INTEGRATING BSC - DEA APPROACH AND ARTIFICIAL INTELLIGENCE IN INNOVATION MANAGEMENT

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Innovation is a key factor for maintaining competitiveness in today's dynamic environment. Innovation-focused management tools, such as the Balanced Scorecard (BSC) and Data Envelopment Analysis (DEA), play a crucial role in this process. BSC provides a comprehensive overview of a company's performance through a balanced set of indicators focused on both financial and non-financial aspects. In contrast, DEA enables the evaluation of the efficiency of individual units within an organization, identifying areas for improvement. Integrating these two approaches into a single BSC-DEA framework creates synergies that enhance strategic decision-making and operational efficiency. Artificial Intelligence (AI) adds another dimension by enabling advanced data analysis and process automation, further increasing the accuracy and speed of decision-making. This combination represents an innovative management approach that allows companies to better respond to rapid changes in the business environment.

KEYWORDS

Innovation-focused management tools, Balanced Scorecard, Data Envelopment Analysis, Artificial intelligence

1 INTRODUCTION

The integration of AI within the BSC-DEA framework represents a transformative approach to managing innovation and efficiency in industrial companies. By combining the strategic focus of BSC, the analytical benchmarking of DEA, and the data-driven power of AI, companies can achieve a level of performance management that is both highly efficient and strategically aligned with long-term goals. This innovative approach not only enhances decision-making but also drives continuous improvement and adaptation in a rapidly changing business landscape.

2 MANAGEMENT TOOLS AND TRENDS

In 1993, Bain & Company, a leading global business consulting firm, initiated a long-term research project focused on management tools and trends. Since then, they have regularly conducted surveys to identify the most popular management tools and monitor the attitudes and behaviors of executives across various economic cycles.

Over the past 30 years, Bain has completed numerous surveys, gathering data from over 15,000 respondents across more than 100 countries worldwide. In their latest survey, conducted in 2022, they received 1,230 completed surveys from a diverse group of international executives. This extensive database provides insights into the evolving trends and preferences in management tools globally.

The Management Tools & Trends 2023 survey offers valuable insights into the tools and trends that are influencing business management on a global scale.

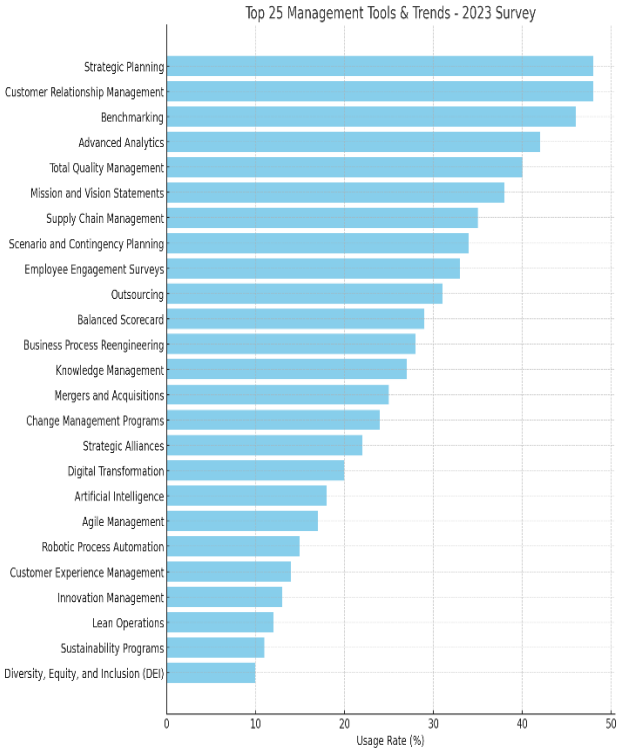

Figure 1. Usage rate of top 25 management tools and trends in 2023 [Rigby 2023]

Overall, the survey indicates a shift towards more thoughtful and impactful use of management tools, with a strong emphasis on digital innovation and organizational resilience.

Main findings from the survey include:

- **Tool Usage and Satisfaction:** While managers are using fewer tools than in previous years, their satisfaction with the tools they do use has increased. This suggests a more selective and strategic approach to tool adoption, focusing on what works best for their specific needs.
- **Top Tools:** The most widely used tools include *Strategic Planning, Customer Relationship Management, and Benchmarking*. These tools are critical for companies navigating the complexities of the modern business environment.
- **Digital Transformation:** Tools related to digital transformation, such as *Advanced Analytics, Artificial Intelligence, and Agile Management*, continue to gain traction as companies adapt to technological advancements.
- **Focus on Sustainability and Diversity**: Tools related to Sustainability Programs and Diversity, Equity, and Inclusion (DEI) have become increasingly important as companies prioritize corporate responsibility and inclusivity.

2.1 *Key innovation-focused management tools*

Several tools are highlighted that specifically focus on driving innovation within companies. These tools are essential for companies aiming to stay competitive in a rapidly changing business environment by fostering a culture of innovation and

continuous improvement. They help systematically manage innovation, from idea generation to execution, ensuring that new products, services, and processes are effectively developed and integrated.

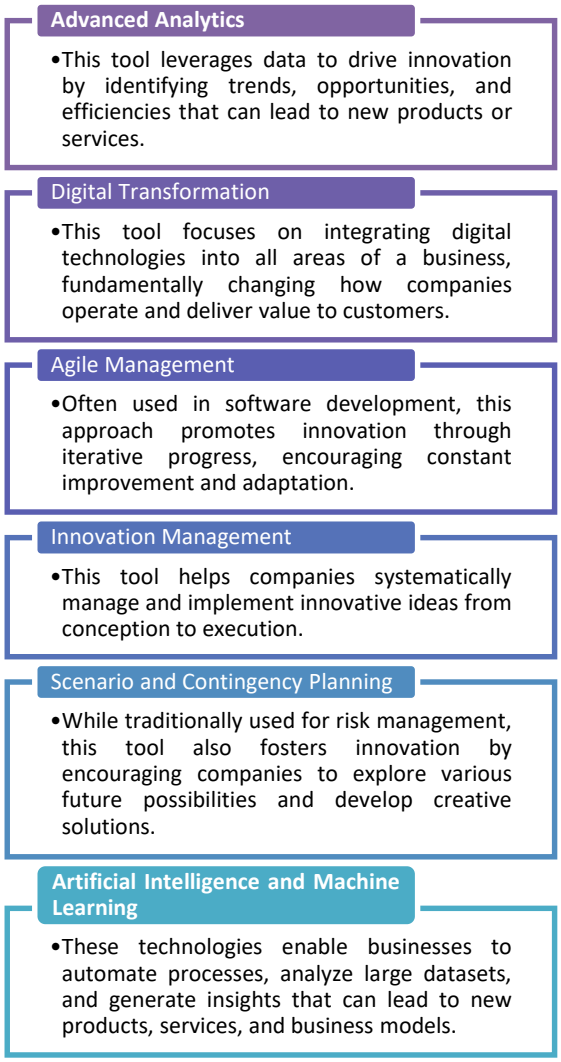

Figure 2. Key innovation-focused tools [Rigby 2023]

Key innovation-focused management tools are becoming essential for companies that aim to stay ahead in a rapidly evolving market by leveraging data-driven innovation strategies. Together **Artificial Intelligence (AI) and Machine Learning** can be powerful tools for companies, enabling them to automate manual processes, optimize customer recommendations, and develop innovative products [Rajendra 2018].

Various subareas of Machine Learning and AI are unlocking innovation in creative fields, sciences, engineering, and others.

2.2 Balanced Scorecard

The 2023 Management Tools & Trends survey provides some important insights regarding the usage of the Balanced Scorecard (BSC). This tool continues to be widely used as a way to measure an organization's performance and shows whether management is achieving desired results. The BSC translates purpose, mission, and vision statements into objectives and performance measures that can be quantified and appraised. These measures typically include the following categories of performance [Kumar 2024]:

- **Financial performance** (revenue, earnings, return on capital, cash flow)
- **Customer value performance** (market share, customer satisfaction measures, customer loyalty)
- **Internal business process performance** (productivity rates, quality measures, timeliness)
- **Innovation performance** (percentage of revenue from new products, employee suggestions, rate of improvement index)
- **Employee performance** (morale, knowledge, turnover, use of best demonstrated practices)
- **Environmental, social, and governance performance** (greenhouse gas emissions, water consumption, employee diversity, health and safety incident rates, number of data breaches).

In terms of satisfaction, the BSC scores relatively well but not among the top-performing tools. It shows moderate satisfaction when used as part of a major effort of company.

BSC does not have a mathematical model or a weighting scheme. This is the reason why it is difficult to make comparisons within and among the companies.

Therefore, several foreign studies deal with innovative approach to a modification of the BSC by the designing of new models in combination with other methods. one of the possibilities is Data Envelopment Analysis method, which is suitable for measuring the efficiency based on of the BSC indicators.

2.3 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a "data oriented" approach for evaluating the performance called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs. DEA used to measure technical efficiency. Being technically efficient means to minimize inputs at a given level of outputs or maximize outputs at a given level of inputs.

Efficiency, in the economic sense is defined as: **Efficiency = Output/ Input**

The measurement of efficiency in production units and the identification of sources of their inefficiency is a precondition to improve the performance of any productive unit in a competitive environment.

Despite the popularity of BSC and DEA approaches, there are only very few studies that examine their integration for better evaluation of the performance and efficiency of industrial enterprises and their processes.

Due to the planned establishment of a systematic relationship between these two methods, it must first gather their significant differences (Table 1).

From Table 1 we can find the following facts:

1. DEA has input and output, but BSC has got multi-viewpoint evaluations.
2. In DEA technique, there is no future view, but BSC focuses on future view based on financial perspective which is the result of the past performance and three perspectives of the growth and the learning, the internal processes and the customer.
3. The DEA technique does not apply the strategy of the organization while BSC method uses the strategy of the organization for decision making.
4. It is more difficult to analyze each involving index in BSC while analyzing the DEA results is easier.

DEA permits to analyze multiple inputs and output factors simultaneously. This ability is very helpful in real-world management situations because there are usually multiple, multidimensional inputs and outputs. From this perspective, DEA is better in comparison with traditional approaches that can only deal with multiple inputs and a single output. Managers can use the results of DEA to improve and increase corporate performance, efficiency and competitiveness.

Table 1. Proposed differences between DEA and BSC method – outputs of deep analysis

Characteristics	BSC	DEA
Way of comparison	Comparison with an ideal virtual unit	Proportional comparison of the same units
View - rating	multiple view - perspectives	input/ output
Mathematical ranking	weak	strong
Application	performance evaluation	technical efficiency
Accuracy of measurement	unclear	high
Presentation of opportunities for improvement	weak	high
Variety of suitable results	not supporting	yes
Future view	yes	no
Relationship to business strategy	yes	no

3 PROPOSAL FOR IMPLEMENTING THE BSC-DEA MODEL IN AN INDUSTRIAL COMPANY WITH THE FOCUS ON INNOVATION PERFORMANCE

The implementation of the BSC-DEA model in an industrial company offers a powerful approach to enhancing performance management. By integrating strategic and operational perspectives, the model provides a comprehensive framework for evaluating efficiency, aligning with strategic goals, and driving continuous improvement. With careful planning and execution, this approach can significantly contribute to achieving sustainable competitive advantages and long-term success.

A detailed explanation of the implementation process for the integrated BSC-DEA model is shown in the Figure 3.

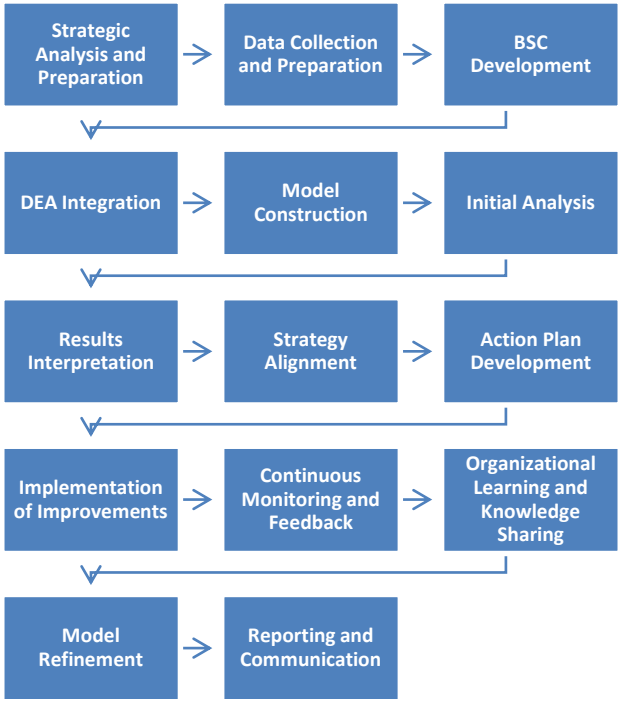

Figure 3. Implementation process for the integrated BSC-DEA model in the company

The integration of the BSC and DEA models offers a powerful framework for industrial companies seeking to enhance their innovation capabilities. This proposal outlines a step-by-step approach for implementing this integrated model, specifically focusing on fostering innovation within an industrial company.

The individual steps of the proposed process of implementing the integrated BSC-DEA model can be described in more detail as follows:

1. Strategic Analysis and Preparation defines strategic objectives (innovative goals) and identifies key stakeholders' expectations.
2. BSC Development means next steps [Kumar 2024]:
   - define perspectives:
     - Financial Perspective: Define clear financial objectives related to innovation, such as increasing revenue from new products or reducing costs through process innovations.
     - Customer Perspective: Set goals for customer-centric innovations, like improving customer satisfaction through innovative products or services.
     - Internal Process Perspective: Focus on optimizing internal processes, such as enhancing R&D efficiency or reducing time-to-market for new products.
     - Learning and Growth Perspective: Encourage continuous learning and development, ensuring that employees are equipped with the necessary skills to drive innovation.
   - develop strategic objectives for each perspective,
   - create a strategy map linking objectives across perspectives,
   - establish key performance indicators (KPIs) for each objective - choose specific metrics for each BSC perspective that will help measure innovation performance:
     - Financial: Percentage of revenue from new products, return on innovation investment.
     - Customer: Customer satisfaction with new products, market share growth.
     - Internal Process: Number of patents filed, time-to-market for new innovations.
     - Learning and Growth: Employee engagement in innovation initiatives, training hours related to innovation.
   - set targets for each KPI.
3. Implement DEA to assess the efficiency of innovation-related activities across various departments or business units. DEA will help identify which units are using resources effectively to generate innovative outputs, such as new products or process improvements.

   DEA Integration requires next steps [Lai 2011]:
   - identify decision-making units (DMUs) within the company,
   - select relevant inputs and outputs based on the KPIs,
   - assign weights to the inputs and outputs based on their strategic importance,
   - determine the DEA model type based on organization characteristics:
     - The CCR (Charnes–Cooper–Rhodes) DEA model is a model of constant returns to scale.
     - The BCC (Banker–Charnes–Cooper) DEA model is a model of variable returns of scale.
4. Data Collection and Preparation means gathering data for BSC KPIs and DEA inputs/outputs.
5. Model Construction involves next steps:
   - develop the mathematical model integrating BSC and DEA,
   - program the model using appropriate software (e.g., R, MATLAB, specialized DEA software, Python

programming language, or Excel for basic data handling and the Solver add-in for optimization).

6. The initial analysis involves running the integrated model, calculating efficiency scores for each DMU, and identifying which units are efficient and which are inefficient.
7. Interpret results by analyzing efficiency scores within Balanced Scorecard perspectives, identifying best practices from efficient units, and determining improvement targets for inefficient units.
8. Strategy Alignment means alignment of DEA results with BSC strategic objectives, adjusting strategies or targets as needed based on efficiency analysis.
9. Develop specific action plans for improvement, prioritizing resource allocation and process enhancements based on the integrated analysis.
10. Implementation of Improvements involves execution of action plans and monitoring of progress using both BSC and DEA metrics.
11. Continuous Monitoring and Feedback involves regularly updating data and rerunning the integrated model, assessing progress towards targets and efficiency improvements, and adjusting strategies, objectives, or metrics as needed.
12. Organizational Learning and Knowledge Sharing means disseminating insights and best practices throughout the organization and conducting training sessions on the integrated model and its implications.
13. Model Refinement entails periodically reviewing and refining the integrated model by incorporating new metrics or adjusting existing ones as organizational needs evolve.
14. Reporting and Communication requires developing comprehensive reports that present both BSC and DEA results and sharing findings and progress with stakeholders at all levels. Usage of this feedback is making continuous improvements to the system.

A proposal of decision – making process of BSC - DEA approach in company is presented on Figure 4.

By following this implementation process, a company can successfully integrate the BSC-DEA model into its performance management system, enabling it to assess financial health, improve operational efficiency, and achieve strategic goals more effectively. This step requires a strong understanding of both BSC and DEA methodologies, as well as proficiency in mathematical modeling and programming. It's often carried out by a team that includes strategists, data analysts, and operations researchers [Niknazar 2010].

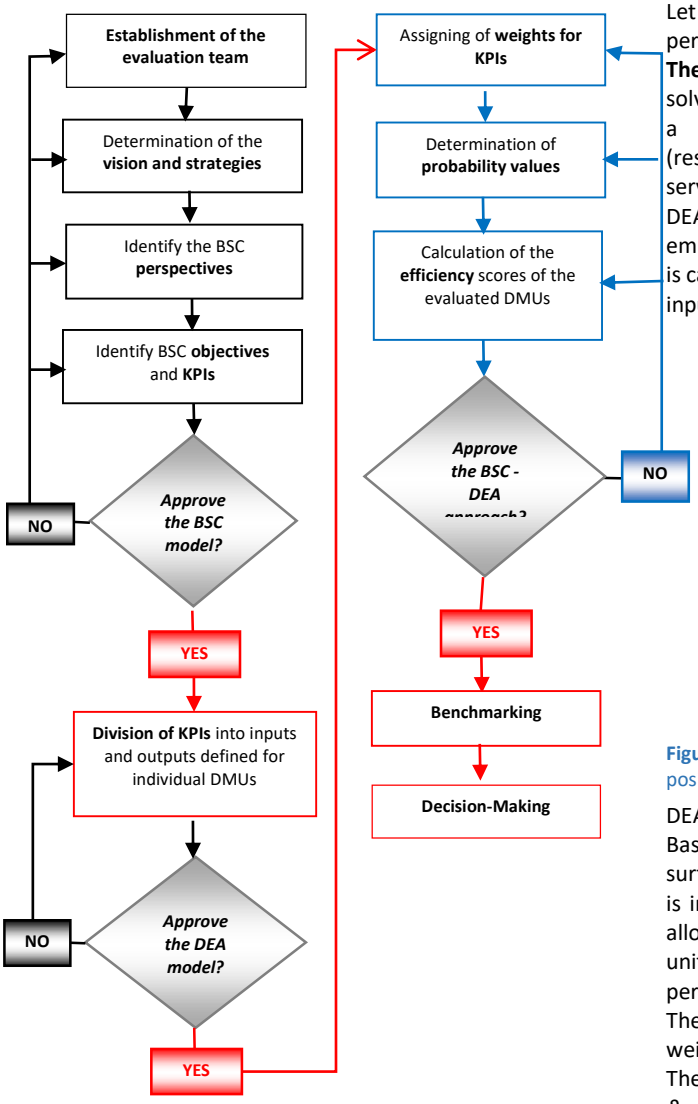

Figure 4. Decision – making process of BSC - DEA model

4 PROPOSAL FOR THE MATHEMATICAL REPRESENTATION OF THE INTEGRATED BSC-DEA MODEL

In the context of the integrated BSC-DEA model, the BSC serves as the foundation for defining inputs and outputs for the DEA analysis.

Let X_{ij} represent the value of the *j*–th indicator under the *i*-th perspective for a given DMU.

The DEA framework evaluates the relative efficiency of DMUs by solving a linear programming problem. Each DMU is engaged in a transformation process, whereby using some inputs (resources) it is trying to produce some outputs (goods or services).

DEA uses all the data available to construct a best practice empirical frontier, to which each inefficient DMU is compared. It is called Production Possibility Frontier (PPF). It assumes that all inputs are used efficiently (Figure 5) [Durkacova 2014].

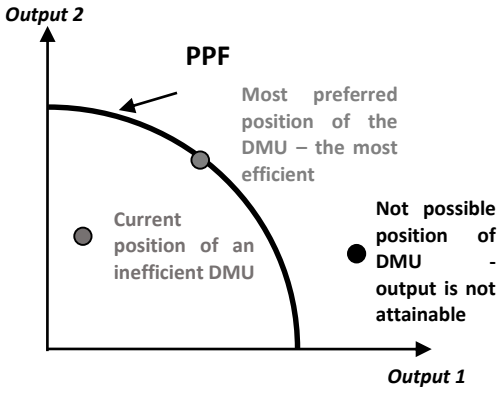

Figure 5. Illustration of a possible location of the most preferred future position of the DMU

DEA uses the production frontiers to assess relative efficiency. Based on inputs and outputs of the units, DEA forms efficient surfaces. If a DMU lies on the surface, it is efficient; otherwise, it is inefficient. One of the interesting features of DEA is that it allows each unit to identify a benchmarking group (a group of units that are following the same objectives and priorities but performing better [Ferus 2010].

The efficiency of each DMU is calculated as the ratio of total weighted outputs to the total weighted inputs [Schmitz 2005].

The efficiency score ***(ϑ)*** for a given DMU ***k*** is formulated as:

ϑq = Weighted sum of Outputs/ Weighted sum of Inputs

$$Maximize\ \theta_k = \frac{\sum_{r=1}^{s} u_r Y_{rk}}{\sum_{i=1}^{m} v_i X_{ik}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r Y_{rj}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1 \qquad \forall\, j = 1,2,\dots,n$$

$$u_r v_i \geq 0$$

Where:

- X_{ik} is the ***i-th*** input of DMU ***k***
- Y_{rk} is the ***r-th*** output of DMU ***k***
- u_r and v_i are the weight assigned to the outputs and inputs ***i***

In the integrated BSC-DEA model:

- **Inputs and Outputs:** The indicators from the BSC perspectives serve as inputs and outputs in the DEA model.
- **Weight Restrictions:** The BSC framework allows the incorporation of managerial preferences and strategic importance into the DEA model through weight restrictions. This can be done by imposing bounds on the weights (u_r,v_i) to reflect the relative importance of different perspectives.

The integrated DEA model can be formulated as:

$$Maximize\ \theta_k = \frac{\sum_{p=1}^{P} \sum_{j=1}^{s_p} u_{pj} Y_{pjk}}{\sum_{q=1}^{Q} \sum_{i=1}^{m_g} v_{qi} X_{qik}}$$

Subject to:

$$\frac{\sum_{p=1}^{P} \sum_{j=1}^{s_p} u_{pj} Y_{pjl}}{\sum_{q=1}^{Q} \sum_{i=1}^{m_g} v_{qi} X_{qil}} \leq 1 \qquad \forall\, l = 1,2,\dots,n$$

$$u_{pj} v_{qi} \geq 0$$

Where:

- ***P*** and ***Q*** denote the number of perspectives considered as outputs and inputs
- s_p and m_q represent the number of indicators under the ***p-th*** and ***q-th*** perspectives
- Y_{pjk} and X_{qik} represent the output and input values for the ***j-th*** indicator under the ***p-th*** perspective and the ***i-th*** indicator under the ***q-th*** perspective for DMU ***k***

Efficiency Score Interpretation: The efficiency score ϑ_k reflects how well a DMU performs relative to its peers, considering the multiple perspectives defined by the BSC. A score of 1 indicates that the DMU is on the efficiency frontier, meaning it is one of the best-performing units, while a score less than 1 indicates relative inefficiency.

5 USAGE OF ARTIFICIAL INTELLIGENCE IN AN INTEGRATED BSC-DEA APPROACH AS A NEW INNOVATIVE APPROACH

Incorporating AI into the integrated BSC -DEA model represents a cutting-edge approach to strategic performance management and operational efficiency. This innovative combination leverages AI's capabilities to enhance both the strategic alignment of the BSC and the operational benchmarking power of DEA [Garcia-Valderrama 2009].

Implement AI tools for automated data collection and real-time updates. This ensures that BSC and DEA are working with current and accurate information.

1. Driven Strategic Insights (Enhancing BSC)
   - Predictive Performance Management: AI models can analyze historical data to predict future performance across BSC's perspectives. This allows companies to anticipate challenges and opportunities, enabling proactive strategic adjustments.
   - Automated Objective Setting: AI can assist in setting dynamic objectives based on real-time data and trends, making the BSC more responsive to changes in the market or internal conditions.
   - Personalized Strategy: By analyzing detailed data on customer behavior, employee performance, and market trends, AI can help personalize the BSC framework to better fit the unique needs of different business units.
2. Enhanced Efficiency Analysis (Strengthening DEA)
   - Real-Time Efficiency Monitoring: AI can continuously analyze operational data and update DEA models in real time, providing instant feedback on efficiency levels across various DMUs.
   - Advanced Benchmarking: AI can enhance DEA's benchmarking capabilities by analyzing vast datasets from across the industry, identifying best practices, and suggesting efficiency improvements.
   - Anomaly Detection and Optimization: AI algorithms can detect anomalies in operations that may indicate inefficiencies or potential risks, allowing for timely interventions and optimizations within the DEA framework.
3. Adaptive Learning and Continuous Improvement
   - Machine Learning Integration: ML algorithms can be used to refine both BSC and DEA models over time, learning from past performance data to continuously improve predictions and efficiency assessments. This creates a feedback loop where the system gets smarter and more accurate as more data is processed.
   - Scenario Simulation and Planning: AI can simulate various scenarios (e.g., changes in market conditions or operational disruptions) and assess their impact on BSC objectives and DEA efficiency scores. This helps companies prepare for different future scenarios and make more informed decisions.
4. AI in Decision-Making and Resource Allocation
   - Optimized Resource Distribution: AI can analyze data to recommend optimal resource allocation across different business units, ensuring that resources are directed where they will have the most impact on strategic goals and operational efficiency.
   - Data-Driven Decision Support: AI provides decision-makers with actionable insights based on data analysis, reducing reliance on intuition and increasing the accuracy and effectiveness of strategic and operational decisions.
5. Innovation in Reporting and Visualization
   - Advanced Analytics Dashboards: AI can create dynamic dashboards that visualize the performance metrics from both BSC and DEA in real-time, making it easier for management to track progress and make data-driven decisions.

Implementing AI into the BSC-DEA framework brings breakthrough benefits, including better performance prediction, process and resource optimization, and more accurate decision-making. This innovative approach enables companies to remain agile, competitive, and efficient in an ever-changing business environment [Niknazar 2010].

6 CONCLUSIONS

Integrating BSC - DEA approach and artificial intelligence in innovation management offers a transformative approach to strategic and operational management. AI enhances predictive analytics, enabling companies to anticipate challenges and

adjust strategies proactively. By automating efficiency monitoring and resource allocation, AI optimizes decision-making and ensures that operations align with strategic goals. Furthermore, AI-driven dashboards and reporting streamline data visualization, making complex insights accessible to all stakeholders. This innovative integration positions companies to remain agile, scalable, and competitive in a rapidly evolving business environment. AI can analyze data and recommend optimal resource allocation across different business units, ensuring that resources are directed where they will have the greatest impact on strategic goals and operational efficiency.

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