technique called sentiment analysis helps to understand customer behavior by examining the text data from social media, onsite reviews, and customer feedback [30]. A study done by Lu et al. [15] shows that customer behavior analysis and sentiment analysis help to increase the companies' insights and, at the same time, increase customer satisfaction by 20%. For this purpose, tools such as Python's Natural Language toolkits and Stanford's Core NLP can be used for sentiment analysis, which can help to get the customer's attention, and for companies to adjust their strategies accordingly.

Supply Chain Optimization: Data analytics helps to improve supply chains by enhancing product demand predictions, inventory management, and logistics. These techniques help to know product demand fluctuations; thus, they help minimize product stockouts as well as overstock situations [31]. Amazon uses data analytics for supply chain management, which helps it deliver products faster, resulting in increased customer satisfaction. The integration of the Internet of Things (IoT) and data analytics helps to improve the transparency and feedback in the supply chain [32].

Competitor Analysis: Data analytics helps diagnose a competitor's growth through competitor analysis. It involves understanding their strategies, financial growth, and market positioning. Sentiment analysis and web scraping on competitors' product reviews and pricing strategies provide valuable insights [33]. It helps to know the competitor's position and plan their positions strategically [34]. Tools like SEMrush and SimilarWeb can be used to drive insights and decision-making.

Innovation and Product Development: Demands of the future market and customer trends can be identified with analytics. Predictive analytics and machine learning techniques help to make predictions of future market demands and guide research and development efforts [35]. Netflix uses predictive analytics to predict its customers' preferences and, with that, develop its content. Results show that companies that use these analytic techniques increase their business success rates [36].

Risk Management and Fraud Detection: One of the main contributions of analytics in the business field is risk management and fraud detection. With the help of machine learning models, businesses can detect anomalous activities such as fraudulent activities [37]. For instance, financial institutions use analytics to monitor their real-time transactions and flag fraudulent activities [38].

Ecosystem Health Monitoring: Tracking the company's inter-department performance, customer and employee retention, and financial growth helps to maintain the health of the ecosystem of a company. It can be monitored with visualization tools such as dashboards and KPI tracking tools [22]. Companies that continuously monitor their ecosystem can better understand the dynamic market and maintain competitive advantages, strategic planning, and resource allocation [39].

Data analytics is essential in business ecosystem profiling and helps in many applications, from market analysis to risk management. By using various tools and techniques, businesses can get a deeper understanding of their ecosystem and can continuously monitor their growth. The integration of data analytics into ecosystem profiling not only standardizes their operations but also promotes innovations and strengthens their position in the current market.

2.4 Visualization Tools and Techniques for Decision-Making

With the availability of vast data, the ability to view the complex ecosystem visually is important for decision-making. Visualization tools and techniques play an essential role in transforming raw and unstructured data into meaningful data to make actionable decisions [40], [41]. Engagingly presenting data helps the decision-makers to explore the relationships of stakeholders, identify patterns, explore trends, and make decisions [42]. This section provides a comprehensive view of some visualization tools and techniques that can be used, especially by researchers in the business ecosystem profiling area, as well as the applications of these tools supported by the corresponding literature.

Network Analysis and Graph Visualization. Network analysis works better in mapping and showing the complex relationships of entities in the business ecosystem [43]. Many tools help to visualize complex and large network graphs. These graphs show entities as nodes and relationships as edges. This analysis helps to identify the various entities and their relationships within the ecosystem, and it also shows the strengths and weaknesses of their relationships [44]. It provides overall insights into the structure and changes within the ecosystem.

Table 1 shows the various tools that help to analyze and visualize the relationships of entities, their strength, and the flow of their relationships in the ecosystems. By using these tools, researchers get a deeper vision of the key stakeholders and their relationships with organizations [45] that helps to find potential risks and promote business growth and innovation [46].

Interactive Dashboards. Interactive dashboards are tools that help visualize the business ecosystem profiling. The profiling helps to create a dynamic and user-friendly interface to view, analyze, and explore complex data. It also helps us to integrate real-time data to monitor activities happening and consolidate data from various sources into a single interface to understand the overall ecosystem's structure. Users can interact by filtering and drilling down into specific data points and can meet specific analytic needs. Various interactive dashboards are there to help businesspeople navigate complex dashboards to uncover meaningful insights and make decisions.

Table 2 shows various interactive dashboards that helped the researchers visualize business ecosystem profiling with real-time data integration and interactive features. They help to view the hidden patterns and trends and can make predictions for data-driven decisions. It helps to present data in an accessible format and allows users to interact with the system.

Geographic Information Systems (GIS). Spatial visualization techniques are useful for analyzing complex data structures in a business ecosystem. These techniques help to visualize data that goes beyond the traditional charts and graphs. They help to understand the geographical patterns, relationships, and distributions within the business ecosystem. They help to map the spatial relationships between different ecosystem components, such as market locations, supplier distributions based on locations, etc. They are mainly used for geographical or location-based decision-making.[43].

Table 3 shows various GIS tools that help with spatial data and hidden details to support decision-making. These tools also help in spotlighting regional gaps in business and improving logistical efficiency [3]. Additionally, they highlight geographic patterns to understand complex ecosystems for smooth business operations based on location-based factors.

Table 1. Network analysis tools (tool references are available in the Appendix)

Tools	Description
Gephi (Bastian et al., 2009)	Flexibility in handling large networks. Helps uncover clusters, central nodes, and weaknesses. Visualizes supply chain networks, partner ecosystems, and social media interactions.
Cytoscape (Shannon et al., 2003)	Helps to visualize complex networks. Supports various layouts and other data analytics tools. Works well with diverse data sources.
Neo4j (Robinson et al., 2015)	Offers real-time data analysis. More focused on entity relationships. Offers the Cypher query language.
Pajek (Batagelj & Mrvar, 2022)	Designed for analyzing large networks. Works well with thousands of nodes and relationships.
Visallo (Visallo, 2022)	Aimed for investigative analysis of complex datasets. Visualization combined with machine learning. Helps in identifying patterns and relationships.
NodeXL (Hansen, D. L., et al., 2011)	Useful for visualizing relationships and social networks. It is integrated with Excel, so it is easily accessible for business analysts. It can map inter-organizational collaborations.
Kumu (Kumu,2022)	Focuses on complex systems and stakeholders. Helps to uncover patterns, trends, and dependencies. Can analyze the flow of resources and influences.
Graphistry (Graphistry, 2021)	GPU-accelerated technology for vast datasets. Helps to uncover patterns and relationships in big data. Better suited to evaluate financial transactions to detect fraud or irregularities.
Sigma.js (Sigma.js., 2022)	Focuses on creating interactive and web-based visualizations. Helps to customize visualizations, which can be shared and explored. Helps to build interactive supply chain networks.
igraph (Csardi, G., & Nepusz, T., 2006)	It can be used for conducting deep network analysis. Helps in finding clusters, paths, and centrality measures.
Tulip (Faysal and Arifuzzaman, 2018)	Supports the analysis of large and complex datasets. Helps to analyze multi-layered ecosystems. Helps to identify intricate patterns and relationships.

Table 2. Interactive dashboard tools (tool references are available in the Appendix)

Tools	Description
Tableau (Murray, 2016)	User-friendly interface. Builds a complex interface by integrating data from multiple sources. Supports drag-and-drop functionality.
Power BI (Microsoft, 2020)	Strong integration capabilities with the Microsoft ecosystem. Provides real-time visualization. Embeds interactive visuals into reports.
Google Studio (Google, 2021)	Provides customizable dashboards that update in real time. Supports collaborative features for teamwork.
Looker (Looker, 2020)	Enables advanced data modeling and visualization. Integrates well with Google Cloud and other cloud-based data sources. Creates dynamic dashboards helping to understand the various ecosystems' performance.
Qlik Sense (Qlik, 2022)	Purely a data analytics platform. Enables self-service visualization. Users extensive technical expertise can explore data and create the visualizations.
Klipfolio (Klipfolio, 2023)	Cloud-based dashboard tool that provides real-time insights. Customizable dashboards that can pull data from multiple sources.
Datawrapper (Datawrapper, 2023)	Easy to create interactive charts, maps, and dashboards. Easy visualization solution for users without extensive technical expertise.

Table 3. Geographic information systems tools (tool references are available in the Appendix)

Tools	Description
Heat Maps (Goodchild, 2007)	Provide a visual representation of data intensity across different geographical areas. Can visualize customer preference areas, market locations, and regional performance. Can help identify high-traffic locations for business placements.
ArcGIS (Longley et al., 2015) (Esri, 2023)	Advanced geographic information system platform. Offers multiple data layer visualizations for spatial analysis. Supports mapping, special data analysis, and location-based data analysis. Can be used for the distribution of businesses, finding customer demographics, and managing logistics and supply chain networks across regions.
Kepler.gl (Fang et al., 2019) (Kepler.gl., 2023)	Powerful open-source geospatial analysis tool for large-scale spatial data. Useful for data exploration and visualization. Helps to analyze and visualize urban mobility patterns.
Leaflet (Agafonkin, V., 2023)	Helps build interactive maps with a JavaScript library. Supports a variety of plug-ins and is highly flexible. Supports interactive and web-based maps, such as customer distribution and market segmentation.
QGIS (QGIS Development Team, 2023)	Open-source geographic information system platform. Helps in customizing and integrating various data formats. Visualizes business operations, such as market reach or logistic efficiency.
Google Earth Engine (Google, 2023)	Cloud-based platform to visualize and analyze satellite imagery and spatial data. Supports large-scale spatial data. It can be used to study environmental factors such as climate change.
Tableau with Geospatial Extensions (Tableau Software, 2023)	Provides advanced mapping capabilities. Can overlay data on maps to visualize spatial patterns. Can profile customer locations and market penetrations across geographic areas.
Mapbox (Mapbox, 2023)	Gets customizable maps, supports real-time data integration and dynamic updates. Helps with location-based analysis and understanding of regional market dynamics. Can create interactive maps to view transportation routes, networks, and customer service areas.

Time Series Visualizations. Time series visualization tools are useful for organizations that collect data over time to analyze and visualize patterns and trends. They help researchers understand patterns, trends, and relationship changes over time with various operational metrics. It helps to understand the long-term trends according to the seasons and forecast future sales, resource allocation, and production schedule [47].

Time series visualization helps understand deviations and anomalies that occur from a normal schedule pattern, and to monitor the overall performance of different areas based on key performance indicators. It also helps to optimize the overall performance and workflow and can reduce downtime. Table 4 shows various tools for time series visualizations.

These visualizations are very important in industrial management to monitor the various operations in the organizations and, based on that, analyze and optimize the overall process over time to avoid delays or errors. They also help organizations to get a deeper insight into decision-making for long-term success and to avoid anomalies.

Augmented and Virtual Reality (VR/AR). The traditional concept of visualization in business ecosystems has changed with AR and VR technologies. Tools such as ParaView [48] and Unity 3D help to explore the 3D view of ecosystem data and help organizations view the relationships and trends in the ecosystem in a spatial environment. For instance, they help to display the geographic-based supply chain networks, which helps to view the complex data in more detail. These technologies allow the decision-makers to take a deeper view of the business ecosystem framework and help to enhance the depth of analysis.

Table 4. Time series visualization tools (tool references are available in the Appendix)

Tools	Description
Tableau, Power BI, and R's ggplot2 (Wickham, 2016)	Helps to create various types of charts and graphs based on time series. Helps to track historical performance, season trends, and predict future trends. Can create interactive and dynamic dashboards and support integration of SQL and IoT platforms.
Garfana (Garphana, 2023)	Open-source tool. Provide time-series data from IoT devices and industrial systems. Supports real-time dashboards and alerting systems.
MATLAB (MathWorks, 2023)	Tool for engineering and industrial applications. Used mainly for advanced modeling and simulations.
Plotly (Plotly, 2023)	Supports Python, R, and JavaScript. Open source tool. Highly interactive with analyzing time-based trends.
TimescaleDB (Timescale Inc., 2023)	A time series database that integrates with other tools for analysis. Supports advanced queries and high data volumes. Can visualize machine performance and environmental data over time.

AI-driven Visualization. AI-powered visualization tools combine machine learning with existing graphical models to view descriptive and predictive insights. Tools such as ARBITER can update the decision-makers' focus dynamically and also can focus on a particular area according to their needs based on real-time data analysis [25]. These techniques help the user concentrate only on specific nodes, filter the relationships, and combine more datasets. The integration of AI technologies is especially important in emerging economies in certain regions, by providing insights into AI readiness and stakeholder involvement [49].

Based on the categories above, a comparison table has been structured to highlight how these tools and techniques can be used for decision-making. The table is structured by comparing (relatively, based on information available to the authors†) different axes, such as effectiveness, use case, complexity, and interaction ease in the business ecosystem. Table 5 highlights the comparison of how data analytics can be done using various visualization tools.

Table 5. Comparison of visualization tools

Visualization Tool/Technique	Effectiveness	Use Cases	Complexity	Interactivity
Network Analysis and Graph Visualization	High	Identify key players, relationships, and interactions in the network	Medium	High
Interactive Dashboards	High	track KPIs in real-time, monitor performance	Medium	Very High
Geographic Information Systems	Low to Medium	Map the spatial distribution of elements	High	Medium
Time Series Visualization	High	Track trends, forecast demands	Medium	Medium
VR/AR Visualization	Medium to High	Provide interactive explorations, visualize complex data	High	High
AI-driven Visualization	High	Identify hidden patterns, detect anomalies, and perform predictive analysis	High	High

3 Findings and Discussions

In this section, we discuss how data analytics and visualization techniques help in the business ecosystem for decision-making. The main insight we get from decision-making relies on an in-

† Please contact the authors regarding more details of the comparison

depth understanding of entities and their relationship, the current market and its changes, and possible risks and circumstances. The actual gap between just availability of data about a complex ecosystem and decision-making based on it can be overcome with data analytics and visualization. These techniques not only provide an in-depth view of complex data but also provide a framework for predicting and simulating outcomes.

A vast amount of data can be generated by business ecosystems from various sources, such as customer interactions, financial matters, government and governing reports, sensors, and social media. Managing this complex data helps enhance prediction, strategic planning, and decision-making.

3.1 Enhancing the Understanding of Complex Data

The vast and complex data related to business ecosystems makes it challenging for academics and practitioners to make accurate decisions. Semantic ambiguities can also complicate the analysis of complex business ecosystems, leading to inconsistencies and confusion during data analytics and interpretation. Adopting a standardized framework or taxonomy for key terms used within ecosystems can solve these challenges for the stakeholders, who can align their viewpoints and reduce the confusion [50]. NLP techniques help to reduce the semantic ambiguity by analyzing the context in which the terms are used, by helping to identify multiple meanings of words based on the surrounding contexts [51].

Decision-makers need to access both structured and unstructured data from various sources to process explorations [18]. To process this data, proper analytic tools are required to extract relevant information by simplifying complex data. The data can be clustered, classified, or segmented using algorithms such as K-means, DBSCAN, or hierarchical clustering based on the shared characteristics of the data. This kind of technique helps in industrial management areas, such as identifying market segments and categorizing customers based on their preferences [36]. Machine learning models help industries to forecast upcoming needs based on the data. Models such as regression analysis and neural networks, such as RNN and CNN, help to forecast data. In industries, it helps predict trends, patterns, and risk factors [28]. Unstructured data can be managed with Natural Language Processing (NLP). By using NLP techniques, we can extract sentimental data, emerging topics, and competitive markets. It helps extract customer reviews, news articles, and social media impacts [52]. Financial institutions can use NLP for sentiment analysis in order to track investor attention and market sentiment and predict stock market movements [53]. Data visualization tools such as dashboards, interactive graphs can visualize integrated data, helping in analyzing both structured and unstructured data simultaneously. A detailed study on the effective visualization of a digital ecosystem with the help of visualization tools on a unified framework is discussed in [54].

3.2 Highlight the Interdependencies of Business Ecosystems

Business ecosystems are highly interconnected, and knowing these relationships is a pivotal factor for strategic decision-making and prediction. To show the interdependence of the entity's relationships, techniques such as network analysis and visualization can be used. Network-based diagrams like Social Network Analysis (SNA) help to view relationships between entities in the ecosystem. These techniques help to map supply chain network dependencies, inter-company collaborations, and influencers within the ecosystem [45]. For instance, automobile manufacturers use network analysis to monitor supply chain networks to find out the inabilities of suppliers, such as financial instability and geographical instability [48]. IT firms use network analysis to monitor competitors' market trends and resource enhancement skills.

Delayed knowledge sharing can also be a challenge in understanding the interdependencies within an ecosystem. When one part of the ecosystem is missing or unclear, it can lead to poor coordination or synergy. Cloud-based collaborative platforms might be able to facilitate real-time updates and instant communication helps in effective information exchange and improves interdependencies [3], [55].

Visualizations like heatmaps show a clear view of bottlenecks within the system flow, underperformed activities, overperformed activities, and risk chances. For instance, logistics companies use heatmaps to visualize supply chain network drawbacks and maintain network distributions [18]. It helps to understand the disruptions in any one particular area and allows better risk management and strategic planning. Currently, organizations use matrices to track the dependencies within organizations, the impact of regulations, and financial relationships in the markets.

3.3 Real-time Monitoring for Decision-Making

Real-time monitoring of an organization's data is very important in today's business field. It helps to maintain the organization's position in a competitive market and also to understand market dynamics. Interactive dashboards and real-time monitoring tools help to retrieve live insights to improve the performance of the business ecosystem. Businesses use real-time monitoring to track logistics disputes, supplier performance, and demand forecasting to avoid shortages or loss [26]. AI-based social media-based tools help to see the sentiment of public opinion to avoid reputation risks [18]. Also, they help to analyze market trends and make decisions [8].

Challenges in combining or integrating data from diverse sources can be solved by incorporating data lakes, which can be applied to both structured and unstructured data. Integrating cloud-based hybrid frameworks can allow real-time access and can also include real-time sensor data [56]. Additionally, the integration of decision support systems and AI helps in both automated and manual decision making, which allows for enhancing the speed and quality of the decision-making process and ensuring businesses remain agile in dynamic environments [57]. For instance, Amazon's real-time analytic platforms monitor customer reviews, and based on that, price distribution varies. Along with that, they monitor competitors' strategies to dynamically adjust product listings [53]. Manufacturing companies use IoT-driven dashboards to monitor machines' performance and reduce equipment failures. It also helps to detect early warning signals and to analyze emerging opportunities.

4 Conclusion

The use of data analytics, visualization, and the tools that enable them has caused a remarkable change in the business ecosystem management. These techniques effectively help manage the whole ecosystem using complex data in a dynamic market landscape. This article has given an overview of how business ecosystem profiling works and the various frameworks considered by the researchers to manage the ecosystem. We have also discussed how data analytics techniques like graph-based models, NLP, and predictive analytics help organizations uncover hidden relationships, monitor dynamic market shifts, and reduce risks and losses. Additionally, the article highlighted the various applications of data analytics within the field of industrial management. The importance of visualization and visualization tools in various areas, such as network diagrams to know the depth of the relationships, interactive dashboards to monitor real-time performances, geographical interactive systems to evaluate the regional gaps or spatial gaps in the ecosystems, and time-series visualization to view the long-term trends and patterns over time are also discussed. These techniques help to simplify the ecosystem's complexity, enable real-time monitoring, and enable mutual decision-making for a strategic outcome.

Even though these techniques provide remarkable insights, they have their challenges. First, data integration: Ecosystems might have structured and unstructured data from various sources. Integrating this data into a framework remains a major challenge [31]. Secondly, scalability: As time passes, the volume and velocity of data increase exponentially. Handling this data accurately and effectively in real-time is a tedious task [17]. Thirdly, Ethical concerns: Data privacy regulations, such as the usage of personal data in the analytical process, need to be kept within some constraints [25]. Fourthly, technology limitations: For complex ecosystems, visualization tools need to integrate data from various data analytics tools or platforms. These integrations affect the interoperability of the systems. For future enhancements, AI-powered analytics and cross-platform visualization tools on interdisciplinary frameworks might help a transformation in the pathway of business ecosystem growth.

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