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ASSESSING COMPANY FINANCIAL HEALTH USING AN INTEGRATED BSC-DEA FRAMEWORK WITH A FOCUS ON PROCESS DIGITIZATION

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Abstract: The integration of the Balanced Scorecard and Data Envelopment Analysis offers a powerful method for evaluating a company's financial health in a multi-dimensional manner, with a strong emphasis on digitization. By combining strategic performance metrics from BSC with the efficiency-focused analysis of DEA, organizations can gain deeper insights into both financial and operational aspects of their business. Digitization plays a crucial role in this approach by automating data collection, enabling real-time monitoring, and improving the accuracy of performance assessments. This digital transformation not only enhances decision-making but also allows for scalable and flexible implementations across various departments. Ultimately, the integrated BSC-DEA approach, supported by digital tools, helps companies optimize their resources, align with strategic goals, and ensure long-term financial sustainability. This research paper also explores the process, mathematical formulation and benefits of using this integrated approach to evaluate company financial health.

Key words: financial health, Balanced Scorecard, Data Envelopment Analysis, model, digitization, software

1. INTRODUCTION

The implementation of the integrated Balanced Scorecard (BSC) and Data Envelopment Analysis (DEA) model in an industrial company involves aligning strategic objectives with measurable performance indicators across key perspectives, such as financial health, customer satisfaction, and operational efficiency. Accurate data collection and validation are critical, followed by the integration of this data into the Data Envelopment Analysis framework to assess the relative efficiency of different decision-making units. The process includes benchmarking performance, identifying areas for improvement, and implementing targeted action plans to enhance efficiency. By leveraging digital tools, cmpanies can automate data collection, enhance real-time monitoring, and make more informed decisions, ultimately aligning with strategic goals and ensuring long-term financial sustainability.

2. INTEGRATED BSC-DEA MODEL

Despite the popularity of both the BSC and DEA approaches, there are very few studies that examine their integration for better evaluation of the performance and efficiency of industrial enterprises and their financial health. Given the proposed systematic relationship between these two methods, it is essential to first summarize their fundamental differences, weaknesses and strengths. In general, DEA evaluates inputs and outputs, while BSC utilizes qualitative or quantitative multi-criteria assessment, DEA does not take into account the company's strategy, whereas in BSC, strategy is the foundation for decision-making process. More weaknesses of BSC and strengths of DEA method are summarized in Table 1.

Tab. 1. BSC weaknesses and strengths of DEA [1]

Weaknesses of BSC
One of the challenges in BSC is having the baseline which performance is measured against. Evaluation is impossible without a benchmark. First, a baseline for evaluation should be determined and then we should do the evaluation against the baseline. However, baselines and benchmarks are hard to determine and can be ambiguous. As DEA is based on relative comparison, the DMUs are evaluated against each other. By combining the BSC with DEA we can answer this important challenge of BSC.
BSC confronts managers with an extraordinarily complex optimization problem because of BSC has complexity and the interrelated indicators. This complexity also rises from the large number of variables. Big companies, which should try to track hundreds of measures in BSC, state that BSC lacks a single complex index to summarize the interaction between these measures of performance.
Lack of a common scale of measurement causes more complexity. Moreover, in BSC, we may have dimensionless ratios and index numbers.
Strengths of DEA
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.
DEA solves an optimization problem and gains its weights result. Hence, DEA is only dependent on the empirical observations. This fact gives the DEA a great advantage over usual optimization procedures.
DEA is a non-parametric approach so it does not need to have an explicit functional form to relate inputs to outputs.

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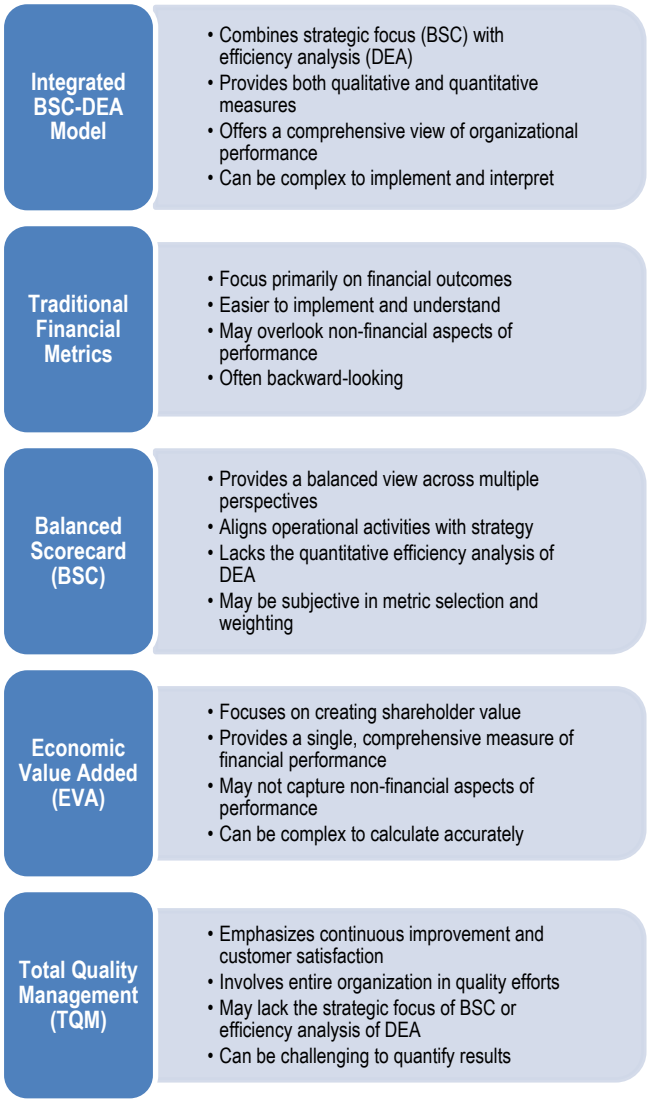
As for the mathematical model, BSC does not provide a mathematical model or a complex index to summarize the interaction between performance indicators for inter-company comparison or comparison of several companies between each other. The use of the non-parametric DEA method offers an overall view of the efficiency of the compared companies based on the calculated efficiency value.

2.1. Comparison of the integrated BSC-DEA model with other performance measurement systems

The choice between these systems depends on the company's specific needs, resources, and objectives. Compared to next systems, the integrated BSC - DEA model offers a more comprehensive view of performance, both strategic alignment and efficiency analysis and a balance of qualitative and quantitative measures. However, it also requires more expertise to implement and interpret, may be more resource-intensive and could be overly complicated for smaller organizations or companies.



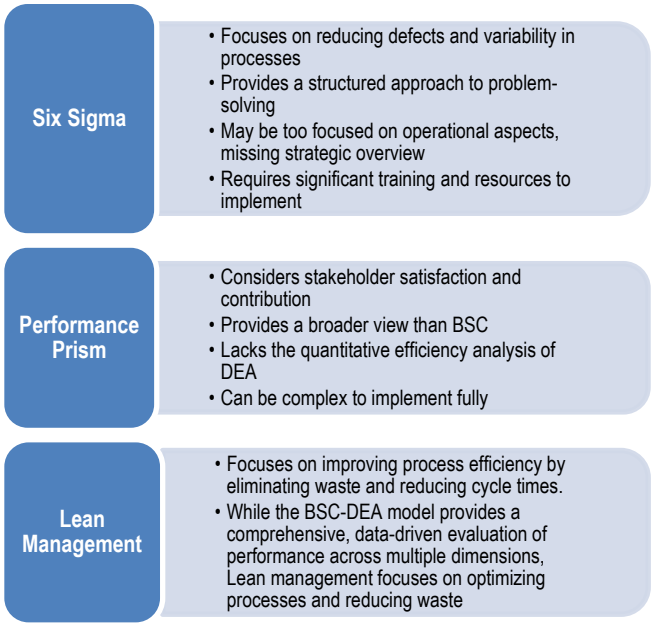


Fig. 1. Comparison BSC-DEA model with other systems [2]

Each performance measurement system offers unique benefits and is suited to different organizational needs. While the BSC - DEA model provide a complete strategic, performance and efficiency-focused approach, other systems like Six Sigma, TQM, and EVA offer more specialized management tools. The choice of system depends on the business's goals, resources and strategic priorities.

2.2. Company's financial health

A financially healthy company typically demonstrates consistent profitability, a strong balance sheet with manageable debt levels, positive and stable cash flows, the ability to invest in growth opportunities, resilience to economic downturns, and good credit standing [3]..

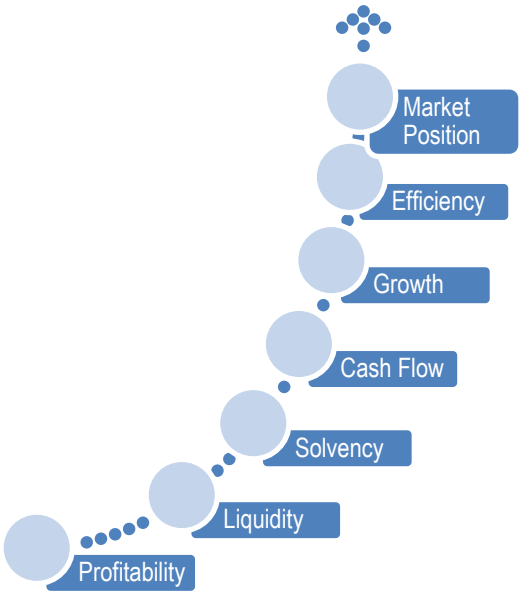


Fig. 2. Key aspects of a company's financial health

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Regularly monitoring the financial health of a company is essential for investors, creditors, management, and other stakeholders. It enables them to evaluate the company's performance, identify potential risks and opportunities, and make informed decisions regarding investment, lending, strategic planning, and resource allocation. By staying informed about the company's financial position, stakeholders can proactively address challenges and capitalize on growth opportunities [4].

3. PROCESS PROPOSAL FOR IMPLEMENTING THE INTEGRATED BSC-DEA MODEL FOR ASSESING A COMPANY'S FINANCIAL HEALTH

Assessing a company's financial health involves analysing financial statements, market performance, and industry trends. The implementation of an integrated BSC-DEA model offers a comprehensive approach to evaluating this issue. Below is a proposal outlining how the integrated BSC-DEA model can be applied in a company to assess its financial health (Figure 3).

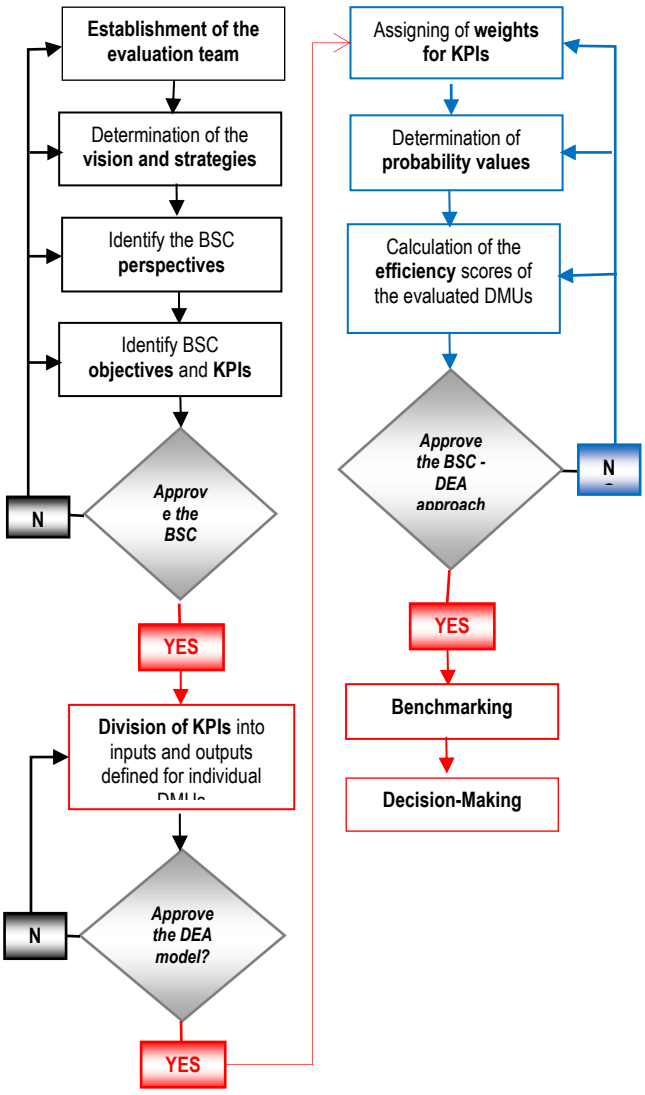

Fig. 3. Decision – making process of BSC - DEA model

The integrated BSC-DEA model offers a robust framework for assessing and improving the financial health of companies and their viability. From the DEA method's perspective, the integrated model formalizes the way to calculate the efficiency of business processes based on identified inputs and outputs, which are the KPIs assigned to specific strategic goals within the BSC perspectives.

From the BSC perspective, the integrated model proposes a new approach to performance evaluation using quantitative analysis that combines KPI values within each perspective into a single value. As a result, the BSC-DEA model for industrial enterprises provides a comprehensive view of the company from both financial and non-financial, as well as short-term and long-term perspectives, and provides valuable insights for managers and stakeholders in understanding and enhancing business performance [4].

3.1. Assessing company financial health using an integrated BSC-DEA model

The specification of the individual steps from the point of view of evaluating the financial health of the company is as follows:

1. BSC framework for evaluation of a company financial health

The BSC provides a structured framework for evaluating company performance across multiple perspectives. When applied to assess financial health, the BSC typically includes the following perspectives, objectives and KPIs [8].:

- Financial Perspective:
  a) Objectives: Increase profitability, optimize costs, improve cash flow, and manage debt.
  b) Key Indicators: Return on Equity (ROE), Return on Assets (ROA), Debt-to-Equity Ratio, and Liquidity.
- Customer Perspective:
  a) Objectives: Enhance customer satisfaction, increase customer loyalty, and grow market share.
  b) Key Indicators: Customer Satisfaction Index, Customer Retention Rate, and Market Share.
- Internal Process Perspective:
  a) Objectives: Improve internal process efficiency and optimize operational costs.
  b) Key Indicators: Inventory Turnover, Production Cycle Time, and Operational Costs as a percentage of revenue.
- Learning and Growth Perspective:
  a) Objectives: Foster innovation, develop employees, and ensure long-term sustainability.
  b) Key Indicators: R&D Expenditure, Training Hours per Employee, and Employee Engagement Index.
- Social Perspective:
  a) Objectives: Enhance social responsibility, community engagement, and employee well-being.
  b) Key Indicators: Corporate Social Responsibility (CSR) initiatives, community investment, diversity and inclusion metrics, employee satisfaction, and turnover rates.
- Environmental Perspective:
  a) Objectives: Minimize environmental impact, improve resource efficiency, and support sustainability.
  b) Key Indicators: Carbon footprint, energy consumption, waste reduction, water usage, and compliance with environmental regulations.

2. DEA Framework for evaluation of a company financial health

DEA is a non-parametric method used to evaluate the relative

efficiency of decision-making units (DMUs) within an organization. When applied in conjunction with the BSC, DEA can assess how efficiently different departments, branches, or business units convert inputs (e.g., costs, resources) into desired outputs (e.g. profits, customer satisfaction) [5]:

– Inputs: In the context of financial health, inputs might include operational costs, capital expenditures, and employee-related expenses. These are resources which the company uses to generate financial outcomes.
– Outputs: Outputs are the financial results achieved, such as profitability, revenue growth, and market share. DEA evaluates the efficiency of converting inputs into these financial outputs.

By integrating the KPIs from the BSC into the DEA model, the company can compare the efficiency of different units in achieving financial health. DEA provides an efficiency score for each unit, highlighting which units are performing well and which require improvement.

Tab. 2. Comparing different DEA models [6]

Model	Scale Assumption	Efficiency Focus	Applicability	Key Advantage
CCR	Constant Returns	Overall Technical	Standardized processes	Simple and widely applicable
BCC	Variable Returns	Pure Technical	Units of varying sizes	Handles scale effects
Additive	Non-radial	Slack-based	Input-output balance critical	Measures input and output inefficiency
Malmquist Index	Time-based	Productivity Change	Longitudinal performance studies	Measures efficiency over time
Super-Efficiency	Constant/ Variable Returns	Ranking Efficient Units	Competitive benchmarking	Ranks DMUs beyond efficiency frontier
Network DEA	Multi-stage Process	Process-based	Complex operations (e.g., supply chains)	Evaluates internal processes separately

Comparing different DEA models involves evaluating how they handle various aspects of efficiency measurement, including their focus, assumptions, and applicability.

3. The integrated BSC - DEA approach

The integrated BSC-DEA approach combines the qualitative and quantitative strengths of both models to provide a more comprehensive assessment of financial health.

Step 1: Identify and measure KPIs

– Define KPIs for each BSC perspective relevant to financial health.
– Collect data for these KPIs across different DMUs within the company.

Step 2: Build a DEA model that uses these inputs and outputs to each DMU.

Step 3: Calculate efficiency scores

– Run the DEA model to compute efficiency scores. These scores indicate how well each DMU is utilizing its resources to achieve financial health.
– A score of 1 indicates that the unit is efficient (on the efficiency frontier), while scores less than 1 indicate inefficiency.

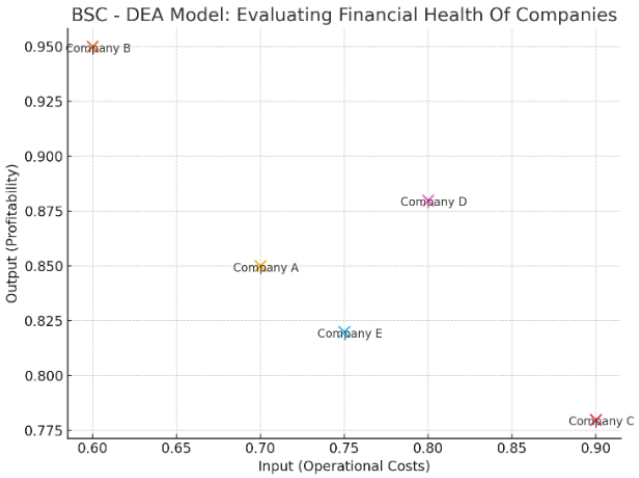

Fig. 4. Visualization of efficiency scores in BSC-Dea model

This graph visualizes the relationship between inputs (operational costs) and outputs (profitability) for different companies, helping to evaluate their financial health through the integrated BSC-DEA approach.

4. Benchmarking

This step includes benchmarking and analysis of:

– the efficiency scores across DMUs to identify best practices and areas for improvement,
– the results to understand which factors are contributing to inefficiencies and how they can be addressed.

5. Strategic insights and decision-making

The integrated BSC-DEA approach provides valuable insights that can guide strategic decision-making.

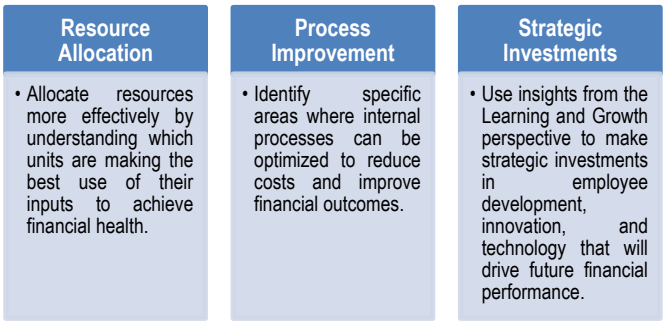

Fig. 5. Strategic Insights of BSC-DEA mdoel

6. Continuous Improvement

One of the strengths of the integrated BSC-DEA model is its flexible nature. By continuously updating the BSC and DEA models with the latest data, companies can monitor their financial health over time and make ongoing adjustments to strategies and operations.

– Implement feedback loops to regularly assess performance, adjust targets, and refine strategies based on the latest insights from the BSC-DEA analysis.
– As the business environment changes, the integrated model can be adapted to incorporate new KPIs, inputs, and outputs, ensuring that the company remains agile and responsive to market conditions.

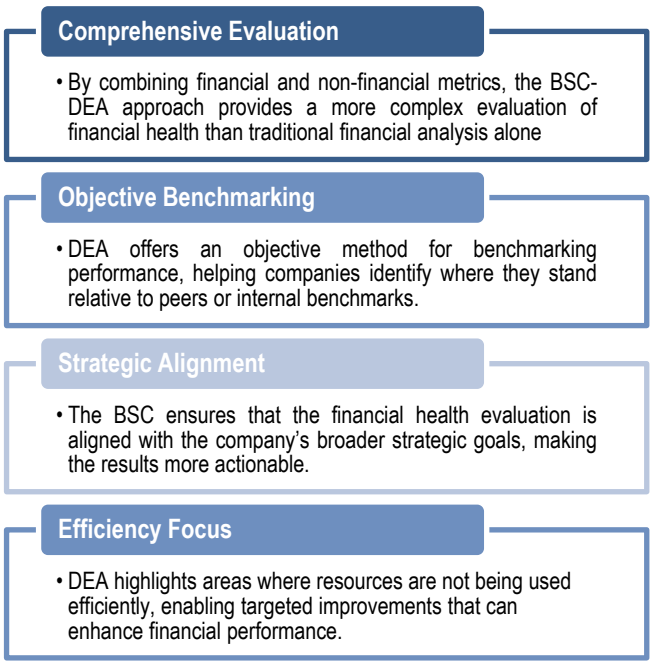

Fig. 6. Benefits of the Integrated Approach

By leveraging the strategic focus of the Balanced Scorecard and the efficiency analysis of Data Envelopment Analysis, companies can gain deeper insights into their financial performance and make more informed, data-driven decisions. This integrated approach not only helps in assessing current financial health but also provides a framework for continuous improvement and long-term financial sustainability.

3.2. Mathematical formulation of the proposed integrated BSC-DEA Model

To mathematically express the integrated BSC-DEA model, which includes the financial, customer, internal process, learning and growth, social, and environmental perspectives, we will construct the model to evaluate the efficiency of DMUs using multiple inputs and outputs derived from the BSC framework.

1. Model variables
- X_{ik} is the *i*-th input for DMU k
- Y_{rk} is the *r*-th output for DMU k
- v_i is the weight assigned to input i
- u_r is the weight assigned to output r
- θ_k is the efficiency score for DMU k

2. Inputs and outputs categorization

The inputs and outputs will be categorized based on the perspectives of the expanded BSC framework:

Inputs X_{ik}:
- Financial Inputs: Operating costs, capital expenditures.
- Customer Inputs: Marketing expenditures, customer service costs.
- Internal Process Inputs: Manufacturing costs, operational expenses.
- Learning and Growth Inputs: Employee training costs, R&D expenses.
- Social Inputs: CSR expenditures, community investments.
- Environmental Inputs: Costs related to energy consumption, waste management.

Outputs Y_{rk}:
- Financial Outputs: Profitability, Return on Investment (ROI), cash flow.
- Customer Outputs: Customer satisfaction, market share, customer retention.
- Internal Process Outputs: Process efficiency, cost savings, production output.
- Learning and Growth Outputs: Innovation (e.g., new products developed), employee satisfaction.
- Social Outputs: Community impact, employee well-being.
- Environmental Outputs: Reduced carbon footprint, waste reduction.

3. Objective function

The DEA model aims to maximize the efficiency score $\boldsymbol{\theta_k}$ for each DMU. The efficiency score $\boldsymbol{\theta_k}$ is defined as the ratio of the weighted sum of outputs to the weighted sum of inputs:

$$\theta_k = \frac{\sum_{r=1}^{R} u_r Y_{rk}}{\sum_{i=1}^{I} v_i X_{ik}} \quad (1)$$

R is the total number of outputs across all perspectives.
I is the total number of inputs across all perspectives.

4. Constraints

To ensure fair evaluation and normalization of efficiency scores, the following constraints are applied:

Efficiency Constraint:

For all DMUs j = 1, 2, ., N, the efficiency score must be less than or equal to 1, indicating that no DMU can exceed 100% efficiency:

$$\frac{\sum_{r=1}^{R} u_r Y_{rk}}{\sum_{i=1}^{I} v_i X_{ik}} \leq 1 \qquad \forall_j = 1,2,\dots,N \quad (2)$$

Normalization Constraint:

For the DMU under evaluation (DMU k), the sum of the weighted inputs is normalized to 1:

$$\sum_{i=1}^{I} v_i X_{ik} = 1 \quad (3)$$

Non-Negativity Constraint:

The weights assigned to the inputs and outputs must be non-negative:

$$v_i \geq 0 \qquad \forall_i = 1,2,\dots,I \quad (4)$$

$$u_r \geq 0 \qquad \forall_r = 1,2,\dots,R \quad (5)$$

These constraints ensure that the DEA model remains consistent and that the efficiency scores are meaningful across all DMUs.

5. Linear Programming Formulation

To solve the DEA model using linear programming, we transform the objective function into a minimization problem, which is equivalent to maximizing efficiency. The goal is to minimize the sum of weighted inputs while ensuring that the weighted outputs are maximized relative to all other DMUs.
- Objective Function:

$$\text{Minimize } \theta_k = \sum_{i=1}^{I} v_i X_{ik} \quad (6)$$

- Subject to the following constraints:

a) Output Constraints:

$$\sum_{r=1}^{R} u_r Y_{rj} \leq \sum_{i=1}^{I} v_i X_{ij} \qquad \forall_j = 1,2,\dots,N \quad (7)$$

b) Normalization Constraint:

$$\sum_{i=1}^{I} v_i X_{ik} = 1 \quad (8)$$

c) Non-Negativity Constraints:

$$v_i \geq 0 \quad \forall_i \quad (9)$$

$$u_r \geq 0 \quad \forall_r \quad (10)$$

7. Interpretation Of Results

- Efficient DMUs: DMUs with an efficiency score of $\theta_k = 1$ are considered efficient, meaning they use resources optimally to achieve their outputs.
- Inefficient DMUs: DMUs with efficiency scores $\theta_k < 1$ indicate place for improvement, as they are not utilizing their resources as effectively as the benchmark DMUs.

The complete mathematical formulation of the integrated BSC-DEA model incorporates a wide range of inputs and outputs across various perspectives.

This model enables companies to evaluate performance comprehensively and identify specific areas for improvement. The resulting efficiency scores offer actionable insights for optimizing resource allocation and achieving long-term sustainability.

4. THE IMPORTANCE OF DIGITIZATION FOR THE INTEGRATED BSC-DEA MODEL IN EVALUATING FINANCIAL HEALTH OF COMPANIES

Digitization plays a critical role in the implementation of the integrated BSC-DEA model for evaluating the financial health of companies. As companies increasingly rely on data-driven decision-making, digitization enhances the accuracy, efficiency, and scalability of performance evaluation models like the BSC-DEA in various areas, which we identify as follows:

- Automated Data Gathering: Digitization enables the automation of data collection from various sources, such as financial systems, customer relationship management (CRM) tools, enterprise resource planning (ERP) systems, and environmental monitoring systems. This ensures that the data used in the BSC-DEA model is timely, accurate, and comprehensive.
- Centralized Data Repositories: By digitizing data management, companies can create centralized databases that integrate financial, operational, customer, social, and environmental data. This centralization facilitates the seamless flow of information across departments, making it easier to apply the BSC-DEA model.
- Dynamic Performance Tracking: Digitization allows for real-time monitoring of KPIs across all BSC perspectives. This enables companies to track their financial health continuously rather than relying on periodic assessments. Real-time updates ensure that the DEA model is always using the most current data for efficiency analysis.
- Immediate Feedback: With digital tools, companies can receive immediate feedback on their performance, allowing for quicker adjustments to strategies and operations. This ability is crucial for maintaining financial health in a rapidly changing business environment.
- Advanced Analytics: Digitization enables the use of advanced analytics, such as machine learning and artificial intelligence, to enhance the predictive power of the BSC-DEA model. These tools can identify patterns, forecast trends, and suggest optimal resource allocations, making the DEA model more powerful and accurate.
- Scenario Analysis: Digital platforms can simulate various scenarios, allowing companies to evaluate how changes in inputs (e.g., costs, investments) might affect outputs (e.g., profitability, customer satisfaction). This capability is essential for strategic planning and risk management.
- Scalable Solutions: Digitization allows the BSC-DEA model to be scaled across multiple departments, business units, or even global operations. As companies grow, digital tools can handle the increased data volume and complexity, ensuring that the model remains effective at evaluating financial health at scale.
- Customization and Flexibility: Digital platforms enable companies to customize the BSC-DEA model to their specific needs, allowing them to focus on the most relevant KPIs for their industry or business model. This flexibility enhances the model's relevance and applicability.
- Dashboards: Digitization enables the creation of interactive dashboards that present BSC-DEA results in a clear and accessible format. Stakeholders can easily visualize efficiency scores, compare performance across business units, and track progress toward strategic goals.
- Automated Reporting: Digital tools can automate the generation of reports, ensuring that stakeholders receive regular updates on financial health without manual intervention. This improves transparency and keeps all parties informed.
- Data-Driven Decisions: With digitization, companies can base their strategic decisions on accurate, real-time data from the BSC-DEA model. This reduces the reliance on intuition and ensures that decisions are backed by quantitative analysis.
- Strategic Alignment: Digitization helps ensure that the insights derived from the BSC-DEA model are aligned with the company's overall strategy. By integrating digital tools into the decision-making process, companies can ensure that their strategies are consistently executed across all levels of the organization.

Figure 7 summarizes the possible digitization tools for implementation of BCS-DEA method in company and the comparison of the software options suitable for BSC-DEA digitalization with visualization features is processed in Table 3.

Digitalizing the BSC-DEA method involves leveraging digital tools and technologies to streamline, automate, and enhance the process of evaluating a company's financial health.

The specific characteristics of individual industries significantly impact the selection of digitization tools when applying the BSC-DEA model.

- Automation and robotics: The use of IoT sensors, AI analytics, and predictive maintenance enables fast and accurate performance evaluation of individual processes.
- Mechanical engineering: The focus on optimizing production processes leads to the deployment of ERP systems and digital twins to simulate production efficiency.
- Biomedical engineering: This sector relies on clinical data management software, ensuring regulatory compliance and efficiency analysis in product development.

Digital tools play a different role in each sector and influence how the BSC-DEA model is practically implemented. This variability underscores the importance of sector-specific approaches to digitization within the BSC-DEA framework.

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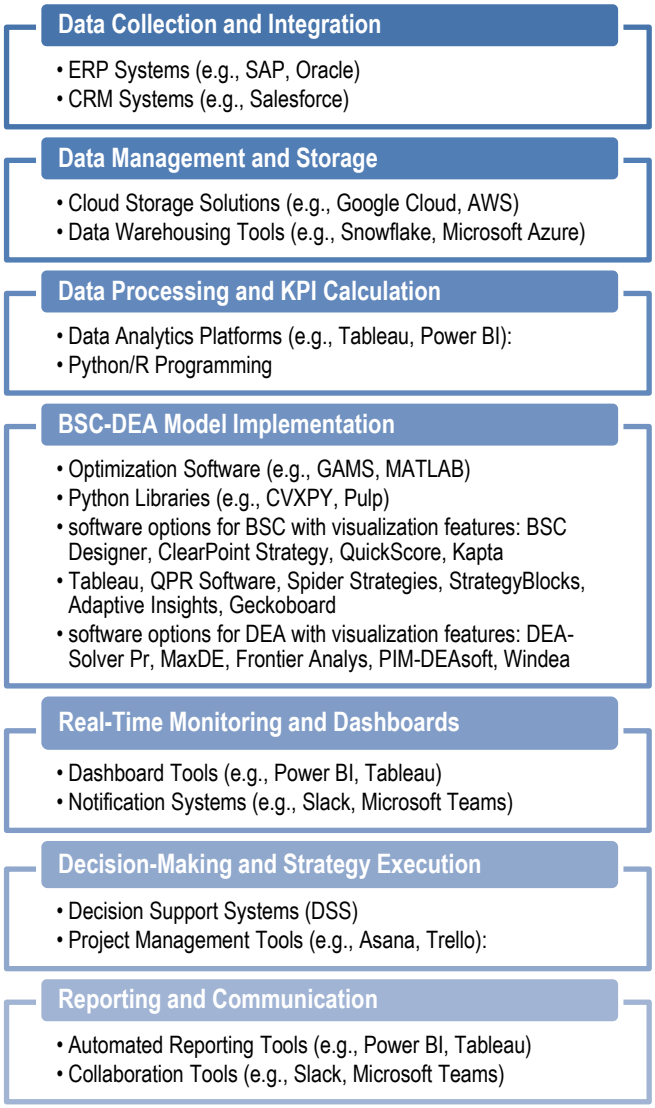

Fig. 7. Digitization tools for BSC-DEA model

Tab. 3. Software options suitable for BSC-DEA digitalization [6]

Software	Best For	Strengths	Limitations
BSC Designer	BSC implementation with strategy maps and KPI tracking	User-friendly, good visualization for BSC	May lack advanced DEA functionalities
ClearPoint Strategy	Comprehensive strategy management with reporting and visualization	Strong BSC features, extensive reporting	May not provide detailed DEA analysis
MaxDEA	Dedicated DEA analysis with advanced models	Specialized in DEA, strong visualization	Lacks BSC functionalities
DEA-Solver Pro	Advanced DEA modeling with a focus on efficiency analysis	Highly regarded for DEA, advanced modeling	Requires expertise, not focused on BSC
PIM-DEAsoft	Intuitive DEA tool with solid visualization features	Good for DEA, intuitive interface	Doesn't focus on BSC
QPR Software	Integrated performance management across BSC and other methodologies	Versatile, strong BSC features	May not have the same depth in DEA
Tableau (customized for BSC-DEA)	Customizable and advanced data visualization	Powerful visualization, customizable	Requires manual setup for DEA
R with Benchmarking Package	Users comfortable with programming and customization	Flexible, advanced analysis	Requires coding skills
MATLAB with DEA Toolbox	Advanced users needing custom DEA solutions	Powerful analytics, customizable	Requires significant expertise
Frontier Analyst	Performance benchmarking with DEA	Strong DEA focus, good visualization	Limited BSC functionality

5. CONCLUSION

By integrating the Balanced Scorecard with Data Envelopment Analysis, companies can comprehensively assess their financial health. This model not only evaluates financial performance but also incorporates the influence of customer satisfaction, internal processes, learning and growth, social and environmental aspects on financial outcomes. It provides a holistic approach to improving financial health by identifying inefficiencies and guiding strategic improvements.

Digitization is essential for maximizing the effectiveness of the integrated BSC-DEA model in evaluating the financial health of companies. It enhances data accuracy, enables real-time monitoring, supports advanced analytics, and facilitates scalability and customization. By leveraging digital tools, companies can make more informed, data-driven decisions that align with their strategic goals, ultimately improving their financial performance and long-term viability.

Despite the widespread use of BSC and DEA models across various industrial sectors, their application differs depending on the industry in which a company operates. In mechanical engineering, performance is primarily evaluated through production quality, cost optimization, and sustainability. DEA methodology provides an advantage in benchmarking the efficiency of production lines, while BSC ensures a strategic framework for long-term management. In biomedical engineering, compliance with strict regulatory requirements and the development of innovative healthcare technologies are top priorities. When applying the BSC-DEA model, it is crucial to incorporate parameters related to regulatory compliance, technological innovation, and patient satisfaction. These differences indicate that industry specificity influences the way the BSC-DEA model is implemented, with various sectors emphasizing different performance parameters.

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