NIU Journal of Management Sciences Copyright©2026
Nexus International University ISSN: *3007-1887;* 12(2): 201-214

A Proposed Integrative Framework among Green Target Costing, Cleaner Production, and Smart Manufacturing to Achieve Cost Reduction and Sustainable Competitive Advantage in Industrial Companies: A Review Paper

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Abstract. The purpose of this research is to introduce an integrated model incorporating three strategies utilized in the field of management and production in organizations; green target costing, cleaner production, and smart manufacturing. The objective of the paper is to demonstrate the role of these technologies in reducing costs and improving sustainable competitive advantage in today's industrial business environment. Based on the literature analysis, there appears to be a gap in current research due to the fact that many previous research papers focus on one strategy only, at best two, which makes the present study necessary to be conducted from a three-dimensional perspective. The research approach used in this study was analytical review and conceptual integration based on the latest literature in order to establish the relationship between the three technologies and construct an appropriate model for them. Based on the findings of the study, it is clear that the integration of these three technologies results in a synergic effect, increasing capabilities of firms to reduce costs, enhance quality of processes and minimize their environmental impacts. Finally, smart manufacturing acts as a platform that enables successful integration and standardization. The study suggests the use of a comprehensive management strategy within the context of industrial sustainability that combines cost management, production, and digital transformation together along with the creation of comprehensive performance indicators that incorporate the environmental, digital, and cost aspects, and further, calls for conducting practical studies that test the model suggested. In this regard, the present study makes a contribution to current literature through its unique contribution in incorporating environmental, digital, and cost aspects into one single framework.

Keywords: Green Target Costing, Cleaner Production, Smart Manufacturing, Cost Reduction, Sustainable Competitive Advantage, Digital-Environmental Integration.

1. Introduction

It should be mentioned that the current reality is characterized by radical changes in the industrial sector because of the increasing awareness of ecological problems, the transition to the new economic paradigm, and growing global competition. Under such conditions, the efficiency of production activities becomes insufficient for ensuring the existence of industrial firms. Consequently, industrial firms must develop production and cost management systems that take into account both environmental and technological aspects. Thus, such firms can achieve a perfect balance among cost saving, sustainability, and innovation.

In this regard, some innovative approaches have been developed to improve the ecological and economic performance of industrial organizations. It is worth noting that green target costing is one of the most popular approaches that have evolved from the basic target costing concept by taking into consideration the environmental aspect of pricing, design, and production activities. Also, cleaner production technology is one of the major technologies used for ensuring sustainability in industry because its objective is the reduction of waste and emissions while at the same time being efficient in its use of resources at all phases of the life cycle of the product. Smart manufacturing, on the other hand, is one of the products of the Fourth Industrial Revolution, which utilizes the integration of the production process with

the information process in order to attain flexibility, precision, and elimination of waste.

Although there have been plenty of researches done on individual technologies or even combinations of two of these three technologies, there is no study that integrates all these technologies into a framework that can help identify how they can work complementarily and synergistically to ensure cost reduction and sustainable competitive advantage. The link between these three technologies is not a mere associative relationship but an interactive one through which environmental and digital exchanges take place in a production process.

It is for this reason that this study attempts to develop an integrated framework which unites these approaches into one, demonstrating the nature of their interdependence and the effect they can produce when used for achieving cost savings and sustainable competitive advantage. Additionally, this study will analyze previous studies on the topic in question, highlight the existing research gaps, and outline future directions for further scientific work.

The relevance of this study arises from the possibility of offering an integrated perspective on accounting and production approaches that had been previously discussed in isolation in the literature. The benefit of such an approach lies in the opportunity for gaining a deeper insight into the role played by the interplay of environmental management and digitalization in generating sustainable competitive advantage and helping the companies in developing countries adapt to both the green and digital economies at once.

1.1 Study Problem

The problem statement in this research can be presented as the following question:

- What is the nature and process of integration between green target costing, cleaner production, and intelligent manufacturing to attain cost savings and increase sustainable competitive advantage in industries?"

1.2 Study Importance

A. Scientific Importance

- With its unique integrative approach, the paper integrates three important fields of research (environmental costing, sustainable production, and industry digitization) that have not previously been explored in their entirety in the existing literature.
- The paper enhances the literature on managerial accounting and industrial sustainability through an integration of environmental, cost, and digital approaches.

B. Practical Importance

- The paper gives decision-makers and industrial managers a framework in the application of integrative practices involving the three technologies in order to reduce costs while at the same time ensuring that sustainability is maintained.
- The document provides an effective guide for determining whether industrial firms are ready for smart green manufacturing.

1.3 Study Objectives

- To investigate the conceptual foundations of green target costing, cleaner production, and intelligent manufacturing.
- To develop an integrative framework that shows the interrelation between the three techniques in reducing costs.
- To explain the concept of how interrelation between the above techniques provides a competitive advantage.
- To develop a Conceptual Framework that could be investigated in further research.
- To conduct a literature review on these techniques to uncover research gaps and opportunities.

1.4 Study Hypotheses

As a theoretical review research paper, the hypothesis will be based on propositional hypotheses which will validate the proposed conceptual model, as below:

H1: The adoption of green target costing helps in achieving effective cost reduction both from operational and environmental perspective in industries.
H2: Cleaner production helps in reducing wastes and efficient resource utilization which improves sustainability in competition.
H3: Intelligent manufacturing helps in improving cost accounting and control measures along with enhancing manufacturing flexibility.
H4: Integration of the three technologies leads to synergies in such a way that greater cost savings will be made compared to individual technologies.
H5: Integrative impact of the three technologies helps in gaining sustainable competitive advantage through environmental and digital innovations.

1.5 Study Limitations

A. Temporal Boundaries
The study covers literature published during the period 2020–2025, which witnessed significant development in industrial digital transformation and environmental sustainability.
B. Spatial Boundaries
The study focuses on the industrial sector in general, with special attention to developing countries and emerging markets due to the challenges they face in implementing the three technologies.
C. Thematic Boundaries
The study is limited to the theoretical and conceptual framework of integration among the three technologies, without conducting field statistical analysis, since it is an analytical review paper.

1.6 Study Variables

1.6.1 Independent Variables:

A. Green Target Costing Technology
This technology is based on setting an environmentally friendly target cost before the start of production, taking into account both environmental and economic aspects in product design and process planning.
B. Cleaner Production Technology
This is a preventive strategy aimed at reducing pollution and waste at the source through improving resource utilization and adopting more efficient production practices. This leads to reducing environmental failure costs and achieving compliance with environmental regulations.
C. Smart Production Technology
This technology is based on the technologies of the Fourth Industrial Revolution (Industry 4.0), such as the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics. Accordingly, smart production is a key enabler for the implementation of both green target costing and cleaner production, due to its ability to provide accurate and real-time data on environmental and operational performance. This enables informed decision-making and supports continuous improvement in environmental and economic efficiency.

1.6.2 Mediating Variable

Integration among the Three Technologies: This represents the interaction and alignment among the technologies in practical application.

1.6.3 Dependent Variables:

A. Cost Reduction
The extent to which a company is able to reduce operational, production, and environmental costs through adopting smart green technologies.
B. Sustainable Competitive Advantage
The company's ability to maintain a long-term competitive position in the market by offering products with acceptable quality and price, with a reduced environmental impact.

1.7 Proposed Integrative Framework Diagram

Independent Variables	Mediating Variable	Dependent Variables
Green Target Costing - (GTC) Product design, cost reduction, environmental cost reduction (emissions, energy consumption, recyclability)	**Integration among the Three Technologies**	**Cost Reduction**
Cleaner Production (CP) Pollution reduction, waste minimization, improved resource efficiency		**Sustainable Competitive Advantage**
Smart Production (SP) Internet of Things (IOT), Artificial Intelligence (AI), Big Data Analytics		

Table (1) illustrates the proposed conceptual framework linking independent, mediating, and dependent variables.

1.8 Analysis Methods & Approach:

Since the study is an analytical review, it adopts the following methodological approaches:

- **Descriptive Analytical Method:** To analyze concepts and theoretical frameworks of the three technologies and review their development.
- **Comparative Method:** To compare results from previous literature and identify similarities and differences with the current study.
- **Conceptual Inductive Method:** To derive an integrated theoretical framework that clarifies the relationships among the variables.
- **Content Analysis:** To classify studies according to the technologies, outcomes, and methodological determinants.
- **Synthesis Analysis:** To synthesize previous findings and build the proposed conceptual model.

1. Arabic Studies

No	Researcher	Year	Title	Objective	Findings
1	Al Baldawi, Shaker et al.	2025	The Role of Integration between Green Target Costing and Time-Driven Product Life Cycle Accounting in Achieving Sustainable Competitive Advantage	The study highlighted that green target costing and time-driven product life cycle accounting are among the most important contemporary strategic techniques in cost and managerial accounting. It aimed to show that integrating these two techniques enables economic units to achieve sustainable competitive advantage through cost reduction, time savings, quality improvement, and enhanced production flexibility.	The study concluded that the Air-Cooled Engine Laboratory, part of the General Company for Electrical and Electronic Industries, urgently needs to implement these two techniques to achieve its goals of improving production efficiency, reducing costs, enhancing product quality, and promoting environmental sustainability and optimal use of available resources. The integration also strengthens the laboratory's competitive position in the market.
2	Al Hasnawi, Karrar Abdul Karim & Yaqoub, Faiha Abdullah	2025	The Role of Cleaner Production in Cost Leadership and Achieving Competitive Advantage	The study aimed to apply cleaner production at Al-Kufa Cement Plant to reduce the amount of waste generated during production while increasing production efficiency using the same input levels as the previous year. This supports cost-per-ton reduction, cost leadership strategy, and the plant's ability to control selling prices, thereby achieving competitive advantage.	Applying cleaner production at the plant allowed a significant portion of raw materials that would have become waste to be transformed into final products, reducing environmental impact and additional disposal costs. Cleaner production also increased output quantity and reduced product cost, supporting the cost leadership strategy and enabling price control to achieve competitive advantage.
3	Al Hasnawi, Wafaa Abdul-Hussein	2024	The Impact of Smart Manufacturing on Achieving Production Flexibility	The study examined the relationship between smart manufacturing requirements and production flexibility at the Soda and Chlorine Production Plant of the General Company for Euphrates. It also measured the gap between the actual factory performance and the application of smart manufacturing and production flexibility requirements.	The study concluded that business survival and growth are major challenges for competing firms. Therefore, alignment between smart manufacturing strategies and production flexibility is essential for competitiveness and sustainability. Statistical results showed a gap between smart manufacturing requirements and actual factory implementation due to insufficient smart manufacturing technologies and a lack of expertise among plant personnel.

2. Foreign Studies

No	Researcher	Year	Title	Objective	Findings
1	Maximilian Stange & others	2023	Target Costing as an Approach to Reduce Costs in Closed-Loop Agriculture Systems: Application for the Cultivation of Algae in Photobioreactors	To provide an overview of the latest technological advancements in agricultural systems, specifically algae cultivation in artificially lit photobioreactors. This technology reduces land and water usage, enhances competitiveness with other agricultural systems, and lowers costs by utilizing target costing in the early stages of development. The study focuses on minimizing energy costs, selecting suitable sites, and utilizing by-products and effluents.	The study concluded that target costing, as a cost management tool, is appropriate for these industries. However, there is a lack of standardization regarding terminology and procedures, which should be adjusted according to specific applications. The integration of target costing with sustainability assessment methods is recommended. Comparisons between target cost values and product life cycle (PLC) were made, and more comprehensive integration within the food production framework is desirable due to increasing consumer demand.
2	Shuaiyin Ma & others	2024	Industry 4.0 and Cleaner Production: A Comprehensive Review of Sustainable and Intelligent Manufacturing for Energy-Intensive Industries	To provide a comprehensive analysis of sustainable smart manufacturing and summarize the principles of Industry 4.0, highlighting how it enhances cleaner production across product lifecycle (PLC) stages.	The study found that cleaner production is a key strategy for energy-intensive industries to maintain competitive advantage. Industry 4.0 and smart manufacturing are increasingly emphasized, integrating manufacturing and maintenance within the PLC. Attention is needed for clean technology integration, industrial data security, circular economy practices, and emerging concepts such as Industry 5.0. Successful application requires collaborative efforts from business leaders, researchers, and governments.
3	Dinh Van Hoang & others	2025	Digital Capabilities and Sustainable Competitive Advantages: The Case of Emerging Market Manufacturing SMEs	To investigate the impact of digital capabilities on the competitive advantages of SMEs in Vietnam from a dynamic capabilities perspective.	The study concluded that digital capabilities have a positive relationship with sustainable competitive advantage. Digital assimilation acts as a positive mediator, and digital leadership significantly influences digital capabilities, digital assimilation, and sustainable competitive advantages.

Distinguishing Features of the Current Study Compared to Previous Literature:

The current study differs from previous literature in that it does not focus solely on the impact of a single technology or even two technologies. Instead, it proposes an integrative framework combining three technologies—green target costing, cleaner production practices, and digital manufacturing technologies ("smart production")—to assess the synergistic effects on cost reduction and It also offers practical guidance to managers and decision-makers on where to invest (technological development, skills training, operational policy). This will help ensure that digital and environmental capabilities generate sustainable competitive advantages.

The table below summarizes the similarities, differences, and distinguishing contributions of the current study relative to prior studies:

No.	Previous Study	Similarities	Differences	Distinguishing Contribution
1	Integration between Green Target Costing and Time-Driven Product Life Cycle Accounting in Achieving Sustainable Competitive Advantage	Focus on green target costing and product life cycle as tools for cost planning and achieving sustainable competitive advantage	Previous study examines **dual integration**; the current study integrates cleaner production and smart manufacturing as well, providing a broader operational and strategic analysis	Demonstrates how digital and operational capabilities enhance the effectiveness of target costing across the product life cycle and provides a **synergistic three-technology model**
2	Role of Cleaner Production in Cost Leadership and Achieving Competitive Advantage	Shared focus on cleaner production as a channel for cost reduction and sustainability	Previous study focuses on a single technology (cleaner production), while the current study examines its interaction with green target costing and digital technologies	Shows the additional benefit of combining cleaner production, digital technologies, and green cost planning, producing greater effectiveness than any single technology alone
3	Impact of Smart Manufacturing on Achieving Production Flexibility	Focus on smart manufacturing's effect on operational performance (flexibility/responsiveness)	Previous study emphasizes operational flexibility as a result of smart manufacturing; the current study extends this by including cleaner production and green target costing practices, and their joint impact on sustainable competitive advantage	Explains mechanisms: how digital data and smart control enable green target costing, how cleaner production reduces variance and hidden costs, and how the three technologies interact to achieve environmental, cost, and strategic objectives simultaneously
4	Digital Capabilities and Sustainable Competitive Advantages: SMEs in Emerging Markets	Focus on digital capabilities and their link to sustainable competitive advantage	Previous study focuses on SMEs and digital capabilities alone; current study integrates digital capabilities with cleaner production and green target costing, including larger firms	Adds a strategic-practical dimension, proposing a multi-level performance measurement framework (technical, environmental, cost integration) that can be applied by senior management
5	Industry 4.0 and Cleaner Production	Both studies address smart manufacturing and cleaner production in industrial sustainability	Previous study focuses on energy-intensive industries; current study applies a multi-dimensional framework (technological, environmental, planning) measuring competitive advantages	Shows how smart manufacturing and green target costing combined with cleaner production enhance cost data accuracy, reduce uncertainty, and accelerate improvement cycles
6	Target Costing in Closed-Loop Agricultural Systems	Focus on target costing as a cost reduction tool	Previous study applied target costing to agricultural systems; current study applies a **broader, multi-dimensional framework** measuring environmental, cost, and strategic outcomes	Demonstrates clear mechanisms for converting digital capabilities into cost and environmental benefits when combined with operational practices and green costing methodology

Key Contributions of the Current Study:

• Transcends simplistic and straightforward causation by introducing a step-by-step causation framework that ties together the three technologies in a coherent manner.

• Includes causal and explanatory analysis rather than merely correlational analysis, filling gaps in existing literature.

• Bridges theory and practice by offering a feasible implementation pathway for industrial enterprises on how digital data integration, intelligent manufacturing, and clean production strategies can work together to cut costs, lessen environmental harm, and boost sustainable competitive advantages.

• Focuses on industrial industries in developing or emerging economies, assessing the potential of these technologies in various settings.
• Considers three aspects—financial (cost-saving), environmental (sustainability), and strategic (competitive advantage)—representing a contemporary approach to integrated performance measurement and strategic cost management research.

Theoretical Foundation:

1 Resource -Based View:

The Resource Based View (RBV) theory presumes that competitive advantage and sustainability of business organizations depend on the creation and implementation of strategic resources which are valuable, rare, hard to imitate, and non-substitutable for the organization. In other words, competitive advantage is not dependent on the market position of firms or any other external circumstances but their uniqueness and non-replicability by other competing companies (Leon–Dominguez et al., 2021).

According to current studies, nowadays digital and environmental resources are regarded as strategic resources for companies functioning in industrial settings. Digital resources which include the development of smart production systems and big data analytics capabilities provide more flexibility and response, thus leading to improved performance (Wamba S.F et al., 2020). Environmental resources, including cleaner production and green target costing practices, are considered to be factors that increase productivity (Zhang & Li, 2022).

Taking into account the objectives of the current study, it is suggested that integration of green target costing, cleaner production and smart production as the bundle of strategic resources can positively affect costs and environmental performance. It can be explained by the fact that RBV theory states the mechanism by which these three factors create firm-specific capabilities.

2 Dynamic Capatilities Theory:

Dynamic Capability Theory (DCT) expands on the RBV framework in the sense that it focuses on resources but emphasizes the ability of organizations to recombine and use their resources and competencies in ways that allow for better responses to the dynamics of change. The current context of industry has been defined by digital transformation and an increase in external pressures, and so it is not enough for companies to have strategic resources anymore; they need to be able to renew and leverage them (Teece, D.J. et al., 2020).

Digital transformation becomes critical in the generation of dynamic capabilities because it allows organizations to sense changes, make use of opportunities, and reorganize their business processes accordingly. Tools used for this purpose may include real-time data analysis, artificial intelligence, and Internet of Things technologies, which help companies with the integration of information concerning cost, environmental, and production factors, while promoting learning and strategy development (Brettel, M., Strese, S., & Flatten, T.C., 2021).

According to the author, the present study indicates the presence of green target costing, cleaner production, and smart production as part of a dynamic capability. The smart production technology gives the basis for obtaining information, whereas cleaner production helps enhance flexibility as well as minimize wastage. Moreover, the concept of green target costing ensures that the decisions made will ensure the achievement of both economical and environmental goals.

Proposed transitional paragraph:
In view of the above theoretical frameworks, it is clear that gaining sustainable competitive advantage through industrial firms involves the implementation of a combination of strategies as opposed to the application of individual tools. It is based on this assumption that the current research aims to create an integrative framework for understanding how green target costing, cleaner production, and smart production interact as a system in the reduction of costs and sustainable competitiveness.

3 The Concept of Green Target Costing (GTC)

Green Target Costing is defined as a tool for profit planning and cost reduction before they occur, committed to continuous improvement in product design internally and externally, with a strong customer orientation, while adding an environmental dimension to create a new green product that aligns with the requirements and policies of the economic unit. It harmoniously integrates multiple functional relationships within a coherent and integrated planning system (Malone, 2015).

It has also been defined as an advanced development of traditional target costing to meet customer demands for environmentally friendly products, while considering environmental standards imposed by legislative authorities at an acceptable price. At the same time, economic units aim to maintain a

competitive market position through providing green products at suitable prices (Al-Jadri, 2018).

Green target costing integrates environmental considerations with traditional target costing in response to legislative issues, consumer demand for environmentally friendly products, and stakeholder expectations. These environmental concerns often relate to the products of the economic unit, such as in the automotive industry, where vehicles must comply with environmental regulations set by legislative authorities (Malone, 2015).
From the researcher's point of view:

•Malone identified some crucial dimensions of GTC:

GTC is a technique for planning for profits and reducing costs before their occurrence, a strategy for continual improvements, customer orientation, environmental inclusion, and functional connections within an integrated system.

•**Al-Jadri** rationalized GTC as the evolution of the classical target costing practice to cater for the customers' demands for environmental products, compliance with governmental regulations on the environment, and the necessity of maintaining competitive advantage.

Based on the above arguments, the researcher endorses these definitions as they link economic, environmental, and organizational dimensions, giving emphasis to the external determinants of GTC (consumer demand and government legislation). The reality of business organizations seems to support these arguments. In addition, it looks like business firms use this model not only for financial benefits but also for sustainability and competitive advantage. Techniques and methods for GTC implementation - such as Green Price Premium and Green Kaizen- are very pertinent in the sustainable product pricing and continual environmental development.

Here the researcher presents an academic definition for the concept which combines all the aspects highlighted in the earlier definitions:

"Green Target Costing can be considered as a contemporary strategy of cost management, which attempts to cut down costs before they occur, by considering the environmental considerations during the design, manufacturing, and pricing process. The goal is to achieve a balance between profitability, customer satisfaction, and environmental regulation. Green target costing is based on collaboration principles, product life cycle considerations, value chain considerations, and the use of green kaizen and green price premium among others."

4 Green Target Costing Steps

According to Al Zalzali, Khalil, and Al Samarrai (2022, p. 235), the steps of green target costing are as follows:

- Identifying and specifying desirable green functions and features.
- Estimating the target selling price and the green price premium.
- Adjusting the green profit margin and calculating allowable costs.
- Allocating costs to green cost drivers.
- Implementing green cost management procedures.
- Applying green Kaizen cost reduction

Source: Reymard S.S de Melon, Adrieli C.V de Carvalho, Alessandra A. Yokota, Ariovaldo D. Granja & Masa Noguchi, ("Zemch and GreenTarget Costing Approaches: Inferencess from a Design Workshop)5th international Conference on Zero Engrgy Mass Customised Housing ZEMCH 2016 .20th -23rd -Dec-2016.

5 Concept of Cleaner Production:

The United Nations Environment Programme (UNEP) defined Cleaner Production as:

"The continuous application of an integrated, preventive environmental strategy to processes, products, and services to increase economic efficiency and reduce risks to humans and the environment." (UNEP/IEO, 1990; Sadaa, 2017).
It was also defined as "an environmental practice that emphasizes the regular reduction of production process costs through re-learning the consumption of raw materials and reducing the generation of industrial waste, in addition to utilizing and recycling materials to reduce environmental impact and increase organizational benefit." (De Cuimaaes, 2018).

Patel et al. (2017) described it as "a preventive approach to managing the environmental impacts of industrial processes and products by using changes in technology, processes, materials, or practices to reduce waste and environmental, health, energy, and resource risks, more efficiently, leading to profitability, improved production efficiency, and competitive advantage. It is applicable to any business field regardless of size and type."
Furthermore, the European Commission – Cleaner Production Review (2017) stated that:

"Clean technologies are those that extract and use natural resources with maximum efficiency throughout their life cycle, generate products with low-hazard or non-hazardous components, minimize emissions to air, water, and soil during manufacturing and product use, and produce durable products that can be recovered or recycled whenever possible, achieving outputs with minimal energy inputs."

The definitions offered by different sources such as the United Nations Environment Programme, the European Commission, and many other scholars show that there is a common belief about Cleaner Production as a preventive strategy, which is proactive, not reactive to environmental issues.

A joint analysis of the definitions highlights the following dimensions:

1. Preventive Environmental Approach

It should be mentioned that all definitions emphasize the preventive nature of Cleaner Production, which means prevention of any pollution instead of dealing with its negative consequences. As per Patel (2017), it reduces the impacts on the environment by introducing new technologies, better procedures, and materials.

2. Economic Approach

UNEP and De Cuimaaes stressed economic efficiency achieved through saving costs and optimizing resource use. This means that Cleaner Production is not only a way to minimize environmental problems; it is a technique to increase competitiveness.

3. Technological Approach

The European Commission underlined the significance of using clean technologies and methods that provide for sustainable resource extraction and utilization with products being reused.

To the researcher, the concept of Cleaner Production is one which combines both the economic and environmental considerations, whereby the objective is to achieve industrial sustainability through waste minimization, resource optimization, and low environmental impact without negatively affecting the quality of the products or the bottom line profits of organizations. In essence, Cleaner Production is more than an environmental consideration since it entails a strategic approach of changing the way industry operates through the combination of environmental concerns, operational efficiency, and profit maximization:

• Goal 9: Industry, Innovation, and Infrastructure
• Goal 12: Responsible Consumption and Production
Therefore, the adoption of cleaner production has become essential, not optional, for industries, particularly with the growing environmental pressure and heightened consumer awareness, as well as the worldwide trend towards stronger environmental legislation.

6 Concept of Smart Manufacturing / Production:

The evolution and changes in industrial settings along with the advent of the Fourth Industrial Revolution, commonly known as Industry 4.0, have resulted in Smart Manufacturing being considered one of the critical foundations necessary to enhance efficiency, flexibility, and sustainability in contemporary production systems. In this regard, Smart Manufacturing entails the deployment of innovative digital technologies like IoT, AI, Big Data Analytics, and CPS in a manufacturing plant to enhance the production process and facilitate autonomous or semi-autonomous decision-making in real-time.

As opposed to conventional automation, the objective of Smart Manufacturing is to establish "smart factories" that can adjust according to changes in demand, environmental conditions, and availability of resources. The notion is believed to be an integral part of manufacturing and production systems management and design encompassing technological, organizational, and human perspectives.

There have been many attempts by both academia and industries to explain the notion of Smart Manufacturing. Although it has enhanced the notion to some extent, it has also resulted in the development of several definitions based on different perspectives like technological, operational, or human perspective.

Prominent scientific definitions include:
• According to NIST (2018), Smart Manufacturing systems are:
Integrated and collaborative systems which react in real-time to dynamic events in terms of demand, factory operations, supply chain activities, and customers' needs, seeking to optimize efficiency and product quality.
• The ISO/IEC definition of Smart Manufacturing, as quoted in Sirris (2021), is:
"The integrated and intelligent application of processes and resources within the domains of cyber, physical, and human, in cooperation with other domains through the value chain, in order to improve performance and create value-added goods and services."

It considers performance measures such as flexibility, efficiency, safety, security, and sustainability.

• Similarly, Ahmed Berari & Marcus (2023) described Smart Manufacturing as:

"A system where adaptation is possible to fulfill design needs with increased precision and dependability for the lowest cost possible, with adaptive product and environment as required, and integration of human beings with machinery."

• Moreover, Kiwook Jung et al. (2017) said that the readiness of Smart Manufacturing systems now rests on continuous improvement and maintenance of performance through the provision of dependable information and responsiveness to environmental changes.

According to the researcher, the notion of Smart Manufacturing represents a genuine and significant aim for industrialization. The definition of Smart Manufacturing is as follows:

"A coordinated production process, making use of a range of cyber-physical systems including IOT, data analysis and simulations, that makes it possible to make decisions through automation or partial automation, but still with the inclusion of a human element, making it possible for this process to adapt to changes in demand and operation conditions."

However, the researcher highlights several challenges:

1.The concept is not fully developed yet

Not everyone agrees about the definition, since some emphasize technology, while others emphasize performance or people.

2.Shortcomings in the transition from theory to practice

Although there may be lofty goals stated theoretically, there are challenges when implementing smart manufacturing in practice, including issues with infrastructure, human knowledge, conversion costs, cybersecurity, data security, and economic sustainability.

3.Incomplete guidelines and legislation

The ISO/IEC standards have started considering the concept, but full-scale global implementation needs certain parameters for measurement and regulation, especially in nations where small and medium enterprises operate.

Important Features / Components of Smart Manufacturing

From the various definitions, the important components are:

- Integration of the physical and digital worlds (Cyber-Physical Systems, IOT, sensors, actuators)
- Real-time data and analytics

Enabling flexible, predictable, and optimized operations.

- Artificial intelligence and machine learning

To improve efficiency, quality, and predictive responses.

- End-to-end integration across the value chain

Not only within the factory, but across the enterprise and supply chain.

- Flexibility and customization

Ability to rapidly adjust production lines or produce small batches according to customer requirements.

- Sustainability, efficiency, and resource optimization

Reducing waste, enhancing safety and security for workers and equipment.

Sustainable competitive advantage refers to an organization's ability to create and maintain superior performance over competitors for a long period, in a way that makes such advantage difficult to imitate or replace by others, while continuously adapting to environmental changes. This concept involves internal elements (resources, capabilities, innovation, leadership, organizational culture, etc.) and external elements (market changes, technology, competitors, regulatory environment, and social environment).

According to Adebanjo et al. (2020), competitive advantage aims at building added value for the consumer through methods and techniques that allow the economic unit to possess a unique feature or characteristic that enables it to outperform competitors in a continuous and efficient manner, while maintaining and delivering that advantage better than others.

Al-Baldawi (2025) defined sustainable competitive advantage as the actions that aim to achieve satisfactory profits for the economic unit in the long term, in which the value resulting from these actions must exceed the costs of the activities performed by the unit over the long term.

Meanwhile, Moulodi (2019) stated that sustainable competitive advantage is the main goal identified by economic units, through which continuity in the market can be ensured for the longest possible period. This arises by adding value to customers through efficient use of available resources, and by adopting diverse and exceptional competencies characterized by creativity and progress that lead to success and superiority over competitors.

The study of Dinh Van Hoag et al. (2025) focused on how the strategic use of digital technology and related capabilities (digital infrastructure, digital knowledge, skills, intellectual property, and human collaboration) can lead to sustainable competitive advantage, if

activated and reconfigured with environmental changes.

Nadeem et al. (2022) explained how organizations can link key elements of dynamic capabilities (strategic routines, strategic value chains, sustainability-oriented transformations, strategic organizational development, etc.) to achieve sustainable competitive advantage.

In light of the above, the researcher believes that sustainable competitive advantage is a composite, multidimensional concept. It is not sufficient for an organization to possess only one dimension (e.g., valuable resources or an innovative product), but rather it is the integration and harmony among these dimensions alongside a real ability to adapt to uncertainty and change. The researcher highlights the following key points:

- **Adaptability and Change:** The world is changing faster than ever (technology, markets, environmental regulations, customer preferences, crises, etc.). Organizations relying only on "fixed advantages" (such as strong business relations or fixed assets) may lose their advantage when a technological or regulatory shift occurs.
- **Innovation and Organizational Learning:** These are not only key to maintaining the advantage, but also to renewing it, and developing new resources when the old ones erode.
- **Balance Between the Three Dimensions of Sustainability (economic, social, environmental):** Organizations that focus only on profit may face ethical and regulatory pressures and may lose "legitimacy," reducing their ability to maintain advantage.
- **External factors cannot be ignored:** (economic environment, regulations, systems, social and environmental trends), as they significantly affect the sustainability of advantage.

Measurement and Practical Application: There is a need for practical tools to measure sustainable competitive advantage, not only theoretical research. Many studies link SCA with financial and operational performance.

Dimensions of Sustainable Competitive Advantage

Economic units have traditionally relied on cost reduction and quality as fundamental competitive dimensions. However, due to developments and changes in customer preferences and intensified competition, other dimensions have emerged, such as: reduced response time, increased manufacturing flexibility, innovation, and achieving efficiency through optimal use of available resources (Al-Baldawi et al., 2025).

Based on previous literature, the researcher believes that the common dimensions used to define sustainable competitive advantage include:

- **Resources & Value:** Resources must create real value for the user or the organization, either by reducing cost or improving quality.
- **Rarity:** Resources or capabilities must be rare among competitors, such that they are not possessed by many.
- **Inimitability:** The advantage or capability must be difficult for others to imitate, whether due to technical complexity, tacit knowledge, organizational culture, brand, patents, etc.
- **Non-Substitutability:** Resources or capabilities cannot be easily replaced by something else that achieves the same performance.
- **Dynamic Capabilities:** The ability to quickly sense changes in the environment, seize opportunities, and adapt by reconfiguring resources and responding to new challenges.
- **Product and Process Innovation:** Innovation can take many forms, including innovation in products, processes, or strategies, while learning from experience makes it hard to imitate the competitive advantage that it creates.
- **Strategic Leadership and Orientation:** Orientation and strategic leadership that combine vision, knowledge management, planning, and decision making.

The Proposed Integrated Framework Between Green Target Costing, Cleaner Production, and Smart Production

Integration between the three tools is an organic connection that seeks to promote sustainable manufacturing practices. The three components each have a specific role in attaining economic and environmental efficiencies.

Green target costing is an important tool in the early design phase that enables the estimation of product cost by accounting for environmental considerations. Environmental costs are included throughout the product's lifecycle, making this tool useful in guiding product and process design toward environmentally sustainable options, such as energy efficiency, recycling, and reduced carbon emissions. Green target costing is thus an effective strategy for developing environmentally sustainable products with low environmental costs, hence clean production methods (Fleih & Al-Qaisi, 2023).

Cleaner production is a proactive concept focused on eliminating waste and minimizing pollutants from their sources via optimal resource utilization, improved production processes, and equipment improvements, resulting in lower environmental failure costs and regulatory compliance, thus green cost targets (Salah Mahdi, 2024).

By employing the smart production technique which involves Fourth Industrial Revolution (Industry 4.0) technology, there will be a connected digital environment created for the effective execution of cleaner production due to tools such as Internet of Things, artificial intelligence, big data analytics, and digital twins. Smart production ensures the accurate measurement of product and process performance in relation to its environmental impact for efficient use of green target costing and cleaner production in decision making (Geng H. et al., 2024).

The researcher feels that integrating these three techniques cannot simply be an option at this time, as it is an absolute necessity and will provide the required means for gaining sustainability, as well as offering the required competitive advantage. This integration of techniques will help in ensuring that operations become efficient and environmentally friendly, thereby laying the necessary groundwork for sustainable competitive advantage and increased chances of survival.

The relationship between these three techniques as far as reducing cost and creating a sustainable competitive advantage is concerned, can be understood as follows:

1. Cleaner Production + Green Target Costing = Low-Cost, Environmentally Conscious Production
   - o Both enhance reduction of environmental and economic waste.
   - o Green target costing is used as a quantitative tool for implementing cleaner production by identifying waste points and costs of emissions/waste.
2. Smart Production + Cleaner Production = High Environmental Efficiency Using Technology
   - o Smart production enables real-time monitoring and analysis of environmental impact.
   - o Facilitates integration of technologies such as IoT to monitor carbon emissions, energy consumption, and material waste.
3. Smart Production + Green Target Costing = Accurate Guidance for Environmental Financial Decisions
   - o Systems such as AI and ERP can predict environmental cost for any product or process.
   - o Supports sustainable design decisions.

Table: How the Three Techniques Support Sustainable Competitive Advantage

Dimension	Contribution of the Three Techniques
1. Reduction of environmental and financial costs	Green target costing + cleaner production reduce waste, increasing profit margin.
2. Regulatory compliance and risk reduction	Compliance with environmental standards helps avoid fines and improve corporate reputation.
3. Product and service quality improvement	Smart operations enhance continuous quality improvement and environmental performance, increasing customer satisfaction.
4. Flexibility and technological innovation	Smart production enables rapid response to market and green customer demand.
5. Building a sustainable brand image	Promoting sustainability attracts environmentally conscious consumers and strengthens market position.

First: Conclusions

Accordingly, the following theoretical findings were made by analyzing relevant literature:

1. The techniques of Green Target Costing, Cleaner Production, and Smart Production all have one common goal of finding balance between cost reduction and sustainability; nevertheless, they have different origins, which implies the inevitability of their integration.
2. Synergy achieved by integrating the techniques means that using them together yields more significant advantages than using them individually, due to information exchange and alignment of goals regarding environmental and digital efficiency.
3. The technique of Smart Production can be considered the backbone of the digital platform that allows effective application of Green Target Costing and Cleaner Production thanks to real-time data processing.
4. Integrating the above-mentioned techniques is considered the way to gain Sustainable Competitive Advantage due to its efficiency, innovativeness, and environmentally friendly character.
5. Earlier scientific research on this topic has mainly dealt with separate investigation of the techniques or with relationships between two of them, while this framework offers an integral view from three sides, thus, addressing the knowledge gap found in recent literature.

Second: Recommendations

Some of the recommendations that the current research paper suggests are listed below:

1.The use of an integrated managerial strategy that combines cost management, production, and technological issues in one single unit to meet sustainability goals should be applied to industrial organizations.
2.The promotion of digitalization in accounting and production management to integrate the three concepts and collect automatic information for performance assessment.
3.The need for conducting empirical quantitative field research by scholars to investigate and prove the existence of relationships between variables discussed in the context of various industries.
4.Establishment of integrated indicators that consider environmental, economic, and technological dimensions.
5.Governmental and organizational policies that contribute to the implementation of principles of the green economy and smart manufacturing in the long-run strategy of the industrial sphere.

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