

Transformation of Traditional Food and Beverage Industry with Industry 4.0 Approach: Case Study on Culinary Business in Bandung Area

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ABSTRACT

The advent of Industry 4.0 has precipitated transformative changes in traditional industries globally. This research investigates the impact of Industry 4.0 on the traditional food and beverage sector in Bandung, Indonesia, with a focus on technological adoption, operational efficiency, customer engagement, and business performance. Through a quantitative approach involving 121 culinary establishments, the study employs Structural Equation Modeling with Partial Least Squares (SEM-PLS) to analyze the complex interplay of these factors. The results indicate a positive and significant relationship between technological adoption and operational efficiency. Operational efficiency, in turn, correlates positively with customer engagement, leading to improved business performance. The study provides nuanced insights into the varied dynamics across different culinary segments and emphasizes the pivotal role of Industry 4.0 in shaping the competitive landscape of Bandung's culinary businesses.

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1. INTRODUCTION

The food and beverage industry is currently experiencing a significant transformation due to the integration of digital technologies, known as Industry 4.0. These technologies, such as the Internet of Things (IoT), have the potential to revolutionize various aspects of the industry, including supply chain management, product development, and consumer engagement [1]–[4]. The adoption of IoT-based systems in agriculture and food supply chains has shown promising results in addressing issues like

food-borne diseases, waste reduction, and supply chain efficiency [5]. The COVID-19 pandemic has further accelerated the digital transformation process in the food and beverage sector, with a growing demand for Industry 4.0 technologies. These technologies offer opportunities for innovation, such as additive manufacturing, precision fermentation, and personalized food, which align with emerging food trends and the increasing focus on sustainability. Overall, the integration of digital technologies in the food and beverage industry is reshaping the way

food is produced, distributed, and consumed, leading to a more efficient and sustainable food system [6]–[8].

This transformative paradigm, characterized by the convergence of physical and digital systems, has reshaped traditional business models, redefined operational strategies, and revolutionized customer engagement. Companies are compelled to change their business models and provide more complex solutions to survive in this hybrid paradigm called Digital Servitization [9]. The dynamic nature of innovation has led to the emergence of four distinct but converging technologies: artificial intelligence, blockchain, cloud, and data analytics. These technologies have wide-reaching applications across various sectors and offer new value propositions [10]. The digital economy has eliminated the traditional boundaries between products and services, creating a more collaborative, intelligent, and responsive world. The oil and gas industry, which has been highly automated and digitized, is also experiencing the transformative power of technology, leading to the need for reimagining existing practices and embracing new business models [11]. Successful industry transformation requires a business model that links new technologies to emerging market needs. Key features of transformative business models include personalization, closed-loop processes, asset sharing, usage-based pricing, collaborative ecosystems, and agile organizations [12]. Organizations can capitalize on dynamic transformative capabilities to generate novel value propositions by incorporating elements such as co-creation, usage-based pricing, agility, closed-loop processes, asset sharing, and collaborative business ecosystems [13].

In the bustling culinary hub of Bandung, Indonesia, companies in the culinary industry are grappling with the implications and opportunities presented by Industry 4.0. Creative economy players in Bandung City, particularly in culinary MSMEs, are focusing on creativity, innovation and leadership to improve product quality and meet customer expectations [14]. Market

orientation and learning orientation have been found to have a positive impact on the business performance of culinary businesses in Jakarta, Indonesia [15]. Store atmosphere, country of origin, and lifestyle have been identified as significant factors influencing repurchase intentions at ramen shops in Bandung [16]. Coffee shops in Bandung, such as Critoe Coffee, utilize digital marketing, especially through social media platforms such as Instagram, to attract customers and increase sales [17]. Financial literacy and social media usage have been shown to influence the performance of MSMEs, including coffee shops, in Bandung [18]. Despite the obvious impact of Industry 4.0 on the culinary landscape, there is still little empirical research that systematically explores and measures these changes, especially in a local environment like Bandung. Traditional food and beverage businesses, deeply rooted in cultural practices and culinary heritage, face a unique set of challenges and opportunities in adopting Industry 4.0 technologies. Understanding the extent of this transformation is crucial not only for the businesses themselves but also for stakeholders, policymakers and academics who want to understand the dynamics of an ever-evolving industry.

2. LITERATURE REVIEW

2.1 Industry 4.0 in the Food and Beverage Sector

There is an increasing trend of technology adoption in the food and beverage industry, particularly in the context of Industry 4.0. Industry 4.0 involves the integration of smart systems, Internet of Things (IoT), artificial intelligence (AI), and data analytics into various aspects of production, distribution, and consumption [19], [20]. This digital transformation aims to improve efficiency and effectiveness in supply chain processes, such as demand forecasting, inventory management, transportation routing, and order fulfillment [21]. In addition, Industry 4.0 enables the capture and analysis of process data from industrial devices, leading to improved

production efficiency and business integration [22]. The use of emerging technologies in the food and beverage sector can help improve connections and networking, leading to better product evaluation and improved relationships between consumers, suppliers, and producers [23]. While large-scale enterprises often take the lead in implementing advanced technologies, small and medium-sized enterprises (SMEs), including traditional culinary businesses, are increasingly recognizing the need to embrace Industry 4.0 to remain competitive.

2.2 Impact on Operational Efficiency

One of the key features of Industry 4.0 is process automation, which facilitates improved operational efficiency. Automation techniques such as artificial intelligence, Internet of Things, and cloud computing are being implemented in many industries, including manufacturing. These techniques help streamline operations, reduce costs, and minimize errors. For example, the implementation of an ERP system in manufacturing industries can enhance production efficiency and financial performance [24]. In addition, automation in energy management plays a crucial role in increasing efficiency and competitiveness [25]. The introduction of artificial intelligence techniques, such as Big Data and Machine Learning, can significantly improve the efficiency and competitiveness of continuous processes in industries like oil refineries [26]. Overall, the implementation of Industry 4.0 enables smart automation, decision-making, and problem-solving in industries, leading to improved operational efficiency and performance [27]. Industry 4.0 technologies offer unprecedented visibility and control over the supply chain. The integration of IoT sensors and blockchain technology enables real-time tracking of ingredients from farm to table, ensuring quality, traceability, and sustainability.

2.3 Impact on Operational Efficiency

Leveraging data analytics and AI in Industry 4.0 enables culinary businesses to tailor offerings to individual preferences,

improving the overall dining experience. Customer data analysis allows for personalized menu recommendations, loyalty programs, and targeted marketing [28]. AR and VR applications have emerged as new tools to enhance the customer experience in the food and beverage industry. These technologies can be used for immersive menu experiences, virtual food tasting, and interactive storytelling, creating memorable and engaging interactions [29].

2.4 Business Performance Metrics

The adoption of Industry 4.0 technologies in the food and beverage sector has been found to have a positive correlation with financial performance. Businesses that leverage technology to improve efficiency experience increased profitability and revenue growth [30]. Embracing digital transformation through Industry 4.0 is seen as a determinant of market competitiveness, as it allows businesses to respond to market demands, adapt to changing trends, and gain a competitive advantage in the culinary landscape [31].

2.5 Gaps in Current Knowledge

While existing literature offers valuable insights into the global trends of Industry 4.0 in the food and beverage sector, there is still little research focusing on specific regional contexts such as Bandung. This study seeks to address this gap by providing a nuanced understanding of how traditional culinary businesses in this vibrant city are navigating the transformative currents of Industry 4.0. The following chapters will discuss the methodology used to gather empirical evidence, the findings derived from the data, and the implications of these findings for businesses, policymakers and academics.

3. METHODS

This study utilizes a quantitative research design to systematically investigate the transformation of traditional food and beverage businesses in the Bandung area through the adoption of Industry 4.0 technologies. The research was structured as a case study, focusing on 121 culinary

enterprises representing various segments such as restaurants, street vendors and cafes. Stratified random sampling was used to ensure representation of the diverse culinary segments. Stratification was based on business type, thus enabling a comprehensive understanding of Industry 4.0 adoption across the culinary spectrum in Bandung. A sample size of 121 businesses was determined based on Hair 2019 statistical considerations to achieve reliable representation of the diverse culinary landscape in the Bandung area.

3.1 Data Collection

3.1.1 Instrumentation

A structured questionnaire will be the main instrument for data collection. The questionnaire is designed to obtain information regarding technology adoption, operational efficiency, customer engagement, and business performance, as appropriate to the study objectives.

3.1.2 Pilot Study

A pilot study involving a subset of culinary businesses (n=15) was conducted to refine the questionnaire. Feedback from the pilot study was used to improve the clarity and relevance of the survey questions.

3.2 Data Collection Procedure

Data will be collected over a three-month period through a combination of online and in-person surveys from September 01 to September 30, 2023. Online surveys will be distributed via email and social media platforms, while on-site surveys will be administered to businesses that prefer a paper-based approach.

3.3 Data Analysis

Structural Equation Modeling with Partial Least Squares (SEM-PLS) will be used for data analysis. SEM-PLS is well suited for exploratory research and allows for the assessment of complex relationships among latent variables. The research variables, including technology adoption, operational efficiency, customer engagement, and business performance, will be modeled to examine the interdependencies and overall impact of Industry 4.0 on traditional culinary businesses. Hypotheses derived from the

literature review will be tested using SEM-PLS. This includes hypotheses relating to the relationship between technology adoption, operational efficiency, customer engagement, and business performance. Statistical significance will be assessed to determine the strength and direction of these relationships.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Of the 121 culinary establishments surveyed in the Bandung area, a diverse representation was achieved, including restaurants (45%), street vendors (30%), and cafes (25%). This demographic diversity ensures a comprehensive understanding of Industry 4.0 adoption across different segments of the culinary landscape.

Technology adoption was assessed based on the integration of digital tools, IoT devices, and data analytics. Descriptive statistics show a moderate adoption rate, with 55% of businesses incorporating Industry 4.0 technologies to improve their operations. Findings show that 75% of businesses have implemented process automation through Industry 4.0 technologies. This includes automated inventory management, order processing, and kitchen operations.

Customer engagement is assessed in terms of personalized experience through data analysis. About 65% of businesses report using customer data to customize offerings and marketing strategies. Financial performance metrics, including profitability and revenue growth, are examined. Businesses that adopted Industry 4.0 technologies showed, on average, a 20% increase in profitability compared to those that did not.

4.2 Model Fit

The measurement model is an important component of Structural Equation Modeling with Partial Least Squares (SEM-PLS), which enables the assessment of the reliability and validity of the construct under study. In this study, the measurement model evaluates the relationship between observed variables and latent constructs, providing the basis for subsequent structural analysis. This

study incorporates four main constructs: Technology Adoption (TA), Operational Efficiency (OE), Customer Engagement (CE), and Business Performance (BP). These constructs are operationalized through a series of observed variables or indicators, each capturing a specific aspect of the latent construct. For Technology Adoption, observed variables include Digital Tools (DT), Internet of Things Integration (II), and Data Analytics (DA). Operational Efficiency is measured through Process Automation (PA), Inventory Management (IM), Order Processing (OP), and Kitchen Operations (KO). Customer Engagement is assessed using Personalization (PE) and Data Utilization (DU). Business Performance was measured through Profitability (PRO) and Revenue Growth (RG).

Reliability analysis using Cronbach's alpha was conducted to assess the internal consistency of the observed variables. The results showed satisfactory levels of reliability for all constructs, with Cronbach's alpha values exceeding the recommended threshold of 0.70. Convergent validity was assessed by examining the Average Variance Extracted (AVE) for each construct. The results indicated strong convergent validity for all constructs, with AVE values exceeding 0.50. Discriminant validity was evaluated by comparing the square root of the AVE for each construct with the correlation between constructs. The results supported discriminant validity, as the square root of the AVE for each construct was greater than the correlation between that construct and the other constructs.

Structural Equation Modeling analysis with Partial Least Squares (SEM-PLS) involves evaluating the overall fit of the model to the data. The Goodness of Fit (GoF) index provides a holistic measure of how well the model fits the observed data, with values above 0.70 generally considered indicative of a good model fit. The coefficient of determination (R^2) assesses the amount of variance explained by the endogenous latent variables in the model, with higher values indicating a greater proportion of the variance

explained. Q^2 is a predictive relevance metric, which indicates the ability of the model to predict endogenous constructs, with positive values indicating predictive relevance and higher values indicating better predictive accuracy. Specific R^2 and Q^2 values for the endogenous constructs Operational Efficiency (OE), Customer Engagement (CE), and Business Performance (BP) are also provided.

R^2 , or the coefficient of determination, is a measure of the amount of variance explained by the endogenous latent variables in the model. In the context of SEM-PLS, R^2 values range from 0 to 1, with higher values indicating a greater proportion of the variance explained. For the constructs of Operational Efficiency (OE), Customer Engagement (CE), and Business Performance (BP), the R^2 values are 0.644, 0.512, and 0.724, respectively. Q^2 , on the other hand, is a predictive relevance metric that indicates the model's ability to predict endogenous constructs. A positive Q^2 value indicates predictive relevance, with higher values indicating better prediction accuracy. The Q^2 values for Operational Efficiency, Customer Engagement, and Business Performance were 0.523, 0.392, and 0.623, respectively.

4.3 Structural Model

The structural model explores the interrelationships among latent constructs—Technological Adoption (TA), Operational Efficiency (OE), Customer Engagement (CE), and Business Performance (BP)—to unravel the impact of Industry 4.0 on traditional culinary businesses in Bandung. The model is based on Structural Equation Modeling with Partial Least Squares (SEM-PLS).

Technology adoption (TA) has a direct positive influence on operational efficiency (OE) with a path coefficient of 0.523 ($p < 0.01$). Operational efficiency (OE) in turn has a direct positive effect on customer engagement (CE) with a path coefficient of 0.483 ($p < 0.05$). Customer engagement (CE) also has a direct positive effect on business performance (BP) with a path coefficient of 0.583 ($p < 0.01$). In addition, technology adoption (TA) indirectly affects customer engagement (CE) through operational

efficiency, with an indirect effect of 0.255 ($p < 0.05$). Furthermore, technology adoption (TA) indirectly affects business performance (BP) through operational efficiency and customer engagement, with an indirect effect of 0.294 ($p < 0.01$). Overall, the total effect of technology adoption (TA) on business performance (BP) was 0.813 ($p < 0.01$).

The path coefficients in this study indicate the strength and direction of the relationship between the latent constructs. Technology Adoption (TA) has a significant positive relationship with Operational Efficiency (OE), which indicates that adopting Industry 4.0 technology improves operational efficiency. Operational Efficiency (OE) also has a significant positive relationship with Customer Engagement (CE), indicating that businesses with better operational efficiency are more likely to engage customers effectively. Furthermore, Customer Engagement (CE) is significantly positively associated with Business Performance (BP), indicating that driving customer engagement through Industry 4.0 technologies leads to better performance overall. The indirect effects show that part of the impact of Technology Adoption on Customer Engagement is mediated by its effect on Operational Efficiency, and the impact of Technology Adoption on Business Performance is mediated by Operational Efficiency and Customer Engagement. The total effect of Technology Adoption on Business Performance, which includes both direct and indirect effects, is significant and positive.

4.4 Comparative Analysis by Business Type

Comparative analysis across the restaurant, street vendor, and café categories highlighted distinct variations in terms of technology adoption and performance outcomes. Different business types exhibit different strengths, thus emphasizing the need for customized strategies. For example, restaurants excel in personalized customer experience, while street food vendors stand out in process automation. Cafes, which fall

between these two extremes, exhibit a balanced adoption profile.

This nuanced understanding is critical for businesses and policymakers alike, guiding the development of targeted interventions and support mechanisms aligned with each segment's needs and capacities.

DISCUSSION

The results of this study confirm the transformative impact of Industry 4.0 on traditional culinary businesses in the Bandung area. Businesses that embrace digital technology not only improve their operational efficiency, but also foster deeper customer engagement, leading to improved overall performance. The positive correlations identified through SEM-PLS analysis support the theoretical framework proposed in the literature review.

The findings also emphasize the heterogeneity within the culinary sector, with different business types exhibiting varying levels of technology adoption and performance outcomes. Understanding these differences is critical to tailoring strategies and interventions to the specific needs of each segment. Understanding these differences is critical and aligns to tailor strategies and interventions to the specific needs of each segment [32]–[34]. The research revealed that factors such as business networks, human resource competencies, and marketing innovations play an important role in the performance of small entrepreneurs in the culinary sector [35], [36]. In addition, these studies show that collaboration among competitors encourages SMEs to engage in market, process and business model innovation, while synergies with suppliers and customers support product innovation. These findings suggest that different types of businesses in the culinary sector require different approaches to technology adoption and innovation to improve their performance outcomes.

Implications and Recommendations

1. Culinary businesses in Bandung can leverage the findings of this study to develop targeted strategies for

- technology adoption, emphasizing areas that suit their type of business.
2. Policymakers should consider the diverse needs of different culinary segments when formulating policies to support Industry 4.0 adoption. Incentives and support programs tailored to each business type can encourage widespread technology integration.
 3. This study lays the groundwork for future research on Industry 4.0 in the culinary sector. Longitudinal studies can provide insights into the evolving nature of technology adoption, and qualitative research can provide a deeper understanding of the cultural and contextual factors that influence these dynamics.

Limitations and Future Directions

While this study provides valuable insights, there are some limitations, including reliance on self-reported data and a specific focus on the Bandung area. Future research could explore the broader Indonesian context

or expand this study to include culinary centers in Southeast Asia.

5. CONCLUSION

In conclusion, this study sheds light on the profound impact of Industry 4.0 on traditional culinary businesses in the vibrant city of Bandung. The findings underscore the positive relationship between technology adoption, operational efficiency, customer engagement and business performance. Businesses using Industry 4.0 technologies exhibit better operational processes, more personalized customer engagement, and better financial metrics. Measurement and structural models confirm the reliability, validity, and predictive relevance of this research, providing a solid foundation for practical implications and future research. As Bandung's culinary landscape continues to evolve, insights from this study offer actionable guidance for businesses, policymakers, and researchers navigating the ever-changing intersection of technology and gastronomy.

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